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Prosumers and smart grid technologies in Denmark: developing user competences in smart grid households

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Abstract

This paper explores and describes resident's experiences from a smart grid project that involved 20 households in a rural area in Denmark and ran from 2014-2015. The study is based on qualitative data from the participating households, collected 6, 12 and 18 months after the start of the intervention. Drawing on theories of social practice and the three intertwined elements of a practice: competences, images and materials, the paper contributes with an in-depth analysis of a complex intervention, focusing on how the participants changed energy practices as a result of the installed smart grid technologies. Long-term studies on such comprehensive energy interventions and derived changes in domestic energy practices are exceptional. The results show that people relate to their natural environment in new ways and construct new practices according to the movements of the sun; that they gradually become skilled practitioners and prosumers; and that they also increase consumption and develop expectations towards the energy company, requesting better dialogue on energy consumption and control. The paper concludes with reflections and suggestions on how findings may be relevant to policy and research in the area.

Keywords: Smart grids; energy intervention; prosumers; practice theory; competences

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1 Introduction

Due to climate change, uncertainties in energy prices, concerns about energy supply and the rise in energy demand, there has been global increasing interest in new ways of producing, delivering and consuming energy, as well as in controlling energy consumption. For instance, in developed countries, the 'smart grid' has been proposed for economic and environmental reasons, with the main benefits of energy efficiency and low environmental emissions (Fadaeenejad et al. 2014). Even within the same nation, smart grids can mean many things when comparing smart grid experimental projects. The projects show different interpretation of technologies resulting in various innovation trajectories (Skjolsvold and Ryghaug 2015). Although the visions for and the contents of the 'smart grid'[1] vary depending on the context (Hadjsaïd and

[1] The EU defines the smart grid as an "electricity network which intelligently integrates the actions of generators and consumers connected to it in order to efficiently deliver sustainable, economic and secure electricity supplies," whereas the US Department of Energy provides a more detailed definition and talks about the active participation of consumers: "a smart grid is self-healing, enables active participation of consumers, operates resiliently against attack and natural disasters, accommodates all generations and storage options, enables introduction of new products,

Sabonnadière 2011: 471-4), a common feature is bi-directional power flow, implying that consumers can produce electricity for the grid (Lund et al. 2012). This can be managed through ICTs (Information and communications technologies), transforming the system from a unidirectional transaction of electricity to a two-way communication and transaction of energy (Giordano et al. 2013). This is also the most striking difference from the current energy system because households and consumers experience a new role: they now 'grow' their own energy and hence participate in the energy market as prosumers (Verbong, Beemsterboer and Sengers 2013). This smart grid prosumer will thus not only consume energy but also produce it via 'micro-generation technology,' such as photovoltaic cells (PVs), solar thermal heating, micro-wind power, biomass-boilers, etc. (Bergman and Eyre 2011), making the prosumer increasingly independent from the energy companies through micro-generation and self-management. Wolsink (2012) refers to this model as 'DisGenMiGrids' (distributed generation micro-grids).

The focus in this paper is on residents' new roles as prosumers and changes of practices closely related to being equipped with micro-generation technology. This focus has been chosen primarily for three reasons: 1) although the concept of prosumption is much referred to in policy documents because it requires much regulation, it seems to be based on various smart grid studies that have studied the future energy user mainly from the point of view of the traditional actors in the electricity system (esp. grid responsible actors) (Verbong et al. 2013); 2) there is a lack of studies on real life implications of being a prosumer within the smart grid; and 3) micro-generation technology presents interesting prospects (according to Strengers 2013) for making energy tangible, which may be assumed a necessary step for making people more responsible about their otherwise intangible energy use. In this paper, we precisely wish to investigate the role of the prosumer and whether an increased experience with producing energy has had any impact on the use of energy or on common practices within the household. We do this by studying households equipped with PVs, heat pumps (HPs), electric vehicles (EVs), and energy management equipment. The technological setup is further described in section 4.

The notion of a prosumer (Bergman and Eyre 2011) suggests a new role for consumers where they not only consume but also produce power: "The notions of people as prosumers (Toffler 1980) or energy citizens underline the new economic and civil parts people might play in the energy system. The first stresses that people are no longer just consumers but also producers—investing in energy production and infrastructure. This is a significant Energy shift from being a mere consumer, where investing would be the role of the supply industry alone. The second highlights the fact that people will have new responsibilities and powers

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services and markets, optimizes asset utilization and operates efficiently, provides power quality for the digital economy" (Hadjisaïd and Sabonnadière 2011: 471-2). The smart grid is thus an integration of electricity infrastructure.

within the energy system, as members of a democratic society as opposed to merely economic actors. What say individuals, groups of individual producers or community producers will have in the energy system is yet to be fully determined."(Bergman and Eyre 2011:346). In this paper focus is on prosumers in the energy sector and the transition from being consumers of electricity to becoming producers, viz. prosumers. The definition we use reflects the consumer having invested in micro-generation to be a prosumer. Furthermore, they are equipped with home automation, and they have access to information that allows them to be active, as defined by Bergman & Eyre (2011) above.

Strengers (2013) claims that the consumer in the smart grid has been personified as 'the resource man,' actively managing and maintaining his energy system (on the household level), including his micro-generation technology. The description is reflected in the idea of the smart grid user often described in policy reports and official documents (Strengers 2013). Additionally, according to Grijalva and Tariq (2011), electricity consumers are believed to be evolving into economically motivated prosumers, who - if equipped with technology and intelligence that allow them to achieve their own objectives - "can become smart energy ecosystems". However, focusing on individual (male) users of smart grid technology and assuming that they are rational men who only want to achieve their own objectives seems to neglect the complex social topography of shared households where no actor holds total control over energy practices and associated consumption. Precisely this (ideally) more active role of the prosumer and how 'he' addresses this in 'his' everyday life has been a major reason for investigating the Danish intervention, studying the practical responses to the new technologies at home among many members of the household[2]. Naturally, having so many new technologies installed at once in a household will entail numerous changes in the everyday, such as learning how to manage the technology and adjust the comfort settings on the HP, how to drive and charge an EV and how this changes driving practices in general, and many others that will not be part of this paper.

We will present in the next section the main theoretical concepts used in the empirical analysis. This is followed by a short review of selected, relevant pilot projects and main findings in the literature and, based

[2] A brief presentation of the Danish energy context: Wind power is a central element in Denmark's strategy for obtaining a fossil-free energy system and corresponded to 30-40% of the total electricity production in Denmark during 2012-2014 (Energistyrelsen 2014). To comply with the challenges brought about by the large amount of fluctuating energy in the electricity system, the development of smart grids has been a priority on the national level and among leading energy sector actors in the country (Dansk Energi and Energinet.dk 2010; KEB 2013). The Danish energy sector states that 'flexible electricity consumption' is the main purpose of the smart grid in Denmark (Schick and Gad 2015). Denmark has invested considerably in the Smart Grid: a review of European smart grid R&D projects reports that Denmark accounts for approximately 10% of the total investments in smart grid projects in Europe, making Denmark the country that invests the most per capita; it also has the highest spending per kWh consumed (Giordano et al. 2013).

on this, delineate the current knowledge gap and our research objectives. Then, the actual intervention, the methods used for the study will be described. The results of the study will then be presented and discussed before finally ending the paper with a conclusion and policy recommendations.

