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Smart grid development and households in experimental projects

Ph.D. thesis

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English summary

The use of renewable energy has become of great interest to the Danish government as it would allow Denmark to become independent of fossil fuels. One of the stated ambitions is that, in 2020, 50% of Denmark´s electricity will come from wind energy. Such changes constitute a significant challenge to the electricity grids and call for the development of smart grids. The Danish Smart Grid Strategy states that 'flexible electricity consumption' is the main purpose of smart grids in Denmark, envisioning that future consumers will have flexible consumption of electricity. Thus, they are expected to respond to the supply side and consume energy when it is available.

The goal of this thesis is to investigate how household consumers are integrated in smart grid development activities. More specifically, it focuses on household consumers, as they are represented in experimental projects in the smart grid area. This is done by building theoretically on the concept of scripts (Akrich, 1992) and on Practice theory (Shove et al., 2009; Schatzki, 2002; Reckwitz, 2002). Empirically, the focus is primarily on development activities in Denmark. The overall research question of the thesis is: How are households in the smart grid being envisioned in experimental projects, and how are they responding to these visions?

This thesis increases the understanding of the visions of smart grids and household consumers and of how they actually are responding to smart grid technologies and concepts. Particular attention has been given to overall visions in experimental projects, the new emerging practices related to the new role of being a prosumer, and lastly, the issues of control.

The results of the first paper show that, although flexible consumption may entail large changes in households' everyday activities, there has been little research on the area in Danish smart grid experimental projects. Overall, the consumers are expected, to some extent, to provide flexibility by changing their energy-consuming practices because of economic incentives by means of manual or automated control of devices. Moreover, the Danish smart grid development community is not acknowledging the role of prosumers in the grid, although the perspective of prosumers might play a role in the transition towards a fossil-free energy system. The following two papers address the issue of household consumers and everyday life aspects in smart grid households and find that there is a contradiction between the common Danish smart grid script and the role of prosumers. Furthermore, the concept of 'remote control' contradicts the rhythm of the practices of everyday life that prosumers strive for in the current PV tariff structure.

Dansk resumé

Brug af vedvarende energi er af stor interesse for den danske regering i dens bestræbelser for at gøre Danmark uafhængig af fossile brændstoffer. Et af de erklærede mål er, at i 2020 skal 50 % af Danmarks elektricitet komme fra vindenergi. Sådanne ændringer udgør en betydelig udfordring for el-nettet og lægger op til udvikling af et intelligent el-net (smart grid). Ifølge den danske smart grid-strategi er et 'fleksibelt elforbrug' hovedformålet med smart grid i Danmark og man forudsiger at fremtidige forbrugere vil være fleksible i deres elforbrug og forbruge energi når den er tilgængelig.

Målet med denne afhandling er at undersøge, hvordan husholdninger er integreret i smart grid udviklingsaktiviteter. Mere specifikt har jeg valgt at fokusere på husholdninger, som optræder i forsøgsprojekter i smart grid-området. Teoretisk bygger projektet på begrebet Script (Akrich, 1992) og på Practice teori (Shove et al, 2009;. Schatzki, 2002; Reckwitz, 2002). Empirisk er der primært fokus på udviklingsaktiviteter i Danmark. Det overordnede forskningsspørgsmål i afhandlingen er: Hvad er visionerne for husholdingerne i smart grid og hvordan reagerer de på disse visioner?

Afhandlingen skal øge forståelsen af fremtidsvisioner af smart grid i forbindelse med private husholdninger, og af hvordan disse rent faktisk reagerer på smart grid-teknologier og koncepter. Særlig opmærksomhed er blevet tildelt de overordnede visioner i eksperimentelle projekter, de opståede praksisser i forbindelse med den nye 'prosumer' rolle og endelig kontrolaspekter i hjemmet som følge af smart grid.

