Pilot Users and Their Families:
Inventing Flexible Practices in the Smart Grid

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Households are increasingly the centre of attention in smart grid experiments, where they are dominantly framed in a role as 'flexible consumers' of electricity. This paper reports from the Danish smart grid demonstration project eFlex, which aimed to investigate the 'flexibility potential' of households, and it shows how householders are far from just 'consumers' in the system. Drawing on empirical material from ethnographic fieldwork in 49 households that tested smart grid equipment, the paper firstly demonstrates how eFlex users were also creative innovators. Secondly, by integrating user innovation literature, domestication theory and practice theory, the paper illustrates how the eFlex equipment interacted with a variety of collectively shared everyday practices in the household and argues that this unique family context accordingly had implications for the 'innovative capacity' of these pioneer users. The paper thus calls for smart grid stakeholders to begin taking the 'innovator role' of smart home users seriously, but equally calls for a more contextual and situated perspective when involving innovative users – their families have an equal part to play in the development of the smart grid.

Keywords: user innovation, family context, smart grid

Introduction

There is no end to the possibilities and benefits embedded in the vision of the smart grid. Globally, it is teeming with projects, plans, experiments and policy road maps for developing this modernisation of the energy system. According to the smart grid stakeholders, one of the important tasks for realising the smart grid is to promote 'flexibility' on the consumption side. Most smart grid projects to date have focused on developing technologies, but increasingly the 'consumer side' has been the centre of attention (Verbong et al., 2013), where the challenge is to unravel how end-users can be motivated to take on the role as flexible consumers.

The bulk of these projects have a rather individualistic and techno-economic approach and often test traditional consumer incentives through quantitative methods by, for example, surveying the response to price signals or detailed information on energy consumption (Gangale et al., 2013).

This paper reports from a smart grid user study which aimed to explore what additional motivations could be in play regarding customers' 'flexibility potential'.

The eFlex project was a user oriented innovation project that was commissioned by the largest utility company in Denmark, DONG Energy (DE). The company hired a consultancy firm to generate in-depth qualitative knowledge on the use of smart grid technology in everyday life through anthropological fieldwork in households in the Copenhagen area.

During the analysis of the empirical material from the user study, I found that many of the 'pilot users' were extensive do-it-yourself enthusiasts, who found innovative uses of the equipment they were given, which moved beyond its intended use. They also had ideas for improving the equipment and even performed concrete technical innovations to it. The households in the smart grid experiment were thus among the recent array of studies that report *energy users as active innovators* (the theme is increasingly gaining attention, see, for example, Heiskanen & Matschoss, 2012; Hielscher et al., 2013; Hyysalo et al., 2013a; Hyysalo et al., 2013b; Juntunen, 2014; Ornetzeder & Rohracher, 2006; Smith et al., 2013).

That the users' innovative capacity in relation to developing the smart grid has not been explored more is especially peculiar in a Danish context, since the government in 2006 announced it would spend DKK 420 million on promoting user driven innovation through a programme, which would last until 2014 (Elgaard Jensen, 2012). A few smart grid projects in Denmark have built on user involvement in the development of energy technologies and systems (e.g. DREAM, eFlex, MCHA), but they have not focused on actual user innovations.

This paper will focus on this particular perspective (see Nyborg & Røpke, 2013, for other aspects of the eFlex project) through the following research questions:

1. How was the eFlex equipment integrated into everyday life in households?
2. What inventive uses and adaptations did the householders make to the eFlex equipment during this integration?
3. What did the family context mean for the users' experimentation?

Although these questions depart from the questions normally posed in smart grid 'consumer studies', the answers will be interesting to system builders, as they address issues about 'the sources of innovation' (von Hippel, 1988) and underline how designers of future systems should recognise that "creativity on the fringes should be appreciated and brought in" (Elgaard Jensen, 2013: 356). Moreover, although the study focuses on innovative users, it also differs from most studies on user-innovators: By approaching the empirical material with a theoretical perspective, which has roots in science and technology studies (S&TS), I also aim to argue for a more situated, contextual and systemic perspective on user innovation than the one Eric von Hippel and colleagues represent.

Accordingly, my analysis of empirical data is informed by three theoretical perspectives: domestication theory (e.g. Berker et al., 2006; Lie & Sørensen, 1996; Silverstone & Hirsch, 1992), social practice theories (mainly as developed by Shove et al., 2007; Shove et al., 2012) and literature on lead users and user innovations (e.g. Franke et al., 2006; Lüthje, 2004; Schuhmacher & Kuester, 2012; von Hippel, 1988, 2005).

The article will be structured as follows: First the eFlex project and the user study will be introduced, followed by a description of the theoretical frame and the methods used. The empirical findings that follow are concerned with how the equipment was domesticated and how it interacted with a variety of domestic practices; how the users experimented and made various innovations, and how these processes and the affordances of the equipment led to conflicts and negotiations in the families. Finally, the paper will discuss how context matters for innovative processes and for 'the commercial attractiveness' of an innovation.

The eFlex Project

In a Danish context, the transition to a low carbon energy system is dominantly framed as an issue of integrating more wind power and using the increasing electricity production for heating (heat pumps) and transport (electric cars) (Energinet.dk & Dansk Energi, 2010). By enabling 'flexible' consumption patterns, the smart grid is argued to resolve issues concerning an increasing share of intermittent energy sources in the system and emerging, new loads from, for example, electric cars and heat pumps.

The eFlex project was commissioned by DE Distribution and conducted throughout 2011. It involved the testing of new smart grid prototype technologies for demand management of electric vehicles, heat pumps and domestic appliances in 119 households in DE's distribution area. The consultancy firm Antropologerne was hired to perform a user study that explored the customers' price sensitivity and different motivations for being flexible consumers. As part of the data collection for my own research project, I was allowed access to the households involved in the user study and conducted 11 of the 49 household interviews included in the study.

The eFlex project design and the intended use of the smart grid equipment

A basic element in the project design was testing of a home automation energy management system, which supported a new communication interface with DE and enabled visualisation of the customers' appliance-specific consumption. The hypothesis was that it would create a new relationship with DE and with electricity as a product, which would encourage flexibility and increase customer acceptance of supply interruption – as well as providing the ability to automate the management of consumption conveniently.

I use the notion of 'intended use' to convey the designed-in features of the eFlex pilot study. This is because the design and equipment in the eFlex project could not be explored in minute detail to infer the sets of "scripts" (Akrich, 1992) they may have – as other interactive ICT's the eFlex equipment appeared to "have more complex affordances than clear scripts" (Hyysalo, 2010: 245). The eFlex system consisted of a number of intelligent power nodes, which the users could control via an on-line 'portal' that could be accessed from either a computer or from an iPod Touch. If the users connected the power nodes to appliances around the house, they would be able to see on the portal how much power each appliance consumed throughout the day. The system was designed so that they could turn them off from the portal, or they could program certain power nodes to turn off or on collectively at specific times of the day, and thus make, for example, an 'out' profile, or 'sleep' profile'. Moreover, the participants had agreed to transfer to hourly pricing and were offered variable distribution grid tariffs. Accordingly, the next 24 hours' dynamic prices, which were visible on the portal, and which the customers were priced after, were based on a combination of dynamic spot prices and variable tariffs and could differ from 1.50 kr. (0,20 €) pr. kWh to 4.30 kr. (0,58€) pr. kWh. Hence, the users were expected to utilise this information to construct certain profiles or turn devices on/off individually at certain times in periods when the price was low/high.

The eFlex project design included 81 households with a ground source or air-water heat pump (HP), 9 households with an electric car (EC), and a 'control group' of 26 'ordinary' households (OH) without either. All three groups had the energy management system described above. In the heat pump group, DE could reduce consumption – or 'optimise' – the heat pump externally for periods of one to three hours through a 'relay box'. This externally optimized group had an extra feature on the portal they could use to follow DE's interaction with the heat pump. Likewise, the charging of the electric car batteries was controlled externally by DE. In this case, the users had to specify through the portal at what time in the morning the battery should be ready and charged, and its minimum percentage level (see Nyborg & Røpke, 2013, for a more detailed description of the design, method and results of the eFlex user study).

Theoretical Frame

The theoretical frame applied in the analysis of the empirical material builds upon domestication theory and a theory of social practices as it has been developed in relation to (energy) consumption, materiality and everyday life (e.g. Reckwitz, 2002; Shove et al., 2007; Shove et al., 2012; Warde, 2005). Whereas domestication theory is an obvious candidate when analysing what happens to both the artefact and the family when new technology enters the front door, a practice theory perspective clarifies how the technology comes in clinch with a variety of everyday practices that constitute the home.