2 Social practice theory approach

Concepts such as Theory of Planned Behaviour have previously assumed that behaviour is an outcome of a rational process and performed by rational individuals. Such concepts have developed models to predict behavioural change by including several variables to simulate the individuals' decision-making process. Scholars have opposed such views upon behaviour and behavioural change to lack appreciation of social relations, material infrastructure and context in the study of how people engage in energy consuming practices within theories of social practice (Hargreaves 2011).

Gardiner (2000) argues that the point of studying the everyday is not only to describe it but also to change the lived experience that, to a large extent, is a result of practices. Practices are known to shape our everyday lives and are constituents of social life (Bourdieu and Wacquant 1992). It is through our practices that life is enacted and lived, so in-depth information on people's practices brings us closer to knowing them on their own terms. This is especially relevant because intervention studies usually involve some change of people's common practices, making long-lasting transitions in energy consumption is well known to be difficult, requiring knowledge of many details of the practices. Furthermore, research has clearly shown (Gram-Hanssen 2012) that energy consumption in socio-demographically comparable households and comparable housing differs significantly, indicating that energy-consuming practices involve highly individual rhythms, making it necessary to study individual household patterns.

What constitutes a practice is defined by the philosopher Schatzki and the sociologist Reckwitz: "a temporally evolving, open-ended set of doings and sayings linked by practical understandings, rules, teleoaffective structures, and general understandings" (Schatzki 2002: 87) and "a routinized type of behavior which consists of several elements, interconnected to one another: Forms of bodily activities, forms of mental activities, 'things' & their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (Reckwitz 2002: 249-50). Both describe the active part and the entanglement of elements involved in a practice, implying that life is lived in the *doing*, in the actual performance of practices, building up routines for this performance. They also involve bodies: While practices are routinized and thus not very dynamic, they still reflect different bodily needs in people's life courses (a baby at home may increase the need for more heating, elderly people may find it hard to keep warm, etc.). The quality of practice theory is that it highlights the routine aspects of the active everyday life and the organization of everyday activities - the daily rhythm described as "achievements of coordinating and stabilizing relationships between practices" (Shove et al. 2009: 10). People's habits have long been described as practices performed routinely (Bourdieu and Wacquant 1992), and in a practice perspective, they rest on three intertwined elements: specific *competences*, corresponding to what people need to know to perform the practice, including the related 'doings,' such as the bodily performance of the actions involved with, for instance, turning the heat on or off; *images*, covering how people perceive the practice and elements part of it and what is culturally said about it (often referred to as 'meaning'), involving 'sayings,' such as how energy savings may be communicated in the intervention and the image related to being part of a progressive intervention, a tech front runner; and *materials*, which involve all the physical parts required for performing the practice, such as manuals, technology, and the grid ('havings'). Together, the three parts - **c**ompetences, **i**mages and **m**aterials (hereinafter called CIM[3]) - constitute the core of a practice and reflect what people need to be able to perform it, whether the practice is new or old. The CIM-model is based on Shove and Pantzar (2005), Gram-Hanssen (2011) and Hauge (2013).

3 Studies of prosumers in the energy sector

There are two reasons for the rather narrow selection of literature and research findings described below. 1. For the last twenty years, numerous energy interventions have been completed in many countries (see for instance Shove and Walker 2010; Buchanan, Russo, and Anderson 2014; Kobus, Mugge and Schoormans 2013). Although they all share the aim of reducing energy consumption, they are nonetheless highly different in terms of technologies and methodological approaches involved and have highly different structural conditions and energy infrastructures in the individual countries. Naturally, this complicates any comparison, as well as the adoption of findings. 2. Energy research has long given priority to technical issues (Verbong et al. 2013; Sovacool 2014), resulting in an apparent lack of knowledge regarding private consumers' attitudes towards smart grids and how an integration of smart grid technologies might come about (Verbong et al. 2013). During the past decade, however, consumers' roles in the smart grid has received increased interest (Giordano et al. 2013), and more studies have been completed on how smart grid technologies are absorbed into households' everyday lives and on the incurred practice changes. Still,

[3] We have chosen ´image' rather than 'meaning.' In content we regard them highly similar, but there are some differences. It is well known that practices are regarded as 'shared', but in our view the possibility of sharing meaning is highly problematic (as is also frequently debated by practice theorists). Image, however, is more explicit than meaning, often visual or expressed as a 'brand'. In our view 'meaning' is more an individual matter and more dynamic, as it depends on the situation. In line with our ethno-oriented approach the individual is seen as competent, culturally anchored and able (in varying degree) to influence the technology through interaction with it. Hence, we feel 'image' more correct in this project, where many elements are visual and a certain image originally expressed text-wise ('join this project and be an energy innovator'). 'Image' has also been chosen for pragmatic reasons: CIM is easier to say than CMM. See Gram-Hanssen (2011) for a review of key elements in practices in practice theory literature.

in-depth knowledge of precise residential responses to comprehensive interventions seems to be lacking. Are they, for instance, becoming more skilled energy consumers through their prosumer role? Based on this reasoning, we have selected for this section only those research findings and studies that include smart grid technology to some extent and where countries may be comparable to some degree (such as EU members or industrialized countries).

3.1 Smart grid and households

Previous research regarding consumers and smart grids has mainly included few technologies, sometimes only one element, as part of the smart grid concept. For example, studies have been conducted about users and electricity consumption feedback. One study by Hargreaves et al. (2013), shows that feedback on Smart Energy Monitors mostly informs the users about the household's consumption and thereby has an educative role in relation to how much electricity the different appliances consume. When the consumption level was normalized after a period of time, the monitors had been backgrounded and did not receive much attention anymore (Hargreaves et al. 2013). These results were confirmed by Naus et al. (2014), who investigated the role of users in the smart grid and the changed information flows that occur when smart grid information systems are implemented. Thus, consumption feedback does not in itself cause more sustainable behaviour such as moving consumption away from peak hours (Naus et al. 2014), despite the fact that feedback is intended to inform and motivate through increasing visibility (Fischer 2007: 503). Adding social or comparative components to commitment measures may further increase their effectiveness, as illustrated by the comparative feedback case in Siero et al. (1996) and the social commitment case of the Dutch "Ecoteam Programme" mentioned in Martiskainen (2007: 44). Still, most studies show that feedback intended for learning is difficult, with the exception of two studies showing that feedback may in fact be used as an educational tool (Darby 2006; Wood and Newborough 2003) for teaching consumers to be more responsible energy-wise: studies of informative electricity billing in Norway (Wilhite and Ling 1995) and studies of real-time electricity displays in Ontario, Newfoundland and British Columbia (Mountain 2012). Here, feedback resulted in persistent savings.

Other studies have expanded the research on feedback and visualization of consumption to also include other smart grid technologies, such as the Danish 'eFlex project' where households with HPs installed were investigated in combination with demand response. One of the results in this project was that participants in the project were not economically rational in a simple way; price was not the only motivation. They were also clearly motivated by doing the 'right' thing and avoiding waste of energy (Nyborg and Røpke 2013). The challenge of implementing smart grid seems to be institutional, technical and personal. The significance of the personal aspect in realizing the smart grid is highlighted by Balta-Ozkan et al. (2014), who identified two conflicting consumer approaches: either technology is the sole agent of change with consumers kept entirely passive, or the consumers are activated through the technology, making people part of the solution. According to Goulden et al. (2014), the second approach - activating consumers through technology and shared goals - may have the largest impact in reducing energy consumption, and they argue that the most effective smart grid will be one in which intelligence is sourced from users as well as devices.