Resultaterne af den første artikel viser, at selv om et fleksibelt el-forbrug kan medføre store ændringer i husholdningernes hverdag, har det været begrænset med forskning på området i danske smart grid eksperimentelle projekter. Forbrugerne forventes at ændre deres energiforbrugende praksisser på grund af økonomiske incitamenter og manuel eller automatisk kontrol over deres apparater. Derudover bliver den nye 'prosumer' rolle ikke anerkendt i den danske smart grid udvikling, selvom 'prosumers' kan spille en rolle i overgangen til et fossilfrit energisystem. De efterfølgende to artikler fokuserer på forbrugernes hverdagsliv i smart-grid-hjem og konkluderer at der er en selvmodsigelse imellem den danske smart grid forestilling og prosumer-rollen. Derudover modarbejder konceptet 'ekstern styring' rytmen af elforbrugspraksisser som prosumerne i øjeblikket tilstræber med den nuværende PV-tariff.

Contents

1 Introduction

The smart grid is envisioned to imply comprehensive changes to the energy system by the extensive use of information and communication technology, which will considerably increase the amount of data exchanged between the involved actors in all parts of the system. It is not an 'end' in itself but rather a path towards a more efficient, flexible, and robust electricity system that can integrate energy sources of the future (Erlinghagen & Markard, 2012). In smart grid visions, the roles of household consumers are often expected to change significantly. For instance, they may have technologies installed that can be remotely controlled and/or increasingly become managers of their electricity consumption and/or production. Nevertheless, the future roles of the household consumers are yet to be defined (Goulden, Bedwell, Rennick-Egglestone, Rodden, & Spence, 2014). Some suggested changes in the electricity grid towards smart grids are apparent in the vast number of smart grid projects and investments that have appeared in recent years on a global scale; see, for instance, (Covrig, Vasiljevska, Mengolini, Fulli, & Amoiralis, 2014) and (ISGAN & IEA, 2013a; ISGAN & IEA, 2013b). Because the implementation of smart grid potentially entails comprehensive changes in the everyday lives of household consumers, the changes at household level deserve further investigation. Furthermore, the growing numbers of experimental projects that include household consumers are relevant to study because they offer the possibility to explore households and smart grid technologies in real life settings. Thus the goal of this thesis is to investigate how household consumers are integrated in smart grid developments. More specifically, I have chosen to focus on household consumers, as they are represented and appear in experimental projects in the smart grid area. This is done by building theoretically on the concept of scripts (Akrich, 1992) and on Practice theory (Shove, Trentmann, & Wilk, 2009; Schatzki, 2002; Reckwitz, 2002). The overall research question is:

> **How are households in the smart grid being envisioned in experimental projects, and how are they responding to these visions?**[1]

Empirically, the focus is primarily on development activities in Denmark. The integration of fluctuating energy sources in Denmark, combined with the increasing installation of electricity-driven technologies to avoid burning of fossil fuels, is expected to pose challenges to the electricity grid. To cope with these challenges, the smart grid has been suggested as a way to manage the increasing pressure on the electricity grid and to ensure more efficient use (KEB, 2013). The smart grid has become a prioritized, strategic area on the national level and among leading energy-sector actors in the country (Dansk Energi & Energinet.dk, 2010; KEB, 2013; Regeringen, 2012). Compared to most other countries in the EU, Denmark has had an

[1] Further descriptions of the detailed analyses are found in section 1.3, Process and analysis approach

ambitious and large smart grid effort for a number of years now. In some respects, it can be considered a leading country. The JRC (Joint Research Centre, European Commission) reports that Denmark has by far the highest investment in smart grids per capita. This is also the case when considering spending relative to the electricity consumption, i.e., spending per kWh consumed. In addition, Denmark has the second-highest total number of smart grid projects in the EU (Covrig et al., 2014). Almost one-fifth of all consumer involvement projects reported in Europe appear in Denmark (Giordano et al., 2013). This makes it relevant to look into the Danish smart grid activities, not only for Danish actors and analysts but also more generally for scholars in the smart grid field.

There have been increasing investments in areas that can benefit sustainable development across the EU. Since 2004, these investments have also included smart grid research and projects. In parallel to R&D and pilot projects, other investments have been made to support this development. For instance, smart metres, which are often considered prerequisites for the implementation of a smart grid, are being installed in many countries in the EU, and according to JRC Science and Policy, 72% of EU customers are expected to have a smart metre installed by 2020. Currently, Sweden, Finland and Italy have installed smart metres nationwide (Covrig et al., 2014). In Denmark around 50% of the households have smart metres installed.