Domestication theory originates in cultural-, media- and consumption studies and in S&TS and arose in the late 1980's as a response to 'the linear model of diffusion of innovations' (Rogers, 1962). The notion of 'domestication' refers to how a new and unfamiliar technology has to be 'housetrained' when it enters a household. The theory emphasises the context-dependent appropriation of artefacts and how their role in a family is an outcome of negotiations. Moreover, these "everyday struggles [...] may have important effects on the shaping of technologies and its 'consequences' " (Lie & Sørensen, 1996: 11). Domestication is a two-way process where artefacts are incorporated into routines and value systems of everyday life and may be ascribed new meanings and functions, but they may also assist in breaking habits or developing new routines in a family. Such dynamics accordingly make a domestication analysis "similar to studying acts of design and innovation" (Lie & Sørensen, 1996: 8).

Although domestication theory was developed in the wake of the pervasive 'practice turn' in contemporary social theory (Schatzki et al., 2001) and evidently pays attention to everyday life practices, social practice theories[1] offer a different theoretical lens than the one domestication theory presents. The subtle put important difference is that in domestication theory, focus is on practices 'with' an artefact and how artefacts *develop* in the continuous interaction with a household's unique culture and identity – its 'moral economy' (Silverstone & Hirsch, 1992). Although the household's unique culture is constituted by practices, the focus in domestication theory is not *on the practices as such*, but on the technology and its interaction with the moral economy of the household and the individuals that negotiate it.

Instead, social practice theories have social practices such as 'cooking', 'playing soccer', 'shopping' or 'googling' as the ontological units of analysis. By drawing on a practice theory perspective, the emphasis is on how ‘social practices’ are more than ‘user actions’ with an artefact or everyday life activities broadly speaking. A practice can be seen as a cluster of activity, which can be conceived of as an entity and which is endurable and recognisable through space and time (Shove et al., 2007). To take an example, the practice of cooking dinner precedes the individual cook, who momentarily and at a specific place performs the practice by linking several *elements* such as artefacts, bodily movements, meanings and know-how – i.e. they ‘use’ a stove, know-how about how to chop a carrot and meanings such as caring for your children or norms about health. Individuals thus

> face practices-as-entities, as these are formed historically as a collective achievement; and through their own practices-as-performance, individuals reproduce and transform the entities over time. Individuals thus act as ‘carriers’ of practices (Røpke, 2009: 2491).

Different theorists include different elements to configure a practice, but Shove et al. (2012) and Strengers (2013), for instance, argue that ‘materials’ – technologies, products etc. – as well as resources such as energy are among the elements that actively constitute practices as they are performed. Consumption or patterns of demand is therefore the *outcome* of our engagement in meaningful social practices.

Thus, by integrating a practice theory perspective in the analysis, more attention is paid to the dynamics of the practices performed in the home, rather than focusing more exclusively on the ‘technology-family dynamics’ interaction. Articulated in this framework, new technology accordingly both changes some practices performed in the household (according to DE’s intentions), but conversely, the eFlex technologies are also integrated in some practices and made to function in these practices. Domestication is thus the way each household finds its own unique way of integrating the equipment as an element in the performance of a range of its everyday practices, which accordingly may develop and diversify the practices (Røpke et al., 2010) or lead to the creation of entirely new ones. In this paper, the artefacts considered in the domestication processes are the portal, iPod touch, power nodes, ‘information’ (variable prices, tariffs etc.), PODIO, heat pump and electric car. ’Equipment’ usually means the portal, iPod and power nodes.

Furthermore, social practice theory is well equipped to investigate “the complex temporal organisation of everyday life” (Shove et al., 2009: 1) and the relation between patterns of energy demand and ‘inflexible’ daily rhythms (Powells et al., 2014; Walker, 2014). In a practice theory perspective an individual follows a path in time and space, and each individual carries out practices that take up time and have to take place in space. This also implies coupling constraints, as Røpke (2009: 2493) argues

> As practices often involve other people, other living organisms as well as man-made and material objects, they depend on the coupling and uncoupling of the paths of all these human and non-human “partners”.

Thus, coordinating practices and paths in a family is hard enough even without new demands that certain practices are dislocated in time through ‘flexible consumption’.

Both domestication theory and the approach to understanding social practices described above contest the idea that users – or practitioners – are 'passive recipients of innovations', a contestation thoroughly fundamental to the S&TS field (Oudshoorn & Pinch, 2003). Instead the theories emphasize that these actors are active, creative and skillful and some of the domestication literature points to how users not only ascribe new meanings and uses to artefacts to make them fit to an everyday life context, but even make concrete user modifications and 'micro-innovations' (e.g. Aune, 1996; Håpnes, 1996; Juntunen, 2014). Also, in the theory of social practices as developed in e.g. Shove et al. (2007), the individual is seen as a competent practitioner, who uses (or consumes) artefacts to engage in meaningful practices or projects such as DIY (do-it-yourself) and who simultaneously develops new skills and knowledge doing that, which has a bearing on future patterns of consumption and product development.

Shove et al. (2007) also draw on the literature on 'craft consumers' (Campbell, 2005). According to Campbell (2005: 27), craft consumers bring "skill, knowledge, judgement, love and passion to their consuming", similarly to how craftsmen approach their work. The notion 'craft consumption' is used to "refer to activities in which individuals both design and make the products that they themselves consume" (Campbell, 2005: 27). Importantly, the 'products' or creations that craft consumer make often consist of a range of items that are themselves mass-produced commodities – they use these as 'raw materials' for a new, 'personalized' creation that allows for creativity and self-expression (Campbell, 2005: 28). Areas of consumer activity in which craft dimensions most clearly exists are such as "the world of DIY and home modification and improvement, together with gardening, cooking and the building and maintaining of a wardrobe and clothing outfits" (Campbell, 2005: 33). The literature on 'creative consumers' (e.g. Berthon et al., 2007) similarly address the ability of users to "adapt, modify, or transform a proprietary offering" (Berthon et al., 2007: 39). Like the other theoretical perspectives, this literature rejects the image of users as passive 'dupes' that are subjects to market forces (Campbell, 2005) and argue that much interesting creative and innovative 'work' happens beyond the moments of acquisition[2].

However, a body of literature concerned with innovative users that has gained most attention within management research (Berthon et al., 2007), deals with the concept of the 'lead user', which was coined by von Hippel in 1986, and this paper draw inspiration from this literature. von Hippel (2011) argues that consumers are a major source of product innovations and that this innovation is highly concentrated on few 'lead users' (von Hippel, 1986). However, von Hippel pays little attention to how the meaning and use of artefacts are dependent on the context they are situated in, which thus matters for what user innovations are possible or make sense. The study of social practices and domestication processes in relation to such active users is interesting, because it can further our understanding of the users that innovate and the innovative processes they are engaged in.

According to von Hippel (1986: 796), lead users are different from 'ordinary users' and can be identified by two overall characteristics: 1) they face needs that will later become general in a market place, and 2) they are positioned to benefit by obtaining a solution to those needs. Together, these features mean that lead users are not only more likely to innovate than 'ordinary users', but also likely to develop commercially attractive innovations (Franke et al., 2006).

The first characteristic says something about a users' *capability* for making commercially attractive innovations, because the lead users are at the leading edge of important trends; they often operate in use contexts that lie in the future for most users, i.e. they "develop a novel use for an existing commodity" (Lüthje & Herstatt, 2004: 557). Lead users are 'expert users' – they often have a lot of use experience in a product field as well as technical skills and product related knowledge and are also often freely drawing on help from a use-community (Franke & Shah, 2003; Franke et al., 2006).

The second characteristic, i.e. 'high expected benefit', relates to '*innovation likelihood'* and a users' *motivation* to innovate and seeks to explain why in some product categories it is the user and not a manufacturer that develop a certain innovation. This characteristic is among other things related to the heterogeneity of user needs: many users are dissatisfied with the existing products that are on the market, and some users will attempt to improve or develop products themselves – they benefit from *using* this solution to their specific needs (Lüthje & Herstatt, 2004). Moreover, users have 'low innovation costs' compared to manufactures in some product areas in terms of access to 'sticky information' about user needs: 'Sticky' information can be explained as the tacit knowledge the user has gained through using the product. While the user is in possession of this information for 'free', it is costly for the manufacturer to get (Lüthje & Herstatt, 2004).

Other motivational factors that characterise lead users is the enjoyment and learning that many of them experience and value from the *process* of innovating as well as recognition from peers in the user community. Some also innovate because they expect a profit from selling the innovation and not just to benefit from using it themselves (See e.g. Raasch & von Hippel, 2013).

Methodology: Empirical Material and Analytical Approach

The empirical material used in this paper consists of field notes, photos and videos from the 49 household visits, as well as dictaphone recordings from my own 11 visits. Each household visit lasted approximately 4–5 hours and included interviews with the families, as well as a 'grand tour' of the dwelling, and the field worker would also have lunch or dinner with the family. The interview guide was developed together with the researchers that took part in the project.

Table 1. Fieldwork was divided into three 'loops' – loop 1 focused mostly on the eFlex portal etc., loop 2 on electric cars and loop 3 on heat pumps. See appendix 1 for an extended table summarizing information about the author's 11 interviews.