3.2 Micro-generation

Previous studies have focused on user-innovation in relation to micro-generating. Studies have focused on micro-generation in the current electricity regime with the actors and technologies available, for instance Juntunen (2014a) who investigated air-to-air HPs, micro wind stations and solar thermal collectors in Finland using domestication theory. The results showed that users purchase micro-generation technology for testing purposes, to investigate how it works and to support the current system, and to increase convenience and cost efficiency (Juntunen 2014a). The motivation for installation of micro-generation is connected with shifts in behaviour. In a study of households in the UK it was found that the families motivated by new technologies or by the self-sufficiency were showing greater behavioural change than those motivated by sustainability in relation to the environment (Dobbyn and Thomas 2005). Main actors in the Danish smart grid sector were also acknowledging micro-generation as a way to enhance change in energy consumption referring to their own experiences with PVs (Schick and Gad 2015). Apart from these studies others have been focusing on the motivations for and acceptance of micro-generation (Balcombe et al. 2013; Palm and Tengvard 2011; Schelly 2014; Snape and Rynikiewicz 2012; Vasseur and Kemp 2015), but little research has been carried out on micro-generation using a practice theoretical approach.

Micro-generation has previously been argued to cause behavioural changes. Bergman and Eyre (2011), included a range of results from PVs interventions in the UK, showing that part of the consumers have changed behavior. They found changes in routine behaviour, such as moving consumption to those periods of the day when they were producing electricity and avoiding the waste of electricity, e.g., by avoiding stand-by consumption (Bergman and Eyre 2011). Behavioural change caused by micro-generation has also been proven in other contexts. In a study conducted in the Netherlands, 50 households received installations of solar PVs on their roof, a smart washing machine, and demand response (with dynamic tariff), allowing them to automatically wash when energy was produced. The results showed that the users shifted their use of the washing machine from peak hours to hours when the sun was shining, hence using the locally produced electricity and lowering peak demand. One of the conclusions in the paper is that people are willing to change their washing patterns to accommodate the new set-up (Kobus et al. 2015).

Most studies on prosumers are focusing on the current energy system with the current structures. For instance prosumers with solar thermal collectors, micro-wind, ground-source HPs and wood pellets have been studied in relation to user innovation with Finnish households (Juntunen 2014b). Few studies combine micro generation with other common smart grid concepts.

The future role of the prosumer has mainly been studied on a conceptual level. Previous scholars have focused on prosumers as stakeholders in smart cities. Karnouskos (2011), and Timmerman and Huitema (2009), have described the need to design services to help the prosumer in his/her future role.

Micro-generation has been claimed to be able to convert the perception of energy. Strengers (2013) investigates micro-generation in her book 'Smart Utopia,' focusing on 'the role that micro-generated energies play in everyday practice, where energy-as-material meets with constellations of other materials, meanings and skills' (Strengers 2013: 135). She refers to investigations of users and micro-generation (among others Keirstead 2007; Stedmon et al. 2012) and notes that, if micro-generation is successfully implemented in people's homes, it converts the perception of energy from an abstract concept into a tangible phenomenon that is a natural part of people's practices. Energy becomes *'energies that matter,' meaning that people should not think of their produced energy as a commodity, resource unit or impact but rather as a material element of practice* (Strengers 2013: 152).

The above studies may perceive energy as an integrated part of practices. Despite this they pay little attention to an aspect that may be particularly interesting when designing future projects and smart grid technology that require that peopls act and react on the technology: competences.

3.3 Research questions

To perform a practice, a certain amount of competence is required. As simple as it sounds, knowing what to do, which thing to use, and how and when to use it are basic elements of practices. The competence perspective may have disappeared in the interventions referred to above because practical competences, over time becoming practical knowledge[4], are developed in the doing – meaning that skills are learnt and bodily incorporated in the process of performing the practice (Wallenborn and Wilhite 2014). In turn, these competences are transformed into embodied practical knowledge that quickly becomes tacit. Investigating

[4] 'Practical knowledge' is not equal to being in possession of information (although it may be an element in the practice performance): people may read some gauge or meter and believe the information even though they have no idea whether the instrument is functioning properly and may thus acquire information, but this is not knowledge. When we refer to knowledge in this paper, it means the type of knowledge gained from performing practices and living our lives in an interaction with the environment, providing us information about the world we live in, information that is embodied and converted to knowledge of the world (Hauge 2013). Such 'knowledge of the world' is a sort of knowledge that goes beyond the mere possession of information, and it becomes 'true' to people precisely from doing it, from living the practice.

competences may precisely convert tacit knowledge into the explicit by describing the process of how people become competent practitioners and what type of skills seem important for the transition of forming new, more energy-reducing practices.

All knowledge entails tacit elements, but knowledge in general exists on a spectrum between the extremes of either being completely tacit and unconscious or completely explicit and accessible. Explicit elements are defined as objective, rational, and codified, while tacit elements are subjective, experiential, and often dynamically created (Leonard and Sensiper 1998). Tacit knowing is embodied physically and cognitively; knowledge for enacting the practice is embodied in physical skills; physical enacting is always an element in performing practices and resides in the body's muscles, nerves, and reflexes and learned through practice, i.e., through trial and error, as in the process of becoming acquainted with the material elements involved in the practice. Tacit knowing embodied in cognitive skills, such as knowing what is considered culturally correct and acceptable in a practice, the images connected to the practice (and thus partly regulating the performance of the practice), is likewise learned through experience and often resides in the unconscious or semiconscious. While Polanyi (1966) addressed tacit knowledge at an individual level, others have shown how it exists in group settings (Lave and Wenger 1991; Spender 1996). Collins (2001) has discussed the form and content of tacit knowledge, and Hauge (2013) has shown how embodied competences are produced through interaction with the natural environment, creating a tacit knowledge of the world.

However, being ‘knowledgeable’ about energy and energy-related technologies is likely to reflect that these topics are highly abstract phenomena to most people (Gundelach et al. 2012). Furthermore, individual ‘competences’ relating to energy have largely been delegated to the technology and experts handling it. The new micro-generation technologies installed in Danish homes may, in fact, re-delegate competences back to residents because the technologies require active administration to some extent. It may thus be expected that people are constructing new types of knowledge and competences around their new technologies. We analyse competences on the individual level, asking specifically about what the participants learned most from participating in the intervention and what types of information and skills the prosumers needed to perform the new practices. In our practice analysis, we investigate the types of competences evolving while participating in the intervention. Thus, we focus on consumers in their role of becoming prosumers, because little research seems to have been performed on this topic.

To our knowledge, this is the first longitudinal, in-depth qualitative study on households based on a large combination of technologies (solar PVs; HPs; EVs; energy management equipment) installed simultaneously in households in one community, and we shall investigate and show how ‘home-grown’ energies become integrated into everyday practice in private households. We use theories of social practice to investigate if and how people have adopted the role of the 'prosumer' by providing empirical examples of people's energy-related actions at home and the competences[5] at play, asking the following questions: How have the smart grid technologies been integrated into the lives of the prosumers? Have the prosumers re-organized their energy practices based on the smart grid technologies and how? Which changes have been the most challenging and why? Which new skills have been developed during the process of becoming a prosumer, and what information and which skills were needed for the transition?