To illustrate what challenges smart grids are expected to solve, I will present two definitions that can clarify the overall goals of smart grids. The "Energy Research Knowledge-Centre (ERKC)" from the European Union has the following expectations for smart grids:

> "Smart Grids are electricity networks that can efficiently integrate the behaviour and actions of all users connected to it — generators, consumers and those that do both — in order to ensure an economically efficient, sustainable power system with low losses and high quality and security of supply and safety. In this perspective, a Smart Grid can be considered as a Smart Electricity System, which encompasses both the grid and the users connected to it, and includes both technical and non-technical building blocks."(Ute & Jäger, 2014)

In the U.S., other issues seem to be more pressing than sustainability, and more focus is placed on the security of delivery of electricity:

> "A smart grid uses digital technology to improve reliability, security, and efficiency (both economic and energy) of the electrical system from large generation, through the delivery systems to electricity consumers and a growing number of distributed generation- and storage resources" (U.S. Department of Energy, 2009)

The visions and prospects of smart grid are not limited to the developed world. From an international survey on drivers for smart grid in both developed and developing countries, the International Energy Agency (IEA) finds, that three out of six motivations are equivalent, even though they are weighted differently. They are: System efficiency improvements, Reliability improvements, and Renewable energy standards or targets (Wang, 2014). Thus, the visions of smart grids vary across the globe, but they also share various main drivers.

The definition of a smart grid that I use in this thesis is the most common one in academic literature, defining a smart grid as an electricity system with bi-directional power and information flow between the supply and demand sides. Thereby, consumers can become producers of electricity and deliver to the grid (Lund, Andersen, Østergaard, Mathiesen, & Connolly, 2012).

This thesis is article-based and consists of an introduction (chapter 1), three papers (chapter 2-4) and a conclusion (chapter 5). This chapter begins with an elaboration of smart grids according to private consumers. Hereafter, the study design and analysis approach are described, including the study's aim and detailed research questions, followed by a description of the applied theoretical concepts and the methods and process of data collection.

1.1 Smart Grid and private consumers

The users are expected to play a core role in the future of smart grids, as opposed to their current role. The new role, being defined within smart grid development, is also dependent on what household consumers are actually willing to accept in terms of change in their everyday lives. Thus, in the end, they will also shape the smart grids by their level of willingness to change (Verbong, Beemsterboer, & Sengers, 2013:118).

In several research and governmental reports and strategy programs, visions about household consumers have been formed; see, for example, (Dong Energy Eldistribution, 2012; KEB, 2013; ForskEl, ELFORSK, EUDP, & InnovationsFonden, 2014; Dansk Energi & Energinet.dk, 2013). The overall perception of household consumers has been changing these past few years in Denmark, and they are given more attention in the development towards a smart grid. They went from being referred to by the utility companies as 'load units' to 'customers' or 'resource units,' which can be seen as a development from being considered a 'burden' to 'someone that should be facilitated' or 'a resource' (Schick & Gad, 2015). Nevertheless, the dominating view of the household consumer in smart grid research in the energy sector is a technological and techno-economic rationalistic ideal of the consumer; see, e.g., (Skjølsvold & Lindkvist, 2015). Dealing particularly with how consumers and ideal consumers are being viewed by the energy sector, in 2013, Strengers has, in her book "Smart Energy Technologies in Everyday Life - Smart Utopia," coined the term 'Resource Man,' which is "..positioned as an efficient and well-informed micro-resource manager who exercises control and choice over his consumption and energy options. In this way Resource Man embodies technique in all his actions [..], by choosing a range of technological and data-mediated tools to suit his unique lifestyle" (Strengers, 2013:34-5). The concept of the resource man notes some of the challenges in current consumer-related smart grid research, which, to some extent, has idealized consumer behaviour to be, among other things, economically rational. Implicitly, it calls for a broader and more open approach to consumers and their energy-related behaviour.