	Loop 1, spring 2011	Loop 2, autumn 2011	Loop 3, winter 2011-12
Households included in the trial (in total 119)	29 ordinary households 26 heat pump owners	9 electric vehicle owners	55 heat pump owners
Households involved in the user study (in total 49)	16 ordinary households 6 heat pump owners	9 electric vehicle owners 3 heat pump owners	15 heat pump owners
Household interviews performed by the author (in total 11 out of 49)	1 ordinary household 2 heat pump owners	3 electric vehicle owners 1 heat pump owner	4 heat pump owners

After each household visit elaborate field notes were written on PODIO, a social media platform that functioned both as a project management tool for DE and Antropologerne and as a platform for the householders to communicate with each other and the eFlex project team.

The analytical process resembled the 'immersion/crystallization' style (Borkan, 1999) by relying on intuition and prolonged 'immersion' in the data. The analysis began by listening through all the dictaphone recordings – often 1–3 hours from each household – and writing down immediate ideas and notes for emerging themes. Subsequently, I transcribed verbatim 5 of the 11 dictaphone recordings as these focused particularly on heat pumps and were to be shared with other researchers for another paper. Concomitantly with this process, all 49 household field diaries were read through several times and emerging themes were further developed and the family stories were written. The dictaphone recordings that had not been transcribed were listened through again and relevant parts in these were also transcribed. Video recordings and photos were mostly used as 'back-up' for field diaries and dictaphone recordings; In a few cases it was for example unclear what was meant in a field diary written by another fieldworker or what was being said on my own recordings and looking through relevant photos or video-material could clarify these issues.

Evidently, this qualitative approach differs from the methods that would normally be used in conventional lead user studies. In these studies much emphasis would be put on evaluating whether the involved users are in fact lead users, i.e. do they display lead user characteristics. This is often done through surveying a user community and self-evaluations or through external domain expert evaluators (see e.g. Franke et al., 2006; Hyysalo et al., 2015). The households included in this paper are thus not 'verified lead users'. However, several of them had developed novel uses with a technology, had modified their equipment, had a lot of use experience, technical skills, were dissatisfied with the current product offers, had community based resources (e.g. PODIO, but several were also involved in heat pump and electric vehicle user communities beyond the eFlex project) and expected a benefit from using their own innovations. They also seemed to enjoy the innovation process and the learning it brought them.

Family Stories

The findings presented in the following consists firstly of two detailed family stories and secondly, I draw on these two stories supplied with empirical material from the rest of the household visits to elaborate more specifically on cross-cutting themes in the material that are related to my research questions.

The family stories are included to exemplify and give a sense of how the eFlex project became situated in different and unique family contexts; because they are *family* stories they illustrate how the inventive users were enmeshed in a household's moral economy and the web of interconnected practices that comprise it, which mattered greatly for the innovative processes and their outcome. Moreover, the stories exemplify three themes, which I, as said, will explicate more on afterwards: The story of Peter & Charlotte is a story about *domestication*, whereas the story about Benny & his wife Marie illustrates dynamics concerning *innovative processes in a domestic setting*. Both stories also illustrate the *negotiations and conflicts* that follow in the wake of introducing such equipment in a (innovative) household.

Family story of Peter & Charlotte

Peter and Charlotte love living in their large country house close to the forest and with a panoramic view over the 2.5 hectares of land they own. As Peter says, 'I am a man of nature'. The house resides in a 'well-to-do' part of northern Zealand, and the married couple share the house with their two teenage sons, who in Peter's view spend far too much time playing on the computer.

The eFlex participation is mainly Peter's project. Although less enthusiastic, Charlotte is curious about what it actually is in their household that consumes most electricity. 'Is it turning on the clock radio, the oven or the lights outside?' she asks. However, she finds it difficult to become part of the project, and she and the two boys have gotten annoyed with how Peter is running around with the iPod all the time. Peter is still experimenting with where to put the power nodes and so far none have been placed in the dining room as Charlotte finds them too ugly and not fitting in with the interior decoration. Peter has put power nodes on the TV in their bedroom, on their B&O clock radio, in the guest room for Charlotte's laptop, on their video surveillance cameras outside, on the TV, lamp and computer in each of the boys' rooms, on their routers and on the quooker and washing machine in the kitchen. The quooker is a tap in the kitchen, from which you can pour boiling water directly into your cup. The couple has realised that the quooker uses a lot of electricity because it is always on 'stand-by' – actually it uses around 1400 Watt for a few minutes several times a day, Peter can see on the portal. So now he has made a profile that turns it off at night when they never use it. He can see that the biggest consumers in the home are the boys' rooms and the kitchen.

Peter goes to bed around 12 at night – unless he stays up a bit to do some programming to improve the webshop of his store. He has set up the system so that the TV in their bedroom is the 'master', i.e. when he goes to sleep he turns off the TV, and all the rest of the things in the house connected to power nodes are also automatically turned off. Peter thinks the system functions very well, although he must admit it requires some skills to learn how to use it and its logics. One morning they were all late, because the clock radio did not turn on because it was set on a wrong profile – and Charlotte could not get her cup of tea because the quooker had not been on when they woke up.

Peter's system of turning off all devices through his iPod when he goes to sleep also means that he turns off the boys' light, TV and computer. Otherwise they will continue playing all night, get up late and be too tired in school. "So I also use it a little to control behaviour now that I have the possibility, right?" as he says. "I'm trying to raise them to know that a good night's sleep is important". He also thinks they shouldn't disturb their friends after bedtime. Actually he did signal this to them even before he had the eFlex system by shutting down their IP addresses on the internet. However, Peter recognises that often the boys would instead just use the neighbours' open WiFi, so it's more for the signalling effect, he says.

The couple realised that the boys' ICT habits actually count for a great part of the household electricity consumption. After they started staying in their rooms at night playing computers, watching TV or communicating with friends, their electricity bill rose by 3-4,000 kr. (400–530 €) a year and now the eFlex project has really confirmed that it is connected to their 'staying-in-the-room-at-night' habits, Charlotte says. Peter estimates he only saves around 500 kr. (70 €) a year turning off things at night, but he likes the idea that all unnecessary standby consumption is turned off. Peter also likes using the iPod and portal as a way of getting a feeling of what is going on at home when he is at work:

> I think it's fun to open it [the portal] from the store and see if it's all running… and see if the boys have come home […]. Then I can see if the computers are on.

Actually, the eFlex equipment has somewhat become part of Peter's incidental 'surveillance' of the boys and their dog-walking chores. The adults take turns walking the family's dog in the morning, as do the boys when they come home from school – the agreement is to take him for half an hour in the woods. However, after the family got the surveillance video camera outside, Peter and Charlotte accidentally noticed when looking through the pictures how the boys 'cheated' and just opened the door to let him out for 5 minutes. And now, even while at work, Peter can also 'survey' whether they are actually in their rooms and playing on the computer instead of walking the dog. He can see

> what time he turns on the computer, right? I can see if there is no electricity consumption. I can look back on the entire past week and see when they've been on and when they've not been on. They don't know quite how much it's actually possible to see on it, you know?

Peter has had discussions with Charlotte about how they can be flexible, and he wants the washing machine and dishwasher to run at night, but Charlotte thinks that the clothes get wrinkly from lying in the machine all night. Furthermore, although she wants to 'learn how to save energy' and 'do things smarter', as she says, things get too much of a hassle and an inconvenience if the machines can only run at night: "If I'm suddenly cooking and I have a lot of pots and pans, then surely the machine just needs to run, so I can also use them later in the evening. Nor can I just plan to always wash clothes at night, because I do not have the time to hang them up".

Family story of Benny and Marie

Benny and Marie are a couple in their sixties who have both retired early. Benny, however, still works 10–15 hours a month as an IT consultant for his old workplace where he was employed as a mechanical engineer. They have lived in the same detached house in the suburb for almost 40 years.

Benny and Marie have had a ground source heat pump with a 300 L buffer tank for three months, because Benny wanted to take advantage of the cheap electricity their electricity company 'Modstrøm' offered them at night by storing extra heat in the tank. But then Benny found out about the eFlex project through a newsletter, which also offered cheaper prices at certain times of the day. They had been Modstrøm customers since 2008 and only recently changed to DONG Energy, because they had to as part of the eFlex project. Marie adds that they were accordingly already 'tuned in' to time-shifting their dishwasher and washing machine to night-time. Benny is very preoccupied with the heat pump and is very willing and proud to show how he can follow its 'workings' on the eFlex portal. He has even volunteered for another project called 'control your heat pump' and explains

> you get more measuring equipment on your heat pump […] you get to see even more how well it works, you can measure your COP value and so on…

Benny considers DE's optimisations of the heat pump too weak, among other things because he has the buffer tank. Consequently he shuts off the heat pump completely between 8–12 and 17–19, where the tariffs are the most expensive. However, he has found a way to 'cheat' the heat pump in order to get heat in the radiators anyway during these expensive hours: Between 5 and 7 in the morning where electricity conversely is cheap he sets the heat pump to deliver a living room temperature of 27 degrees so the pump heats up water to meet that temperature. However, his thermostats on the radiators in the living room are not 'fully open', as many heat pump owners are told they should be, but are instead put on, for example, 21 degrees – this means the extra hot water is saved in the buffer tank instead and can be used in the expensive hours between 8 and 12.