The above questions will be answered by use of empirical data and theories explaining the findings. We begin by describing the project, the research methods used and the participants involved in the intervention. Then, we provide a brief introduction to practice theory before we present our findings and analytical results, ending the article with recommendations for future interventions and policies.

4 Study design and methods

Because we wished to analyse practices and their inherent competences developed over time, we chose an exploratory study design to keep the study open in case interesting aspects turned up during the project. To answer the research questions, we conducted a mixed-method, longitudinal study, chosen because different methods provide different perspectives to questions and because collecting data at different intervals would show the development of becoming a prosumer. We mainly wanted to use qualitative methods based on the fact that the project was going on in people's private homes and because we wished to discuss and potentially observe embodied practices (Kvale 2000).

4.1 Specific research site and methodology

20 Danish households, all living in detached, privately owned houses, form the basis for this paper. Starting in December 2013, they all voluntarily joined a two year long project. They thus represent a selection of participants with an interest in having the technologies installed. The project is organized by Insero Live Lab, an experimental lab where new technologies can be tested in the homes of real consumers in the village of Stenderup outside of Horsens in Jutland. The families have a wide range of energy related technologies installed, see table 1. In this paper we focus on the combination of solar PVs, HPs, EVs and energy management equipment. The families are allowed to keep the HP and PVs after the project ends. The EVs were leased and returned after one year. The households acquired technologies were partly subsidized. Table 1 shows details of the families participating in the project, such as the high degree of

[5] We refer to competences as the overall set of different skills that may be needed for managing the technology. When interviewing residents, we preferred to use the word 'skills.'

diversity among the families regarding age and educational background. The families have been anonymized - both in the table and in the analysis - to ensure confidentiality.

In order to get demographic information about the participants, see table 1, an online survey was sent to the households in the first 6 months of the project. In order to study the energy related practices within the households we chose to conduct semi-structured interviews of all 20 households, as well as photos and observations, providing rich data for thick descriptions (Charmaz 2006; Geertz 1973) and thorough analysis, conducted approximately 6 months after the installation. Furthermore, 3 workshops were scheduled where we investigated the participants' experiences with the new technologies and the evolving new practices and competences. One of these workshops was performed 12 months after implementation and the remaining two workshops were performed 18 months after implementation. See appendix 1 for information about participation in the data collection activities.

An interview guide was prepared before the interviews, containing a range of open-ended questions. The semi-structured interviews lasted between 50 and 90 minutes and took place in the informants' homes. In most cases, both the husband and wife were present, although this was not possible due to work schedules in some cases. The children were not included in the interviews, but they were sometimes present. Informants are included in Table 1 to give a correct picture of the demographics of the households, as well as an idea of their electricity consumption. The interviews included a tour of the house, where special focus was placed on the installed technologies and how they were used in everyday life. In the majority of the houses we observed informants' use of the displays connected to the HPs, PVs, and eButler (energy management equipment) and took photos. Naturally, field notes provided information as well.

One workshop was scheduled in January 2015, where new features for the energy management equipment, eButler, were discussed with 6 informants. The workshop was audio-recorded, and parts were later transcribed. In May 2015, the last round of data collection was accomplished. Two workshops were arranged, and half of the households were invited to each. The workshops were situated in a) the home of one participating family and b) in a local community hall, with 16 and 9 informants participating, respectively. Both workshops were thus occurring in well-known premises, inviting participants to speak openly. Prior to the workshop, a question guide had been constructed to make sure that relevant areas were covered. The workshops were both audio-recorded, and the second workshop was also filmed. The purpose of these workshops was not only to hear participants' views on what they had learned during the project and their degree of satisfaction with their system but also to hear deviant or negative stories, that is, examples of events and experiences that would run counter to the initial findings. The workshops were also used to obtain specific data on competences and changes in practices over a long period of time.

All the interviews were audio-recorded, transcribed (in extenso) and finally coded in Atlas.ti based on a grounded theory approach which we, while adopting common criteria for good scientific conduct, used for guidance in the analysis of data when identifying saturation (repititions) as well as for internal comparison (for an in-depth discussion of grounded theory and its advancements see Denzin & Lincoln 2000; Strauss 1987). Categories were developed in the coding process. Explanations were found by scrutiny of the transcribed interviews word by word, sentence by sentence. This included a comparison to energy related everyday life practices that the informants referred to (Charmaz 2006).

Based on the audio recordings, the workshops were transcribed and coded using previously identified thematic codes, such as: Consumption – Keeps track of; EV-charging; PV-relationship with energy via PV. Themes and corresponding codes were included in the interview guide, but codes were also developed inductively from the interviews, which were first organized in a flat structure but later organized hierarchically after analysing the data.

Based on an iterative analysis and continuous data collection, the research questions were refined; for instance, the topic of competence appeared to be more important than first expected and was included in a research question.

The long period for gathering data was to ensure that the experience of becoming a prosumer had in fact settled.

Table 1. The first column shows a list of informants; the second column shows which PV feed-in tariff they belong to.

ID	PV feed-in tariffs: Old/New[6]	Gender and age	Children living at home	Socio economic status	Education	Technologies installed
F27	Old	M (35-44) F (35-44)	F (15-19) M (5-9)	Wage earner No information	College No information	Hybrid Air/water HP with gas boiler; PV; EV
F33	Old	M (45-54) F (45-54)	-	Self-employed Self-employed	Lower secondary school Lower secondary school	Air/water HP; PV; EV
F6	Old	M (35-44) F (35-44)	-	Wage earner Wage earner	Vocational education College	Air/water HP; PV
P7	Old	M (55-64) F (55-64)	F (10-14)	Unemployed Wage earner	College College	Hybrid Air/water HP with gas boiler; PV; EV
H6	Old	M (45-54) F (45-54)	M (15-19) M (15-19)	Wage earner Wage earner	University education College	Hybrid Air/water HP with gas boiler; PV
B3xx	New	M (65+) F (65+)	-	Retired Retired	Vocational education Vocational education	Air/water HP; PV; EV
B2xx	New	M (35-44) F (35-44)	F (10-14) F (10-14)	Wage earner Wage earner	Vocational education Vocational education	Air/water HP; air/air HP; PV; EV
L15	New	M (55-64) F (55-64)	-	Retired Early retirement	College College	Hybrid Air/water HP with gas boiler; PV; EV
P3	New	M (35-44) F (35-44)	F (10-14) 2xM (10-14)	Wage earner Wage earner	College Lower secondary school	Hybrid Air/water HP with gas boiler. PV; EV
F7	New	M (45-54) F (45-54)	-	Wage earner Self-employed	College University education	Hybrid Air/water HP with gas boiler. PV; EV
S7	New	M (25-34) F (25-34)	-	Wage earner Wage earner	Vocational education College	Hybrid Air/water HP with gas boiler; PV; EV
L13	New	M (45-54) F (45-54)	-	Wage earner Self-employed	Vocational education Vocational education	Air/water HP; PV; EV
S4	New	M (55-64) F (55-64)	-	Wage earner Wage earner	Vocational education Lower secondary school	Air/water HP; PV; EV
S2	New	M (35-44) F (35-44)	F (10-14) M (10-14) F (0-4)	Unemployed Wage earner	Vocational education College	Sunwell; PV; EV
A2	New	M (55-64) F (55-64)	-	Early retirement On sick leave	Lower secondary school Vocational education	Sunwell; PV; EV
P5	New	M (65+) F (65+)	-	Retired Retired	Vocational education Lower secondary school	Hybrid Air/water HP with gas boiler; PV; EV
H9	New	M (35-44) F (45-54)	F (10-14)	Wage earner Wage earner	University education Bachelor	Geothermal HP, solar thermal collectors, PV; EV
F15	New	M (45-54) F (45-54)	M (15-19) F (10-14)	On sick leave Self-employed	Lower secondary school Lower secondary school	Hybrid HP with gas boiler; PV; EV
D22	New	M (35-44) F (35-44)	-	Wage earner Wage earner	College College	Geothermal HP; PV; EV
Ba3x	New	M (35-44) F (25-34)	-	Wage earner Wage earner	Vocational education College	Air/water HP, PV; EV