In the next sections, I will go through three concepts in smart grids that I have paid particular attention to in my studies. The first concept is flexibility because it is a key aspect of smart grids that ties together the consumer side and the utility/grid side. Secondly, control is investigated because it is considered to be a central means of creating flexibility. Lastly, the concept of prosumers will be investigated, as it shows an alternative role for household consumers in the transition towards a fossil-free energy system. The role of the prosumer can, to some extent, question the centralized approach to the electricity system, which is the dominant vision in smart grid research today. The areas of flexibility, control and prosumers were identified in connection with the initial, explorative part of my study and the analyses reported in paper 1. It is, moreover, inspired by other scholars in the field of smart grids and consumers, not least the work of Strengers, 2013 and Nyborg, 2015.

1.1.1 Flexibility

Flexibility refers to the flexible consumption of electricity. Thus, flexibility equals electricity consumption that can be moved to other periods of the day. The Danish energy sector states that 'flexible electricity consumption' is the main purpose of the smart grid in Denmark (Schick & Gad, 2015). In relation to flexibility and electricity consumers, Lunde, Røpke, & Heiskanen, (2015) refer to experts from the smart grid field:

> "It is the desire to reduce CO2-emissions and to become independent of the OPEC-nations and oil, that makes us go for renewable energy, […]this drives us into wind turbine based electricity production […]. The socio-economic best thing to do with the electricity produced by wind is to consume it ourselves, rather than sell it to Germany and other places. Then we have to invent these devices to use the electricity. Electric vehicles and heat pumps changes [consumption] from a petrochemical sector to an electricity sector, they need the electricity produced by the wind turbines […]. Here comes the problem: All these new consumption devices create some [consumption] fluctuations we can't deal with, and they create some

> expensive grids, where we have to make investments. […] We simply need the customers as partners in the future, to consume the energy when it is produced." (Lunde et al., 2015)

Thus, the consumers have been designated as important from the experts' point of view in relation to consuming energy from wind power[2]. Within smart grid research, the demand side is expected to respond to the supply side and consume energy when it is available. This includes the hours of the day and year when the demand is the highest, often referred to as peak hours. Thus, the consumption should be minimized in peak periods to flatten the consumption to fit better with the generation of renewable energy. Thus, the focus in the smart grid does not lie in energy conservation so much as in the ability to shift consumption to more suitable times (Powells, Bulkeley, Bell, & Judson, 2014).

Household consumers are receiving increasing interest in the role of providing flexibility to the grid. The Smart Grid Network was established in 2010 to come up with recommendations as to how to promote smart grid development to the authorities and the electric sector. Based on their recommendations, the Danish Smart Grid Strategy was completed by the government. The Danish Smart Grid Strategy sees the potential for moving electricity consumption to off-peak periods, limited as the situation is today. Nevertheless, they expect expanded potential because of increased electricity consumption due to new (and old) technologies being installed on the grid. In this respect, the core technologies are heat pumps (HPs), electric cartridges in district heating, electric vehicles (EVs), and larger electricity-consuming household appliances, which all contribute to the general transition from fossil fuels towards renewable energy sources in society (KEB, 2013). These technologies can be (or already have been) developed to act in a flexible manner according to price signals or to be remotely controlled. They will be described further in the control section below.

Introducing the household consumer to the price of electricity has also been investigated to move the consumption away from peak hours. Usually the price is variable, meaning that it changes according to the time of day (to avoid peaks on the grid). Price signals have been tested in various international projects; see (Darby, 2012; Darby, Anderson, Bs, & White, 2011) for some examples. Although prices and economic incentives are often investigated in smart grid development activities, other incentives have also been used, such as the environment and community, where the households are incentivized by doing something good for the environment and the community. Price signals or dynamic pricing has been constructed of different components (e.g., spot-market and tariffs); see paper 1.

[2] The wind power production in Denmark corresponded to 43% of the total electricity consumption in 2015. The annual average figure increased from 17-20% in the second half of the 00s and has hence more or less doubled over a few years (Energistyrelsen 2014 and EFK 2016).

Powel et al. (2014) investigate a range of households that have been engaged in a pilot project where they receive a time-off-use (TOU) tariff to move consumption away from the peak hours. Thus, the project investigates if TOU tariffs can engage the households in being flexible and move consumption away from peak hours. The results showed that TOU tariffs may have some impact on households changing their consumption patterns. Nevertheless, the study also showed that many energy-consuming practices are difficult to change within the everyday life of household consumers (Powells et al., 2014).