The couple do not have a fireplace, which many other eFlex participants say they light up if they think DE's optimisations lower the household temperature, but their walls can also store a lot of heat, he thinks. Marie tells me she never turns up the thermostats as she doesn't believe it matters. But she is happy the heat pump can be set to a 'travel mode' during the winter, so the temperature does not go below 10 degrees and "the living room plants do not suffer any hardship". Marie is not always satisfied with Benny's experimentation with the heating. She doesn't know, for example, how to turn up the heat in her hobby room on the 1st floor. She tries to turn up the thermostat and says:

> but I really don't quite know what is going on in this house. But, I try to turn it up… Benny, he tries so many things, so what's going on all the time, I'm not quite aware of.

Neither is she totally happy about the temperature of the water after they have got the heat pump:

> It's got better, because it's been set a little low, but I still think it's bad with the water for dishwashing, because it has to run for so long for it to become warm enough for grease and so on to come off, and I don't think he has quite finished regulating that yet.

Benny emphasises that he *has* finished regulating it and that the temperature can't get higher than 50 degrees, unless the HP needs to use too much electricity. He has, however, set the HP to heat up the water in the system above 60 degrees about once a month to avoid legionella bacteria contamination of the water. He doesn't believe the optimisations have any influence since they never eat before 19 or shower between 8 and 12 or from 17 to 19. But Marie says

> there are things such as when I for example bake a cake and cookie dough and so on. I use water in the kitchen at many times during the day […] it's not quite warm enough.

Benny has experimented a great deal with putting power nodes on the refrigerator, freezer (the nodes are locked so it's not possible to accidently turn them off) and dishwasher, and he is happy he can now see how much electricity they consume. He tried to put a node on the washing machine and dehumidifier in the basement but it kept shutting down. He also has a node on the circulation pump for the HP, which he at first made a turn-off profile for during the night, but now he lets it run because the price is low at night anyway, so they may as well have that comfort. Moreover, he put a node on an outside lamp, on their music system, DVD, TV, laptop, and the radio in the living room. He noticed that their hard disk recorder uses a lot of electricity, but he couldn't turn it off to save stand-by because it's an old model that forgets all the time settings when it's turned off. Marie's frustrations not only concern the heat pump but also the eFlex equipment, because she does not really understand what the iPod or power nodes are for. Benny already has two iPods on which he recently downloaded the eFlex app and all their music, so they can bring them on car vacations, for example. He secured the iPod from DE onto a little loudspeaker system in the basement besides Marie's laptop, computer screen and printer so she can turn her ICT devices on, but she's not happy about it:

> It's really hard, because at the same time all our music is set on completely different methods... You know, Benny loves these kinds of things... 'Then you just have to push there and there' you know... And then constantly new and new and new things come along and I'm just not that much into machines... There are too many thingies and gizmos, and they are not just DONG Energy's.

Findings

Domestication and de-configurations
As we can observe in the family stories, the use of the eFlex equipment and the meanings ascribed to it are quite different between the two families. The equipment became domesticated into a family setting with its own unique moral economy, which was under constant negotiation, and which had an influence on what the equipment was actually used for and what practices it co-developed with. Taking Peter's story as an example of a domestication process, we saw how the equipment supported his and Charlotte's interests in identifying the devices consuming most in the household, quite in line with a household moral of avoiding unnecessary waste. Moreover, it inspired reflections on washing clothes and kitchenware at night, which was in line with the intended use of the equipment. However, the project and the eFlex equipment also *became something else* through the domestication process – e.g. a means for Peter to control his sons. The project entered a household with a moral economy connected to ideas and meanings about 'an active lifestyle' and a love for nature. Moreover, Peter considered it valuable for his boys to get enough sleep to perform as well as possible in school. Peter's use of the eFlex equipment was clearly domesticated into this setting, since he used the eFlex equipment in his already existing practice of controlling and surveying the sons through the video camera or the shutting down of IP addresses to signal 'bedtime'. Now, with the eFlex equipment, he instead simply shut down the computers or looked on his iPod from work when they had been in their rooms and what they were doing there. This domesticated use of the eFlex technologies was both for 'getting a feel of home', but also to explore and confront the boys' 'passive' computer games – especially at night – or their cheating with walking the dog in the forest, which was part of the nature he would like them to appreciate more.

Intended and unintended uses
Generally, domestication of the equipment led to both intended and non-intended uses. Concerning the former, knowledge about electricity prices and tariffs on the eFlex portal often inspired the moving of laundry and dishwashing – or even things such as baking and pottery hobbies – to night-time or weekends. The power nodes were often connected to lamps, TV/music-sets as well as computers and were used for identifying 'large consumers' or gaining a better sense of the consumption patterns of the household, which meant for example that they could turn off unnecessary consumption or even replace inexpedient

devices. Some users also experimented with using power nodes for 'flexibility', which actually required a rather creative use of the equipment[3]. For example, the pilot user Hans would make a profile to turn his chest freezer off from 10 pm and until 2 am. In the meantime the temperature had risen about 1 °C, so when turned on again, the freezer would restore the temperature and 'move' some of its consumption to the cheapest period after 2 am. However, as Peter's story illustrated, the equipment was also used in ways that were not according to the intended use. Another example was Martin, a dedicated father and husband, who used the iPod or computer to turn off his 3-year-old daughter's cartoons from the kitchen.

> Then, when it's time for bed, she can see we don't have the remote, because she has it, but then we can say…'Now there is no more TV [aired] today'

– an explanation she would instantly accept. In other cases, if Martin was at work and worried because he couldn't get in contact with his wife through the phone, he could see on the portal she was home, because the TV was on – and he would turn the TV on and off to see if she was awake and 'provoked' to ring him back.

Thus, the eFlex project interacted with a myriad of practices as varied as cooking, laundry, dinner and dishwashing, airing-out, watching TV, playing computer, communicating with friends, brewing tea and coffee, commuting to work, lighting a fire in the fireplace, bed-time rituals, 'leisure/passing time' practices, parenting, walking the dog, theft protection, heat comfort, hobbies and many more. New practices were, however, also created, more in line with the equipment's pre-configuration, e.g. several pilot users took up the novel practice of routinely checking the portal at night before going to bed. Although difficult to state when the equipment was integrated as a new element in an already established practice – e.g. turning on the computer and checking emails before bed – or whether the practice could be 'classified' as new, it is evident that something happened to *both* the equipment and to the practices performed in the households.

Next, I want to focus more on two specific issues that appeared in the domestication process: user innovations and conflicts and negotiations in the family.

Inventive and creative users

In the above-examined families, we saw how Eddie, for instance, developed a novel use in relation to the optimisation of his heat pump, whereas Peter was often spending time programming to improve his web shop. Such observations were common in the families and in general many of the eFlex pilot users had extensive technical skills. In a survey that Antropologerne made among the 119 households (89 answered), 24% of the pilot users identified themselves as the user profile 'the technical'. This was one out of five user profiles that had been made on the basis of the anthropological fieldwork and the users were asked to place themselves in the category they believed described them best. The other four profiles were 'the economical', 'the curious', 'the participating' and 'the comfortable'. 'The technical' were all male and often engineers or had another technical background. They were among other things described as being interested "in mechanics and/or new technologies, are often frontrunners and are willing to try out new things" (Antropologerne, 2012: 50). They were more technological savvy than most and had extensive knowledge of the energy system as well as 'smart home' use experience. Several of them already had some sort of 'smart home' systems in the house, such as

IHC lighting control or they were involved in electricity production themselves by having installed solar panels or had a share in a locally-owned wind turbine. They often took a keen interest in the functioning of these technologies – or planned to install them themselves, such as the user Flemming who had bought two m2 of PV solar panels, which he wanted to solder together and install on his roof. Often, the users were engaged in DIY projects in the home. The user Jens, for example, made an intelligent heating and electricity system in his house, but also found it inconvenient that the house's in-built vacuum cleaner system did not have an on/off button on the handle of the hose, so he made such a switch by using the remote control for a car alarm. As heat pumps and electric cars are still not widespread in Denmark, the eFlex users were early adopters of these technologies and they had moreover become 'expert users' of these technologies.

Innovative uses and short circuits

Many users seemed especially dissatisfied with the way the heat pumps were optimised. The rationale behind the eFlex project was that the flexibility concerning heat pumps should be taken care of by DE – ideally in such a manner that the households would experience no comfort loss or any sort of hassle connected to providing the flexibility. However, many pilot users clearly expressed a desire to take a more active part in the system, as we saw with Benny and several other users such as Hans, who would turn his heat pump off between 10 pm to 2 am and take advantage of the kickback effect, similar to his freezer experiment.