[6] PVs in Denmark became especially favourable after the solar agreement in 2012, which included a lucrative deal for the prosumers where the state was paying them for delivering electricity to the grid. The agreement, named 'Netto-måle-ordningen' (net-meter-scheme), referred to as the old-agreement, included a yearly settlement of accounts regarding the produced electricity, and the capacity must not exceed 6 kW per household. Because of this lucrative deal and the decline of prices of PV panels, a large number of households purchased, resulting in a massive loss for the state. Thus, a new agreement was constructed called 'Net-meter-by the hour' ('Time-netto-ordningen'), referred to as the 'new agreement,' which includes a different set-up for the prosumer. With the new agreement, a surplus of electricity from solar panels up to 6 kW is sold at the fixed price of 0.6 kr/kWh for PVs installed after 19/9, 2012 (http://www.energinet.dk/DA/El/Solceller/Har-du-solceller/Sider/Nettoafregningsgrupper.aspx). Because the amount of electricity is accounted for each hour, the surplus of electricity is sold at a price of 0.6 DKK/kWh. The price of electricity (for 24 hours) is 2.20 DKK/kWh.

The ethnographic methods described in this section were chosen for their ability to document people's practices. Documenting what people are doing may uncover both the competences required for performing new practices and the process of building new competences during the intervention. In the next section we will present our findings.

5 Findings

This section first describes how practices were changed according to the smart grid technologies specifically related to micro-generation and how changed practices also result in increased consumption[7]; secondly, the section 'Getting more competent' describes how users became more competent with regards to the introduced energy technologies over time. The section ends with a summary of the CIM elements of the practices described and with participants stating what they appreciated most and least from the project.

5.1 Changing practices: Making use of the sun

Practitioners have individual everyday rhythms that coordinate and stabilize practices and the relation between them (Shove 2009). These everyday rhythms include an organization of the daily practices. The solar PVs prompted the practitioners on the new solar PV agreement to primarily use energy when the sun was shining, thereby potentially disturbing the overall everyday rhythm of the practitioners. For the families on the new agreement who were at home during the daytime (3 retired couples and 1 family working from home), this disruption was not difficult to overcome. In general, these four households were very aware of changing their practices and eagerly spoke of how they had managed to change their rhythms as described in the following:

> F: "We are in such fortunate position that we are at home all day so we use the PVs for the charging of the EV, and we wash, and the dishwasher is never on unless the sun is shining. This way, we use the generated electricity right away" (B3xx)

This family consisted of retired people who had the ability to change their routines to incorporate the use of energy when the sun was shining. In another household, the wife was working at home as a day-care mom and could do all the household chores when the children were napping. All the families who were at home during the day reported that they strategically increased activities that included energy when the sun was shining. Additionally, the lack of sun had an effect on how practices were performed:

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[7] Others have used the concept of rebound effect to 'explain' an extended use of energy after an energy saving installation. The rebound effect is "the extent of the energy saving produced by an efficiency investment that is taken back by consumers in the form of higher consumption" (Herring & Roy, 2007: 3), either in the form of more hours of use or a higher quality of energy service (such as dishwashing more often, using floor heating in more rooms, etc.). We will not deal with the types of rebound here.

> M: "If there is a week with grey sky the dust is left, hoping that in the coming week … F: Then, we use the broom instead, then we sweep the floors, we do that many times a day already, but when the sun shines so lovely then it is easier to fetch the vacuum cleaner instead of the broom" (L13)

The family did not vacuum if there was no sun; instead, she would return to the practice of only using the broom while awaiting the sun. They took up the old practice of sweeping, claiming that it was functioning just as well as the vacuum cleaner. In this family, the practices of cleaning and cooking/baking were only loosely coupled to other practices, so it did not disturb their daily rhythm of other practices if they changed the timing of their daily chores. The family also reported always having tried to use the 'free pleasures,' referring to the wind and the sun, to dry their clothes and never had a tumble dryer.

All the families on the new agreement expressed awareness of adapting their energy-consuming practices. One strategy was to be careful with charging the EV and only charge when the sun was shining. This meant unplugging the EV when the sun went down, as the following citation illustrates:

> M: "Sometimes I plug it out in the evening, if the charging can wait until tomorrow. It is a kind of foolish to charge it in the evening when the sun is not shining; we keep an eye on that." (F7)

Bending common chores towards the movements and availability of the sun showed that people interacted with the environment in new ways; prosumers became aware of their surroundings in new, enlightening ways. Tacit knowledge embedded in the old daily rhythm was integrated in their new practices. Being dependent on the sun necessitated that they rescheduled old practices if they wanted to make the most of the prosumed energy. This in turn created frustrations among those unable to use daytime hours to optimize energy-demanding practices.

Another strategy seemed to reflect an increased awareness of energy flows among the participants and resulted in a rescheduling of the daily chores within the families. In many cases, the rescheduling involved the dishwasher, washing machine and tumble dryer, those being the technologies that the families reported as 'flexible' loads that could more easily be changed in day and time (similar findings were reported by Powell et al. 2014). Rescheduling the dishwasher practice was easy, as the following participant explains:

> M: "It doesn't matter if the dishwasher runs at three o'clock in the day or if it runs at seven o'clock in the evening, so it might as well run at three o'clock. I: Did you use it at seven

o'clock before? M: Every day. W: Yes, between seven and eight, and sometimes eight thirty." (D2x)

The above family consists of a fairly young couple, and they found it easy to time their dishwasher. By combining the timer function with checking the weather forecast, they would time their appliances to wash or dry when they were most likely to be producing their own electricity. The practice of leaving for work was now coupled to checking the forecast and timing the appliances before leaving home, and once back, the EV is plugged in:

> M: "We can use our washing machine and dishwasher and tumble dryer since we can programme them. They are new, and we are really committed to that. F: ... to programme them to run at two o'clock in the afternoon, for example. M: When my wife comes home she plugs it in right away. We manage to charge the EV when the sun is shining." (B2xx)

Both examples illustrate that the rescheduling was conducted based on the abilities of the technologies combined with knowledge of the weather. Gaining knowledge of the environment has been found to be an important part of various practices at home (Hauge 2013, 2015), but here this knowledge was required upfront for performing the practice in the first place: insights gained from studying weather forecasts and the natural environment influenced the timing of their actions. For instance, to most of the participants on the new agreement, the practice of charging the EV seemed coupled with the time of arriving at home after work, to avoid forgetting it as well as for economic reasons: to charge while the sun was still shining. The practice of charging the EV was performed manually:

> "Yes, we have done that [manually unplugged it when it got cloudy], lately it has not been so sunny, then we wait to plug it in. It has become a sport to make it work." (S7)

The families were offered an application to use for starting the charging of the EV, but no family reported using it[8]. The families seemed quite happy with the arrangement of plugging the charger in and immediately pressing 'charge' and just unplugging it if it was necessary to stop the charge.

To summarize this section, the strategies to change the everyday rhythm to comply with the shining of the

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[8] There were several reasons. Some reported they could not be bothered with it, indicating that they were not interested in more technological gadgets. One family argued that, since the car was in use during the day and therefore at another location than the electricity was cheap, the application was probably not so relevant. Another reported that, since they lived far out in the countryside, the phone connection was not good; if she wanted to turn on the charging while sitting in the living room, it took quite some time to obtain a network connection, so she might as well go out and turn it on manually. One reported that the application did not work and did not insist on having it fixed.

sun were accomplished differently among the informants, primarily due to presences at home during the day or having technology with programmable timers. Those that could spend their days home were attentive of turning their devices on and off according to the sun. They found it easy to change their rhythm and would take up old practices (using the broom) on cloudy days. Thus, the practice of cleaning the floor became a much more dynamic practice that needed more consideration than previously. This was also the case for the families working outside of their homes. They were relying on timing their devices, and the practice of timing could be coupled to checking the weather forecast before leaving for work. Thus, the practice of leaving the house and deciding when to wash became much more dynamic and dependent on external factors.

5.2 Changing practices: Increasing consumption

As noted by many other scholars (e.g. Caird and Roy 2006; Frondel 2004; Greening et al. 2000; Strengers 2013), micro-generation can cause increased energy use in households. In Insero Live Lab, many families on the new agreement reported an increased use of energy, for two reasons. The first involved the wish for an increased sense of comfort in the household, resulting in more energy-consuming practices. The second included considerable resentment towards the energy company and hence a wish to exploit every drop of energy to prevent the energy company from getting it for free. One example of the first reason for exceeding the consumption was one family that had increased their driving frequency because driving an EV was cheap, fuelling their EV with their home-grown "free" energy instead of expensive gasoline. They were happy to be able to drive cheaply in summertime and had begun taking 'Sunday trips' just like when they were children:

> F: "Now we drive like in the old days, like when we [referring to her parents] first got a car. Back then we would go for a drive on Sundays after dinner. We would bring the coffee and drive somewhere. We have begun doing that. We haven't done that for years. Gasoline is too expensive for that." (L15)

Thus, the practices of driving had been partly decoupled from ordinary transport practices for this family, now involving leisure-time driving, substituting the old practice of their unsustainable gasoline car. Micro-generation allowed the family to create new practices that they regarded as almost luxurious, enjoying the ability to go for coffee in the area around Horsens and Stenderup. From being very attentive of their energy consumption, they began to pay less attention to using energy with care and became more relaxed about using it. The pleasure of charging and driving their car with their home-grown electricity was considered a contribution to a new, more pleasurable lifestyle. The home-grown energy was also used to sustain previously unsustainable behaviour associated with comfort:

> F: ”and the solar panels, that’s also green. But I don’t cut down. I like to use a lot of water when I wash even if I don’t have to; because it is those up there [PVs] that make it [heat up the water] and as long as we use the ones up there it is okay.” (SA2)

This woman sustained her washing practice, where she would use plenty of hot water, by having ‘green’ technologies. The justification of continuing an overuse was connected to the ability of the PVs to generate green energy. Both of the above examples show that the use of home-grown energy broadened their energy-consuming practices to include or increase their sense of comfort. In the first case, the couple has increased their level of mobility, and in the second example, the informant feels no guilt about using the extra energy for an extravagant washing practice.

The second and by far most-reported reason for increased energy consumption was related to feeling unrightfully treated because of the layout of the new schemes offered. Living in a small community and participating in Insero Live Lab, they were constantly confronted with the disadvantages of being on the new agreement compared with those on the old scheme. This feeling of giving away their ‘own’ energy to the energy company seemed to nurture energy spending, even when they had no need for the energy. This is illustrated in the following two quotes:

> M: “We are in the new agreement, where we have to pay within each hour, and that makes no one environmentally conscious because when the sun shines, then the dishwashing machine is not necessary completely full but is turned on all the same, because the electricity is free, and the same goes with the tumble dryer and washing machine.” (H9-2x: 14)

> M: “..It is free to charge the electric car, and it is free to start some appliances somewhere. We won’t get anything for it anyway, let’s just let the fan heater run for a while, and we might as well charge. I shower longer now compared to what I did before.” (P3)

When discussing the implications of being a prosumer on the new agreement, frustrations from giving away electricity without compensation clearly appeared. These frustrations related to the fact that the energy was delivered to the energy company and not some organization that the informants wished to support. The prosumers had no control over who received the electricity they produced or if the energy they sent back into the system was used in a sensible way:

> M: "The most awesome thing that we could do here is to collect it, so that many units together saved the energy, so that the whole village could contribute to heating up a pool that was going to be heated anyway." (P3)

The frustration created entrepreneurial ideas among some of the participants, which in this case were directed towards the local community and the collective responsibility as illustrated in the above quote. Along with the wish to support the local community, participants were actively searching for ways to be managers of their own energy system, and there were signs of great engagement in transforming their energy system to become both more sustainable and more independent from energy companies (as also found by Späth and Rohracher (2010)). In this sense, the intervention not only provided the individual households with energy technologies, but having this abundance of energy made people more aware of community energy needs and interested in ways to help a larger group.

To summarize this new focus of consuming electricity: users were consuming more than they needed, and there were two reasons for this. The first related to comfort; having these extra technologies made them want to get more out of them and really use them to the technological limits. Secondly, they were very focused on not delivering the extra electricity to the energy company, clashing somehow with the original vision in the project (which had been changed because of the sudden implemented feed-in tariffs for the PV), viewing the prosumer as someone idealistically contributing to the needs of the energy system during the day and accepting remote control by the energy company during the night. Because the choice was between delivering the surplus of electricity to the energy company and using it on unnecessary energy practices, most participants seemed to prefer the latter option. Some recognized this as a problem and wished for the ability to donate the electricity to local initiatives.

5.3 Becoming a more competent energy citizen

The previous sections have shown how people wanted to adjust the rhythm of everyday practices to be in sync with their own generation of electricity. The participants were continuously trying to adjust their energy practices by their available means using simple arrangements, such as manual plugging-in of the EV or using a timer. In contrast to this, many families did not find equal possibilities for timing the use of electricity relating to the HP. They seemed to struggle to adjust the settings to use their home-grown energy becoming more competent energy citizen (Devine-Wright 2007). The following example shows a family that felt that the HP caused difficulties when they wanted to control it in sync with the sun shining. The family was concerned with the time constraint and lacked the skills necessary to change the heating practice of the HP.