Some users even made actual short circuits to the eFlex relay box to improve the way their heat pumps were optimised. For most of the heat pump types, DE had two ways of optimising through the relay box: either allowing the air temperature in the house to drop, but maintaining production of hot water, or stopping the heat pump completely – and there was a relay for each function in the box. The user Henry, however, thought the first option would not provide him enough savings, so he short-circuited one of the two relays, so the heat pump would always shut off completely during optimisations. As he explained:

Figure 1. Jens observed that DE often only optimised his heat pump once a day, so he made an electric hob that allowed him to optimise twice a day.

> You just unscrew the lid of the relay box and put a cord between the two legs of the resistor… It has been discussed on PODIO and I can see that several others have short-circuited the resistor just as I have.

Similarly, Jens made an electric hob that allowed him to optimise twice a day.

Another example was Martin: Power nodes did not have ground connections at the beginning of the project, so the users were not able to safely connect refrigerators etc.:

> So I made an extension cord that coupled the ground connection around the unit itself, and then I posted it on the net and said, well, here I have a solution.

This self-made solution, however, was not allowed, and DE introduced instead power nodes with earth connections[4]. Often the pilot users also had many more ideas for the improvement of the equipment, e.g. that the power nodes should also turn off automatically when the HP was turned off.

Users 'tap into' companies

In lead user literature, the user is seen as a source of information for firms, who can tap into their innovativeness to produce breakthrough products. However, in the eFlex project the opposite process also became evident, as several users had entered the project to learn more about smart grid development and 'harvest' the knowledge and network that was created and facilitated by DE. The eFlex user Flemming had, for example, bought his electric car to get some experience with the car and had a business plan to develop intelligent charging solutions for the smart grid. He had volunteered for the eFlex project among other to learn and

> to meet someone and get some experiences with it [flexible charging etc]. That, for sure.

Innovation in a Family Setting: Conflicts and Barriers

In the following I will present my findings concerning some of the conflicts and barriers I observed in the families relating to participation in the eFlex project. Of course, in some families there were no actual conflicts and in those families where there were, the picture was varied and the reasons for conflicts were many-faceted. However, three themes will be presented here.

Figure 2. Martin's homemade ground connection for power nodes

Loss of control & equipment designed for one person

The affordances of the equipment did not support a collective domestication and shared use in the family (see also Antropologerne, 2012 on this), *but* at the same time, the equipment was tied up to the electricity system, which the entire family was dependent on. Often it was only one person in the home that was "running around with this iPod" and had free access to the portal 'control room', which meant a loss of control for the other family members. As one wife, Christina, expressed her frustrations:

> Now you have this DONG gizmo, so now nothing is on anymore, so when I get up in the morning and need to turn on the lights in the children's room, that damn device, it has meant I cannot turn on anything…

This naturally limited the sort of experimentation that was possible for the pilot users, as Flemming acknowledged:

> But it's also… I really don't dare do so much. Because whenever I do something, it turns off the DVD or the TV and then they all go crazy! So, it's kind of limited how much one dares to do.

Visualisation and surveillance

This sort of 'dominance' that the pilot users exerted could also be related to the visualisation and surveillance of electricity consumption, which the equipment allowed. The eFlex users could gain some insights the other family members could not to the same degree. This meant first of all that already ongoing negotiations about what was in the first instance meaningful to use energy on were sparked into life. Many spouses had different ideas about whether lighting in the garden or in unoccupied rooms was important, or about what the comfort temperature should be in the house. Secondly, the visualisation feature also allowed the surveying of what other family members were doing at certain times and places, which had obvious implications for the power relations in the family. As one wife said jokingly when her husband showed her the portal, "so that means I can actually go in there [portal] and see, if you are doing anything…?" Not surprisingly, many of the children in the families refused to have any power nodes in their rooms[5].

Interruption of practices and structural barriers

Remembering that energy consumption happens in the course of performing 'time-and-place bounded' practices, which are often tightly coordinated in everyday life, experimentation with *flexibility* also resulted in conflicts, because other family members' performance of practices was disrupted. In Benny's story, we saw for example how flexibility with the heat pump interfered with Marie's washing-up practices in the kitchen. And as we saw in Peter's story, Charlotte was critical of the idea of postponing the dishwasher or laundry to night-time, because this manoeuvre would mess up her planning. She did not have time to hang up the clothes in the morning, which was a time slot that was filled with other practices that took up her time. This was a problem mentioned by many of the eFlex users' wives. Another example was Hans's wife Liv, who thought that his experimentation with night-time washing interrupted their son's sleeping:

> Hans: But in reality we haven't done much to investigate if it is a problem; there are doors in between and if we close the door, then…
> Liv: Really, Hans, if he says he can't sleep because the washing machine is centrifuging, then surely I believe him… I don't have to investigate anything!
> Hans: No, but what I mean is that we have not really done anything to find out if there is a problem and if we could find a solution…

Such considerations for the life paths of others, which hindered experimentation activities, did not have to be conflictual, as in Martin's case. He stopped experimenting with making profiles for the refrigerator to turn off during the day when his wife went on maternity leave and would suddenly stay home all day.

Experimenting with flexibility also clashed with structures or time-bound practices performed outside the home. Martin mentioned how his ability to be flexible with charging his car also depended on his working hours and congestion patterns; with his type of battery, if he were to take full advantage of the cheapest electricity prices in the early morning hours, he would have to postpone the time he left in the morning. Conversely, that meant he would run into another problem of travelling peaks and congestion. The user René similarly expressed how flexibility with laundry not only depended on their 'willingness' to do it, but also on the temporal patterns of their sons' leisure activities:

> When you're a family with children, then you have to do the laundry… The kids have to play soccer tomorrow, their clothes need to be dry.

Discussion

The above findings illustrate that if we are to better understand the dynamics related to the innovative users, we have to take the specific context in which innovation occurs into consideration. As I have shown, householders adopted and adapted the eFlex equipment "to their local conditions and the particularities of their houses and everyday practices" (Hyysalo et al., 2013b: 491). In other words: the users did not experiment in isolation, they were part of a system; the moral economy and practices of the families as well as the material 'particularities' of the house – e.g. size, insulation degree, number of rooms, built-in appliances or accessible power plugs, piping, types of radiators or floor heating, buffer tanks – also had agency (Latour, 1992) and had 'a hand in the innovations' simply because they were all constitutive in defining uses and assigning meaning to the eFlex project. They had an influence on the practices the equipment interacted and co-developed with, and thus on the types of innovations that were meaningful or even possible at all.

This point is addressed to the user innovation literature, which from an S&TS and social practice theory perspective could be enriched with insights regarding how products are always part of networks and social practices, but it also has obvious empirical implications if smart grid stakeholders will eventually take the innovative capacity of users into account.

As Hyysalo (2009) is arguing, other approaches are needed to complement the otherwise dominant focus on the economic rationale behind user-innovation behaviour, i.e. that innovations are seen as the result of individual users' rational decision making, where they weigh up benefits (e.g. use, enjoyment etc.) and dis-benefits or cost (often not monetary).

Although it is emphasised in the literature that benefits can also be things such as enjoyment or learning and although frameworks rooted in for instance creative psychology have been brought in recently (Faullant et al., 2012), the focus is still on *individuals* and the resources they can draw on – whether inner resources or outer resources such as user-communities. Thus, from an S&TS perspective, the dominant focus in user innovation literature on inherent motivational factors and skills of individuals could be supplemented with a focus on the socio-material system and situated context in which innovation happens. In short, a new set of questions related to why (and where) users innovate and what other factors than the 'innovative mind' are at play for the result, are needed.

There needs to be attention as to *how or why* the use context has a bearing on the innovations. The last 30 years of S&TS research have pointed to how innovation is part of a network, and that doesn't change because the innovator is a user – the sticky information does not just reside in his or her head but in the system of which the innovation is part. A user will perhaps be able to point to new product ideas and solutions based on the needs he has already encountered in his context, but, again, needs are not static or predetermined, but co-develop with the system, and innovation happens as a result of a situated interaction (Suchman, 1987).

A more contextual and 'systemic perspective' on sticky information would perhaps be beneficial. It would be interesting to pose more questions about sticky information that are not just about how costly it is to transfer, but about 'what it is' and does a lead user have 'free' access to it? In relation to theories about innovative users: Are the dynamics concerning why, how, where and what 'drives' certain innovations answered by focusing on, for instance, individuals' expected benefit? A more in-depth engagement with "practices and community dynamics of users" is also what Hyysalo (2009: 254) is calling for in an article on micro-innovations in sports industry development. He emphasises the importance of looking at how the collective user community takes part in reproducing but also changing 'kayaking' practices for which the lead users make innovations. In his words:

> Lead users are like citizens of the ancient polis of Athens: a competent, willing and visible elite who are easily seen to constitute the relevant sphere of action. But analogous to Athen's democracy, without the means to pay sufficient attention to the majority of its inhabitants – peasants, women, slaves and foreign merchants – our view of user innovation would miss important issues if the, less grandiose, inventive inputs of other-than-lead-users were neglected. (Hyysalo, 2009: 254)

When dealing with the innovative user, we should therefore also deal with his or her 'fellow' carriers or practitioners and the continuous and collective development of the practice the innovation is part of – all carriers of practices are in a sense innovators as well as producers and consumers at the same time (Pantzar & Shove, 2010). In the case of innovations to a product such as a 'smart home energy management system' it would definitely make sense to consider the context of the household or family of the innovator: they also use and depend on the system, which is subject to innovations, and they take part in developing the practices the system becomes part of and for which innovations are made. User innovation research has only explored user innovations that occur in the context of everyday family life by survey (von Hippel et al., 2012) and hence has not addressed how the specific socio-material configuration of each household and the network of meanings, materials and practices the innovator is situated in matters for the innovative processes 'on the fringes'. In short, no attention has been focused on innovations *in* more complex webs of artefacts and meanings than just a user-product relation. More attention is also needed regarding innovations *to* networked systems such as the eFlex smart home equipment. A discussion of the latter and its deep entwinement with domestic practices comes next.

eFlex system and energy is an element in many domestic practices

The many conflicts and considerations that have been described in the findings were related to the large number of domestic practices that the eFlex system interacted with, which conferred special challenges for 'the eFlex innovators'. More specifically, the many practices presented a challenging context for experimentation and innovation for two reasons: firstly, because they were 'hung up' on a networked system in the home (the smart home equipment connected to the energy system) and, secondly, the everyday lives of families are already challenged by 'coupling constraints' between life paths and practices, which the eFlex users' demands for experimentation with flexibility did not ease.

The eFlex equipment was tied up to the energy system of the house and thus figured as a material element in many practices performed by all members of the family. It seems self-evident that innovations to a *shared* system with many users will confer negotiations and accordingly have implications for the innovative processes. Such implications do not come into light if we only study innovations to single products, which currently seem to be the focus in user innovation literature. However, the users' experimentation in the eFlex project came to have quite a literal influence on other family members' performance of practices. For example, Marie clearly resisted her husband's participation in eFlex and the results the low-temperature water had for her heat comfort and her ability to bake cakes and wash her dishes. Other examples such as Christina's opposition to the interruption of her child caring at night, or Flemming's family, who went 'crazy' when his experimentation interrupted their TV watching, illustrate the pervasiveness of practices and domains that are related to the home's energy system and thus involved in experimentation with such smart home systems.

Life paths and coupling constraints – many practices and many considerations

Concerning the second issue, the positioning of practices in time and space also had implications for the experimentation that could be done with flexibility. In a practice theory perspective, daily rhythms are "achievements of coordinating and stabilizing relationships between practices" (Shove et al., 2009: 10). For example, 'doing the laundry' may be a project that consists of a closely related bundle of practices, i.e. a practice of washing clothes and a practice of tumble drying or hanging up clothes. Dislocating the washing practice in time has therefore implications for this and other 'bundles' of practices and their coordination: Charlotte opposed washing clothes at night; she was afraid the clothes would wrinkle if lying in the machine nor did she have time to hang the clothes up in the morning. This was an issue raised by many (often wives of) eFlex users, who would for example spend time in the morning getting the kids ready for school. Washing and drying clothes is often done successively, and separating the practices and introducing a timeslot for hanging up clothes in the morning instead of in the evening was not easy – it conflicted with other practices that were scheduled in the morning. Conflicts and considerations in relation to flexibility experimentation were also related to the previously mentioned 'coupling constraints': Change or dislocation of a practice – for instance delaying family dinner – can impinge on several individuals' paths, as a practice can be a 'node' that several paths run through. In the eFlex study it seemed that the more actors – e.g. children and pets – there were in a household, the harder it became to be flexible with practices (see also Nyborg & Røpke, 2013; Nicholls & Strengers, 2015). Finally, constraints on experimenting with flexibility were also related to how domestic practices are structured or tied to systems or practices external to the household, as we saw in the case of René and Martin.

Conclusions

In this article, it has been shown how the quite simplified – but dominant – portrait of the 'smart grid user', whose relationship with energy is framed solely in terms of his or her role as *consumer* of it (Strengers, 2013), and who uses and understands technologies in an expected and uncomplicated way, misses an important part of the picture.

Households are so far an unrecognised source of innovations and ingenuity when it comes to developing a low carbon energy system, and users certainly display a desire to "exercise control over the consumption process" by employing skill and mastery in humanizing and "creative acts of self-expression" (Campbell, 2005: 24, 27). Although there was probably a higher concentration of 'lead users' among the eFlex users than in the general population, the point remains clear: users are everyday inventors of both the technologies and the practices these are part of, and they can and do play an important role in the development of large provision systems. As Hyysalo et al. (2013b: 490) write in one of the few papers that engage with this issue:

> the inventive user can speed up the development and proliferation of distributed renewable energy technologies [...] through their alternative designs.

Instead of keeping supposedly 'ignorant' publics out of the development process "they should be seen as valuable and generative to the innovation of smart grids" (Schick & Winthereik, 2013: 96). The interpretive flexibility of the smart grid is still great, and multiple roles for the householders can be constructed – e.g. the 'innovator role' that has been sketched out here. Continuing the same policies and scopes for user studies, which reproduce an old notion of the 'demand side' (Wolsink, 2012; see also van Vliet, 2002), may lose sight of the negative energy impacts the 'consumer role' could have (Nyborg & Røpke, 2011).

Furthermore, the S&TS research provides a better understanding of "how and why new products and technological infrastructures are acquired and how they affect practices as they are absorbed into everyday ways of living" (McMeekin & Southerton, 2012: 357) – and consequently better enlighten innovative processes 'on the fringes' of the smart grid field. The previous discussion illuminates the network of practices and systems the eFlex equipment interacted with, which complicated the innovative processes. Moreover, the discussion also underlines how flexibility from households is a complex matter that involves quite a lot of considerations and inter-related factors. It points to how taking on the 'flexible consumer role' depends on more than ‘willingness’ or motivational factors. Thus, a stronger S&TS focus would deepen our knowledge of the role that users or publics have in constructing certain sustainable transition pathways and support the basis for making policies that to a higher degree fertilise the dispersed creativity of users.

Lastly, the fieldwork demonstrated the need to promote a far more ‘user-driven’ roll out of heat pumps and other small-scale renewable technologies as opposed to the current technology-driven process and the ‘one-size-fits-all’ logic. As Hyysalo and colleagues (2013b: 490) are arguing:

> It appears that supplier models do not cater sufficiently for the variation in users’ homes, which leaves unexplored design space for users to focus on.

Thus, there is room for users to innovate on e.g. heat pumps to make them more user-friendly for the entire family and more suited to different and varying contexts. Just as user-oriented innovation methods are being used to increase the value of many other products, it would perhaps be beneficial for heat pump producers to integrate innovative users more in the development of these technologies. However, as I have argued in this paper, when involving innovative users we should remember also to talk to an entire household just as the eFlex project did – both to explore the ‘validity’ of the innovative users’ concepts, but also to be inspired by the inventive inputs of other-than-lead-users.

By taking such ideas into consideration, we can hopefully expand the current narrow focus on the relatively high private financial investment in a heat pump to explain why Danes are not taking up heat pumps in the speed that policy makers and producers had imagined (Catalyst Strategy Consulting, 2013).

Acknowledgements

I am grateful to Poul Brath, DONG Energy, and Antropologerne for letting me take part in their project – and to Rikke Ulk, Pi Ammentorp, Louise Buch, Rikke H Andersen, Lise Røjskjær, Nadia Koppel, Trine Demant, Karen G Jensen and Louise Torntoft for contributing with empirical material to this paper. I also wish to thank Eva Heiskanen, Inge Røpke and two anonymous reviewers for their very useful comments.

References

Akrich M (1992) The De-scription of Technical Objects. In: Bijker WE & Law J (eds) *Shaping Technology/ Building Society*. Cambridge and London: The MIT Press, 205–224.

Antropologerne (2012) *eFlex :: Fleksibelt Elforbrug. En Kvalitativ Undersøgelse af, hvordan Deltagerne i Projekt eFlex Oplever Hverdagen med Energifleksibilitet.* København: DONG Energy and Antropologerne.

Aune M (1996) The Computer in Everyday Life: Patterns of Domestication of a New Technology. In: Lie M & Sørensen KH (eds) *Making Technology our Own? Domesticating Technology into Everyday Life*. Oslo: Scandinavian University Press, 91–120.

Berker T, Hartmann M, Punie Y & Ward K (eds) (2006) *Domestication of Media and Technology*. London: Open University Press.