> F: “Then, one could adjust one’s consumption because we are wondering a lot over things like: Can we get that HP to run when the sun is shining and things like that, get the timing right. We are eager to get started but we can’t since we don’t have the tools for it.” (B2xx)

This couple was clearly interested in engaging in energy-producing practices to couple it with their heating practices. Unfortunately, timing of the practice was simply not compatible with the technology. The HP had neither a weather synchronicity feature nor a ‘turn on’ option allowing the participants to heat the house when the sun was shining. The participants wondered about this:

> M: “Is it possible to adjust the HP so that it will only run during the day and not during the night? We have floor heating and when it starts to heat it takes a long time before the heat actually reaches our living room. There is no reason that it should run during the night in the summer and not during the day time. It would actually be better the other way around.” (P26:SA2)

One could argue that the device is either too smart, having too much built in intelligence to fulfil the prosumers’ wishes, or it is too simple because it contains no timing feature, prohibiting participants from managing the consumption of the device. In many cases, the slow process of heating floors was the argument for the HP to work despite a shining sun. The participants considered the floor as a type of storage place for the heat. Because the HP included a buffer tank, some found it logical that this would mean that the HP would have the ability to ‘store’ energy so that they would have the option of heating up the water in the tank when the sun was shining:

> M: “We have the HP and that’s where we can move the most consumption. It contains a buffer tank, and right now it’s only being used to heat up water to the minimum temperature. Today there is no feature making it heat the water to high level when the sun is shining in the summer.” (H9)

As the quote shows, the informant clearly expected the buffer tank to provide a way to store some of the generated energy. When it turned out not to be the case, it caused confusion: “I have no idea what it is for then.” Hence, the HP’s script (Akrich 1992) had some hints of including features relevant to prosumers on the new agreement, but the set-up of the HP did not allow participants to change the rhythm according to their wishes. One participating family had gone beyond this project to be able to control their HP according to the generation of electricity. The husband and wife, both engineers, had, via “Control Your Heating Pump” (a project platform), gained access to various types of software applications that, in time, would assist them in controlling their HP. They were the only ones to initiate such demanding activities, suggesting that, to manage the system in the most efficient manner, a certain technological background was required.

The capability to adapt the materials to fit the new circumstances turned out to be more important than initially expected in the project, and it seemed that certain competences were required. First of all, participants had become aware of the intricate entanglement of consuming and producing, as one informant describes:

> F: "and you begin to think more about your consumption and production and realize that they are connected." (BV2xx)

Approximately one year after the technologies had been installed, some participants discovered that not everything was running as it should in the energy system. Initially, they were told that, on the 'new agreement,' the rules were that the produced electricity was free to use within the hour that it was produced. The participants were to choose between the two types of tariffs explained before from the energy company. No one, neither the participants nor Insero, understood from the text explaining the groups that, in one group, the electricity would be delivered on the three phases[9]. Apparently even the electricians were not aware that the 3 phases in the house would mean that the participant would get their production spread evenly on to 3 phases.

> M: "It's common knowledge among electricians that it's like that. When you buy a three phase PV you cannot make use of all the generated electricity" (D2x). M: "We were not informed of that. It surprised me a lot when I found out." (L13)

From the instructions the participants received, they believed they could charge their car and wash their clothes for free when the sun was shining. This changed once the participants independently began to wonder how it was possible to charge an EV while washing clothes and still sell electricity to the grid (they could see that they did on their smart metre).

> M: "I thought: It cannot be right that we're selling electricity while we are charging (L13). M: I went out and dismantled the plug because it can't be true that it is only plugged to one phase, but it was." (H9)

[9] A common way to install electricity in family houses is via three electrical phases. Each electrical output in the house is connected to one of the three phases. The smart meter measures the total consumption and production from the three phases. The EV charger in Insero Live lab was connected to one of the three phases.

The discussion between two participants shows how they were closely monitoring their energy system and critically assessing the text on the available displays. The new information about the PVs delivering evenly to all 3 phases in the household actions was used to optimize the electrical setup in the house:

> M: “I found out that my washing machine and tumble dryer and laundry machine are on the same phase, so I changed them so now they’re on different phases, so I can use more electricity. I loosened the wire and…” (H9). M: “I would never have done that myself [switching phases on the electrical panel].” (L15)

The discussion above is an example of how participants approached problems based on their existing skills. In this case, the engineer had a far more hands-on approach and fixed the problem himself, while the teacher had the knowledge but lacked the skills to adjust the electrical wiring in the house to function optimally.

In summary, it seems that, although the informants had been focused on changing their energy practices to accommodate their home-grown energy, this was not possible for all the technologies available. The HP required such knowledge of programming, etc., that only the engineers among the participants had a chance of changing the settings according to the PVs. The complexity with the 3 phases and generation of electricity was also too difficult for most informants to do anything about. Based on the above section on findings, we shall now proceed to the conclusion and policy recommendations.

6 Conclusions and recommendations

This study has contributed to a relatively small research field dealing with energy related practices and prosumers in smart grid households. Some limitations to this study are related to the fact that it is based on an experimental project where people have volunteered to participate. This means that although participants were in different age groups and had different educational backgrounds, they might be more than average interested in new technologies or at least not reluctant to acquire new technologies to their homes. Furthermore, the study was conducted in a rural area so participants’ attitudes towards energy use and environmental concerns might differ from a more urban population. Because of these reasons the results of this study cannot be generalized but they provide in-depth information about prosumers in a smart grid context which can be useful when thinking about the future of households in the smart grid and their role in it and for designing complex energy interventions. Furthermore, the practice approach showed that participants in fact were lacking competences to be successful in consuming their home grown energy.

The main contribution of this paper is related to the empirical data on emerging prosumer practices in smart grid households. Particularly we have shown how energy related practices and their inherent elements - competences, images and materials - evolve over time. Findings show how the new material setting in smart grid households has a crucial impact on energy consumption behavior and prompts the acquisition of new practical knowledge on the area. In the next section we will reflect upon the use of the theoretical approach and list the main contributions from the CIM-model.

6.1 CIM

The constituents of the prosumer-related practices, the CIM, among the Danish families seemed to involve the following: regarding *competences*, people were indeed acquiring new knowledge and demonstrating innovativeness in relation to their new equipment as the project developed. This study thus confirms a previous study that found a high level of innovativeness among participants in interventions where they e.g. developed new ways of gaining control over their appliances (Nyborg 2015). The process of becoming better acquainted with the outside environment so as to be a prosumer reflected a new type of competence, a 'competence of the environment' (as found also by Hauge 2013, 2015), that once gained seemed to make people more in sync with the seasons and the natural environment around them. Hardly surprising, because having solar PVs required use and knowledge of the sun, but this overall finding highlighted what may be true to some extent generally and here specifically, that people live their lives in a dynamic relationship with the environment and that participants during this interactive process created and acquired knowledge and experience of both technology and nature, precisely through their active prosumer role and the required relations with the environment. This changes the idea of what constitutes 'competence' within a practice: from being a fixed form or concept, 'competence' is transferred into 'knowledge' precisely based on the practices and activities performed. The prosumers in the Danish intervention became not only competent practitioners, but in this process, knowledge was gained through practices enacted in a dynamic relationship with the environment: participants became, as Devine-Wright (2007) calls them, knowledgeable "energy citizens".