Berthon PR, Pitt LF, McCarthy I & Kates SM (2007) When Customers Get Clever: Managerial Approaches to Dealing with Creative Consumers. *Business Horizons* 50: 39–47.

Borkan J (1999) Immersion/Chrystallization. In: Crabtree B & Miller W (eds) *Doing Qualitative Research*. Thousand Oaks, CA: Sage Publications, 179–194.

Campbell C (2005) The Craft Consumer: Culture, Craft and Consumption in a Postmodern Society. *Journal of Consumer Culture* 5(1): 23–42.

Catalyst Strategy Consulting (2013) *Nye Forretningsmodeller til Acceleration af Varmepumpe-udrulning*. København: Dansk Energi.

Elgaard Jensen T (2012) Intervention by Invitation. New Concerns and New Versions of the User in STS. *Science Studies* 25(1): 13–36.

Elgaard Jensen T (2013) Doing Techno Anthropology: On Sisters, Customers and Creative Users in a Medical Device Firm. In: T Børsen & L Botin (eds) *What is Techno-Anthropology?* Aalborg: Aalborg University Press, 331–364.

Energinet.dk & Dansk Energi (2010) *Smart Grid i Danmark*. Fredericia: Energinet.dk.

Faullant R, Schwarz EJ, Krajger I & Breitenecker RJ (2012) Towards a Comprehensive Understanding of Lead Userness: The Search for Individual Creativity. *Creativity and Innovation Management* 21(1): 76–92.

Franke N & Shah S (2003) How Communities Support Innovative Activities: An Exploration of Assistance and Sharing Among End-Users. *Research Policy* 32(1): 157–178.

Franke N, von Hippel E & Schreier M (2006) Finding Commercially Attractive User Innovations: A Test of Lead User Theory. *Journal of Product Innovation Management* 23(4): 301–315.

Gangale F, Mengolini A & Onyeji I (2013) Consumer Engagement: An Insight from Smart Grid Projects in Europe. *Energy Policy* 60: 621–628.

Grimpe B, Hartswood M & Jirotka M (2014) Towards a closer dialogue between policy and practice: Responsible design in HCI. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems,* Toronto, ON, Canada, 26 April – 1 May 2014: 2965–2974. New York, USA: ACM.

Heiskanen E & Matschoss K (2012) Exploring emerging customer needs for smart grid applications. In: *Innovative Smart Grid Technologies (ISGT Europe) 2011 Proceedings. Online at IIE Xplore,* Manchester, IEEE, 5–7 December 2011: 1–7.

Hielscher S, Seyfang G & Smith A (2013) Grassroots Innovations for Sustainable Energy: Exploring Niche-Development Processes Among Community-Energy Initiatives. In: Cohen MJ, Brown HS & Vergragt PJ (eds) *Innovations in Sustainable Consumption. New Economics, Socio-Technical Transitions and Social Practices*. Cheltenham, UK: Edward Elgar, 133–158.

Hyysalo S (2007) Versions of Care Technology. *Human Technology* 3(2): 228–247.

Hyysalo S (2009) User Innovation and Everyday Practices: Micro Innovation in Sports Industry Development. *R&D Management* 39(3): 247–258.

Hyysalo S (2010) *Health Technology Development and Use. From Practice Bound Imagination to Evolving Impacts*. New York & London: Routledge.

Hyysalo S, Helminen P, Mäkinen S, Johnson M, Juntunen JK & Freeman S (2015) Intermediate search elements and method combination in lead-user searches. *International Journal of Innovation Management* 19(1): 1550007.

Hyysalo S, Juntunen JK & Freeman S (2013a) Internet Forums and the Rise of the Inventive Energy User. *Science & Technology Studies* 26(1): 25–51.

Hyysalo S, Juntunen JK & Freeman S (2013b) User Innovation in Sustainable Home Energy Technologies. *Energy Policy* 55: 490–500.

Håpnes T (1996) Not in their machines. How hackers transform computers into subcultural artefacts. In: M Lie & KH Sørensen (eds) *Making Technology our Own? Domesticating Technology into Everyday Life.* Oslo: Scandinavian University Press, 121–150.

Juntunen JK (2014) Domestication Pathways of Small-Scale Renewable Energy Technologies. *Sustainability: Science, Practice, & Policy* 10(2): 28–42.

Latour B (1992) Where Are the Missing Masses? The Sociology of a Few Mundane Artefacts. In: Bijker WE & Law J (eds) *Shaping Technology/Building Society: Studies in Sociotechnical Change*. Cambridge, Massachusetts: MIT Press, 225–258.

Lie M & Sørensen KH (eds) (1996) *Making Technology our Own? Domesticating Technology into Everyday Life*. Oslo: Scandinavian University Press.

Lie M & Sørensen KH (1996) Making Technology our Own? Domesticating Technology into Everyday Life. In: Lie M & Sørensen KH (eds) *Making Technology our Own? Domesticating Technology into Everyday Life*. Oslo: Scandinavian University Press, 1–30.

Lüthje C (2004) Characteristics of Innovating Users in a Consumer Goods Field: An Empirical Study of Sport-Related Product Consumers. *Technovation* 24(9): 683–695.

Lüthje C & Herstatt C (2004) The Lead User Method: An Outline of Empirical Findings and Issues for Future Research. *R&D Management* 34(5): 553.

McMeekin A & Southerton D (2012) Sustainability Transitions and Final Consumption: Practices and Socio-Technical Systems. *Technology Analysis & Strategic Management* 24(4): 345–361.

Nicholls L & Strengers Y (2015) Peak Demand and the 'Family Peak' Period in Australia: Understanding Practice (In) flexibility in Households With Children. *Energy Research & Social Science* 9: 116–124.

Nicolini D (2012) *Practice Theory, Work, and Organisation. An Introduction.* Oxford: Oxford University Press.

Nyborg S & Røpke I (2011). Energy impacts of the smart home - conflicting visions. In: *ECEEE 2011 Summer Study: Energy Efficiency First: The Foundation of a Low-Carbon Society*, Belambra Presqu'ile de Giens, France, 5-10 June 2011: 1849–1860. Stockholm: ECEEE.

Nyborg S & Røpke I (2013) Constructing Users in the Smart Grid—Insights from the Danish eFlex Project. *Energy Efficiency* 6(4): 655–670.

Ornetzeder M & Rohracher H (2006) User-Led Innovations and Participation Processes: Lessons from Sustainable Energy Technologies. *Energy Policy* 34: 138–150.

Oudshoorn N & Pinch TJ (eds) (2003) *How Users Matter: The Co-Construction of Users and Technologies*. Cambridge, Massachusetts: London: MIT.

Pantzar M & Shove E (2010) Understanding Innovation in Practice: A Discussion of the Production and Re-Production of Nordic walking. *Technology Analysis & Strategic Management* 22(4): 447–461.

Powells G, Bulkley H, Bell S & Judson E (2014). Peak Electricity Demand and the Flexibility of Everyday Life. *Geoforum* 55: 43–52.

Raasch C & von Hippel E (2013) Innovation Process Benefits: The Journey as Reward. *MIT Sloan Management Review* 55(1): 33–39.

Reckwitz A (2002) Toward a Theory of Social Practices. A Development in Culturalist Theorizing. *European Journal of Social Theory* 5(2): 243–263.

Ritzer G (2014) Prosumption: Evolution, Revolution, or Eternal Return of the Same? *Journal of Consumer Culture* 14(1): 3–24.

Ritzer G (2016) *Introduction to Sociology*, 3rd edition. Thousand Oaks, California: Sage.

Rogers EM (1962) *Diffusion of Innovations*. New York: Free Press.

Røpke I (2009) Theories of Practice – New Inspiration for Ecological Economic Studies on Consumption. *Ecological Economics* 68(10): 2490–2497.

Røpke I, Christensen TH & Jensen JO (2010) Information and Communication Technologies – A New Round of Household Electrification. *Energy Policy* 38(4): 1764–1773.

Schatzki TR (1996) *Social Practices. A Wittgensteinian Approach to Human Activity and the Social*. Cambridge: Cambridge University Press.

Schatzki TR, Knorr Cetina K & von Savigny E (eds) (2001) *The Practice Turn in Contemporary Theory*. London and New York: Routledge.

Schick L & Winthereik BR (2013) Innovating Relations – or Why Smart Grid Is Not Too Complex for the Public. *Science & Technology Studies* 26(3): 82–102.

Schuhmacher MC & Kuester S (2012) Identification of Lead User Characteristics Driving the Quality of Service Innovation Ideas. *Creativity and Innovation Management* 21(4): 427–442.

Shove E, Pantzar M & Watson M (2012) *The Dynamics of Social Practice. Everyday Life and how it Changes*. London: Sage.

Shove E, Trentmann F & Wilk R (eds) (2009) *Time, Consumption and Everyday Life. Practice, Materiality and Culture*. Oxford and New York: Berg.

Shove E, Watson M, Hand M & Ingram J (2007) *The Design of Everyday Life*. Oxford: Berg.

Silverstone R & Hirsch E (eds) (1992) *Consuming Technologies: Media and Information in Domestic Spaces*. London: Routledge.

Smith A, Hielscher S, Dickel S, Söderberg J & van Oost E (2013) *Grassroots digital fabrication and makerspaces: Reconfiguring, relocating and recalibrating innovation* (working paper). SPRU, University of Sussex: Working Paper Series, SWPS 2013-02.

Strengers Y (2013) *Smart Energy Technologies in Everyday Life. Smart Utopia?* Basingstoke: Palgrave MacMillian.

Suchman L (1987) *Plans and Situated Actions: The Problem of Human-Machine Communication*. Cambridge: Cambridge University Press.

Toffler A (1980) *The Third Wave*. New York: William Morrow.

van Vliet BJM (2002) *Greening the grid: The ecological modernisation of network-bound systems*. Wageningen University: Wageningen.

Verbong GPJ, Beemsterboer S & Sengers F (2013) Smart Grids or Smart Users? Involving Users in Developing a Low Carbon Electricity Economy. *Energy Policy* 52: 117–125.

von Hippel E (1986) Lead Users: A Source of Novel Product Concepts. *Management Science* 32(7): 791–805.

von Hippel E (1988) *The Sources of Innovation*. Oxford: Oxford University Press.

von Hippel E (2005) *Democratizing Innovation*. Cambridge: The MIT Press.

von Hippel E, De Jong JPJ & Flowers S (2012) Comparing Business and Household Sector Innovation in Consumer Products: Findings From a Representative Study in the United Kingdom. *Management Science* 58(9): 1669–1681.

von Hippel E, Ogawa S & De Jong JPJ (2011) The Age of the Consumer-Innovator. *MIT Sloan Management Review* 53(1): 27–35.

Walker G (2014) The Dynamics of Energy Demand: Change, Rhythm and Synchronicity. *Energy Research & Social Science* 1: 49–55.

Warde A (2005) Consumption and Theories of Practice. *Journal of Consumer Culture* 5(2): 131–153.

Wolsink M (2012) The Research Agenda on Social Acceptance of Distributed Generation in Smart Grids: Renewable as Common Pool Resources. *Renewable and Sustainable Energy Reviews* 16(1): 822–835.

Notes

1 There is not one unified 'practice theory' and practice theoretical ideas are represented in a range of disciplines such as philosophy, cultural theory, history, sociology, anthropology and S&TS. Instead, practice theories constitute "a rather broad family of theoretical approaches connected by a web of historical and conceptual similarities" (Nicolini, 2012: 1). However, the philosophers Andreas Reckwitz (2002) and Theodore Schatzki (1996) have developed a rather coherent approach to the analysis of social practices, and the practice theorists referenced in this paper have more recently built a somewhat distinct understanding of the dynamics of social practices related to fields such as energy consumption and the design of ordinary products in everyday life.

2 In a smart grid context, the concept of the 'prosumer' (Ritzer, 2014; Toffler, 1980) has been widely adopted. Originally, the prosumer was characterized as a person who takes part in producing something that they consume, content on the internet being a classic example. According to Ritzer (2016), the concept overlaps with the older, more familiar idea of a 'do-it-yourselfer'. The 'prosumer' notion is used rather inconsistently in relation to the discussion of the smart grid to signify a new, more 'active' type of consumer in the energy system, who takes part in renewable energy production through micro-generation technologies such as photovoltaic cells and micro-wind power. The prosumer in the smart grid thus also breaks with the passive consumer paradigm, but they are not necessarily characterized as particularly innovative.

3 Many users were confused about what the primary aim and intended use of the power nodes was. Whereas DONG Energy had mainly included them to support increasing 'electricity awareness', many of the householders had gotten the impression they were mainly supposed to use them for flexible consumption. This was a type of use, which the design of the equipment did not support very well and accordingly it required quite a lot of inventiveness to find ways to actually use them for flexibility (see Nyborg & Røpke, 2013 for more on this).

4 Companies' challenges in terms of working with inventive or creative users are well known and discussed in e.g. Berthon et al., 2007. User alterations to different aspects of the 'electricity hardware' in a home, e.g. power outlets etc., is dangerous and is inhibited through safety regulations, which probably makes the utilisation of consumer creativity more complicated in this area.

5 Such "digital panopticon" effects are known from elsewhere as an almost inevitable part of automation (see e.g. Grimpe et al., 2014; Hyysalo, 2007).

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APPENDIX 1

Table 2. A summary of the 11 households that were interviewed by the author. Besides the six examples of user innovations below – which includes 'innovative uses' that greatly improves the functioning of the technology to fit the users' needs – and the innovations that "Henry" and "Jens" made, 'actual' user innovations were observed in three other diaries; these included a user putting extra insulation on the heat pumps' tubes, a user building an electric car from scratch and a user working on designing an IT-solution to survey and control the energy consumption in the home. However, many more eFlex pilots were involved in activities that could be described as craft consumption – as creative and somewhat 'innovative' activities; they were, for instance, often active DIY enthusiasts who renovated the house themselves or made elaborate repairs to products in the home. Also, many householders displayed 'lead user characteristics' although no actual innovations were evident in their field diaries. As user innovations were not originally in focus when the interview guide was designed, the observations below are not necessarily 'representative' of the actual amount of user innovations that were made in the households, as we may not have detected them all. Moreover, as stated in the methodology section, the 'lead user status' of the users in this paper is not verified according to conventional methods.

Nr.	Household	Housing – type	Heat pump, electric car or 'ordinary' household?	Examples of activities indicating 'lead userness' – not just related to eFlex product categories
1 (Loop 1)	Father: IT system developer in private company (42). Mother: Nurse (40). Two boys (8, 11).	Detached house with a garden	Air-water heat pump	None observed
2 (Loop 1)	**"Peter & Charlotte"** Father: Entrepreneur (46). Mother: Logo designer (47). Two boys (14, 17). A golden retriever.	Large villa with a garden	'Ordinary' household	Peter is doing programming to improve his web shop.
3 (Loop 1)	Father: IT consultant in private company (38). Mother: Senior position in an energy company (39). A boy (3) and a girl (6).	Detached house with a garden	Ground source heat pump	None observed
4 (Loop 2)	**"Flemming"** Father: Electronics engineer and entrepreneur (49). Mother: Stay-at-home-wife (49). A girl (12) and a boy (15).	Detached house with a garden	Electric car	Flemming is working to develop a new type of charger for electric cars
5 (Loop 2)	Father: Engineer, venture capitalist (49). Mother: Engineer, employed in husbands' company (49). A girl (9) and a boy (13). An au-pair girl.	Large villa with a garden and a swimming pool	Electric car	None observed

Table 2 cont.

Nr.	Household	Housing – type	Heat pump, electric car or ‘ordinary’ household?	Examples of activities indicating ‘lead userness’ – not just related to eFlex product categories
6 (Loop 2)	Husband: Pensioned from an office assistant position in a municipality (66). Wife: Office assistant in a municipality (62).	Detached house with a garden	Ground source heat pump	The husband is a passionate amateur-gardener and made a self-build, movable trash bin for garden waste made from an old pram.
7 (Loop 2)	**“Martin”** Father: Authorised electrician, studying to become electrical power engineer (28). Mother: Tailor, entrepreneur (28). Two girls (a new-born and 3).	Small flat	Electric car	Martin is dissatisfied with eFlex power nodes – made a ground connection on them himself. He is currently also rebuilding a gasoline car into an electric car.
8 (Loop 3)	**“Hans & Liv”** Father: engineer, works with renewable energy in large energy company (54). Mother: Manager in a pharmaceuticals company (47). Two girls (9, 15) and a boy (18).	Detached house with a garden	Ground source heat pump	Hans is dissatisfied with power nodes and experiments with new uses to improve flexibility. He is also dissatisfied with the heat pump optimisation offered by DONG Energy and improves it through innovative use. Siv was dissatisfied with information on the eFlex portal and made Hans make an alternative visualisation of electricity prices on paper to place around the house.
9 (Loop 3)	Father: Operational planner officer in the municipality (39). Mother: Physiotherapist, consultant in private company (36). A girl (2) and a boy (4).	Detached house with a garden	Ground source heat pump	None observed
10 (Loop 3)	Husband: Retired, previously constructional engineer (67). Wife: Retired, previously upper-secondary schoolteacher in biology (67).	Detached house with a garden	Ground source heat pump	None observed
11 (Loop 3)	**“Benny & Marie”** Husband: Retired mechanical engineer, now part-time IT consultant (66). Wife: Retired teacher and nature guide (62).	Detached house with a garden	Ground source heat pump	Benny is dissatisfied with the heat pump optimisation offered by DONG Energy and improves it through innovative use.