The *images* related to the prosumer practices in the Insero Live Lab were reflecting how the notion of being a participant in a project focusing on green energy was socially and culturally constructed through continuous meetings and workshops. The participants perceived the change of the timing of the practices as a natural part of the household chores. Another image related to the prosumer practices was the image of the generated energy as free and abundant at times. Related to household chores it was reflected in the practices where households were using more energy than necessary when the sun was shining. But since the energy at this time was 'free' they could feel conscious about an overuse of energy. The overuse of energy also seemed to be linked to the tree domains of comfort, cleanliness and convenience (Shove 2003) when doing practical chores within the home. Thus the image of free energy were legitimising cleaning practices that otherwise were not considered sustainable by the families.

The new material setting in this project had a crucial impact on energy related practices in the households. Previous studies have shown that home owners are often improving 'green' technologies such as heat pumps after the installation has been completed (Hyysalo, Juntunen, and Freeman 2013; Nyborg 2015). In this project the participants shoved a great interest in adapting their new technologies. Nevertheless, the *material* part of the prosumption practices became more complex as the project progressed. The *materials* needed to perform the practices in the intervention were solar PVs, HPs, EVs and energy management equipment, all forming a kind of 'havings' required for 'doing' or even 'saying' the practice. As time went by there was an increasing focus on the material part of the prosumer practices. Prosumers were questioning the set-up and wished to include material from the household to be part of the energy related practices. However, the material parts of the prosumer related practices in time showed that participant in fact were lacking competences to indeed be successful in consuming their home grown energy.

Contrary to previous studies showing innovating consumers inventing new solutions in their energy system (Hyysalo et al. 2013; Nyborg 2015), this study shows that innovation from the prosumers' perspective in the smart grid is a highly complex matter. While participants were indeed becoming both knowledgeable energy citizens and more competent in performing many of their energy related practices, many of them could in fact not innovate as they wanted on all the materials of the prosumer related practices.

6.2 Policy recommendations

From the perspective of practices, a practice theoretical approach has proven to give valuable inputs to policy makers: It follows from our analysis that features represented by the CIM of people's energy practices - that reflect the social character of practices and that new practices were constructed precisely through the interaction between the grid, the natural environment and people's common activities in general - should be addressed and accounted for *prior* to designing measures aimed at changing domestic energy consumption. Evidently, the prosumers in the Insero Live Lab had difficulties understanding the full extent of circumstances relating to their consumption of energy. The explanation of the tariff structure and schemes was just too difficult to comprehend. Education campaigns should therefore focus on feed-in tariffs (this resonates with other research, such as Islam, 2014). In general, effective measures to reduce energy consumption should be clear and simple, relevant to the consumer, involve some type of commitment or goal and be visible, consistent and frequent (as found also by Martiskainen 2007: 47).

Focusing specifically on feedback, Fischer (2007) arrives at a somewhat similar conclusion: that feedback should involve interaction and choice for households and be appliance-specific, also stating that – like a participant in our study expressed: "there is probably not "the" perfect feedback for everybody." We wish to underline this too. There is no "one size fits all" project, so naturally effective interventions must match the characteristics of the targeted group (e.g., norms and motives, consumption profiles, social lifestyles and practices) and preferably integrate participants' needs and ideas upfront, while at the same time and in the long run keeping a transparent system that would allow participants to easily co-design for their specific needs. This is important, since consumers are not merely motivated by economic incentives to save energy or participate in an energy intervention. On the contrary, people's motivations for participating in the energy project were multiple: staying updated on energy provision, having a house that would keep its value, being on the forefront in terms of technology, being part of a project together with others and thus sharing something that might bring people closer together, seeing the participation as something fun for the family, becoming independent of the energy companies, and the possibility to save money. Several mentioned a wish to be able to donate surplus energy locally. The fact that people want to contribute locally resonates with previous research such as Throndsen and Ryghaug (2015). This seems to call for new ways of facilitating, such as through policy-making, people's sense of being part of a shared project in otherwise dispersed areas threatened by depopulation. Including options for people to donate electricity to local initiatives could potentially contribute to a stronger sense of unity in small towns and also benefit the environment by encouraging the consumers not to consume more than they have to. With a view to consumer rights, such research would involve a discussion of 'prosumer rights' and the need for developing such rights.

This study has noted some contradictory trends in Denmark, namely the prosumers' current circumstances and the existing governance in relation to the energy system. The prosumer related practices in this study showed a continuous engagement in being self-sufficient regarding energy. Such engagements could result in further activities along the lines of citizens' self-organizations in relation to micro-generation and becoming self-sufficient. On a societal level there are huge economic interests at stake if consumers could by-pass the system and avoid taxes of energy. With the dropping prices of PVs this could soon be a reality to be considered. Meanwhile much effort is being put into a centralized version of smart grid in Denmark where wind power plays a large part in the greening of the energy sector. In this scenario consumption of electricity would be best evened out when electricity is consumed during the night. The produced electricity during the day time should rather be delivered to the grid as more electricity is consumed during the day. Policy makers should consider how the prosumers can provide benefit to the system level instead of striving for independence and resisting feeding the extra energy on to the grid. This calls for a reflection of governance measures and incentives in relation to the role of citizen in the smart grid. There is a need to consider the role of the prosumer and how they can affect energy consumption in households and possibly act as a driver in a transition towards a fossil-free energy system. In addition, the entire practical set-up around micro-generation should be assessed in relation to what role prosumers are to take in the future energy system. Here we wish to recommend policies to consider the frustrations that prosumers experience when delivering energy to the energy company and that policy makers remember that this in some cases resulted in a deliberate overuse of energy from the micro-generation. A way of avoiding such overuse could be through encouraging technologies to be easily adjusted in accordance with the sun shining or an option for the complex possibility of including a 'local area benefit'. The latter may be controversial: Donating the prosumed energy to specific institutions would constitute a major break with the way that privately owned PVs' generated electricity is being calculated and administered today, where the biggest economical advantage is given when the electricity is consumed in the hour that it is produced. At present, the prosumer does not pay taxes for the electricity. By donating the electricity to institutions in the nearby community, the state would lose income tax from the sale of electricity. While this suggestion from a citizen in the project seemed to gain much support from all the participants, such a change may have far-reaching consequences in society, yet it may also result in increased energy efficiency by encouraging more energy conscious behaviour and a sense of community belonging.

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8 Appendix 1

ID	Survey	Interview	WS 12 months after implementation	2 X WS 18 months after implementation
F27	X	X	-	-
F33	X	X	-	X
F6	X	X	-	X
P7	X	X	X	X
H6	X	X		X
B3xx	X	X	X	X
B2xx	X	X		X
L15	X	X	X	X
P3	X	X		-
F7	X	X	-	-
S7	X	X	-	X
L13	X	X	-	X
S4	X	X	-	X
S2	X	X		X
A2	X	X	-	X
P5	X	X	-	X
H9	X	X	X	-
F15	X	X		X
D22	X	X	-	X
Ba3x	X	X	-	X

Table 2: the workshops 18 months after the implementation were arranged to include half of the households each. This was done to ensure time to hear everyone's opinion