One of the latest Danish projects investigating price signals is the “Wind with new electricity habits” project from 2014, where 350 households received variable prices (in 3 steps) along with access to a webpage showing their consumption by the hour to help them move consumption away from the peak period (17.00-20.00). The results showed that some participants found it difficult to move the consumption away from the peak. There were some practices that were harder to change, such as cooking (confirming the results from Powells et al. (2014) above). Furthermore, the households could move 10% of their consumption from daytime to nighttime and 19% of the peak period could be moved to night time. Although the consumption was indeed moved, a new peak period appeared between 20:00-23:00 (Seas-nve, 2014). This indicates the difficulties in having consumers act according to prices. If they all react similarly, the result is a moved peak, which does not solve the problem. To solve some of these issues, an aggregator has emerged in the field. The aggregator is an international trend in current smart grid projects, and its key goal is the commercialization of flexibility. Specifically, the aggregator will collect loads that can offer flexibility and control them according to the needs of the power system. Thus, this role will insure that devices will be controlled according to the system’s needs and therefore avoid the construction of new peaks (Niesten & Alkemade, 2015).

Thus, in relation to flexibility and private consumers in Denmark, there are many technologies that are proposed as important. These technologies thus might ‘help’ consumers to move their usage of energy to times where more renewable energy is available. In the next paragraph, I will elaborate on issues of control in relation to smart grids and household consumers. Control issues in smart grids are a main topic in paper 3.

1.1.2 Control

Household consumers are often confronted with aspects of control in connection with smart grid experiments and technologies. The Danish Smart Grid Network expects control to be added to several household appliances:

> "Until now there has been great interest in reducing energy consumption by private and public enterprises. If control equipment is installed to reduce energy and electricity consumption by lights, pumps, heating, cooling, ventilation, IT servers and other electricity consumption, it will be relatively easy to add an additional facility for automatic control so that appliances etc. can be switched on or off according to price signals or some other remote control. "(KEB, 2013)

From this, it is clear that automatic control of appliances plays a role in visions of the smart grid in Denmark. Furthermore, the two main visions of automated control are referred to above, namely automatic control, where appliances react to signals, and remote control, which is managed outside the household. There is no consensus among the engineers and software developers of the energy sector as to the role of automation and control in smart grid households (Strengers, 2013). Scholars have studied people's views on control in focus groups with household individuals in charge of their household's energy bill. They were then asked about their views on remote control and different types of variable electricity prices. The study showed that remote control can have an impact on the sense of control that householders have over their home (Fell, Shipworth, Huebner, & Elwell, 2014). Because the households in the study had no actual experience with either variable prices or remote control, it is easy to assume that their points of view might have been different if they had experience.

Studies on control and smart grid households are scarce, and most studies only mention control briefly. This was one of the reasons for commencing on paper 3 to study control issues in a smart grid trial and in smart grid households. In the process of writing paper 3, I became familiar with one other study that also accounts for the lack of control studies. Hargreaves et al. (2015) use three narratives to describe control in smart homes[3]. The narratives each define control in different ways. The 'functional narrative' approaches control in a 'techno-centric' way, focusing on how appliances can be controlled and the barriers to it. The 'instrumental narrative' focuses on interaction between the user and technologies, not necessarily labelling control as being good in itself, as the first narrative does. The third narrative, the 'sociotechnical narrative,' assumes that control does not only occur within the smart home but rather must be seen as a part of society in a complex way. Studying households that have been transformed into smart homes, he concludes that future research of control should include all three narratives because control in smart homes is an interlinked concept (Hargreaves et al., 2015).

[3] Referring to (Wilson, Hargreaves, and Hauxwell-Baldwin 2014)

Linked to these homes in the smart grid where new aspects of control appear, other issues need to be considered. One example is the increased possibility of interconnecting and analysing data sources. When devices are automatically controlled, they rely on programmes that have been developed to predict the future based on past analyses. Additionally, automated control can be perceived as performative because the device (programmed or remotely controlled by a program) will decide when to act. The data needed to perform the control leads to issues of surveillance, which also deserves more investigation in relation to the effect it has on everyday life (Klauser, Paasche, & Söderström, 2014). Surveillance may also play a role within family life and potentially disturb the power structure and private lives of family members (Nyborg, 2015).

In the next paragraph, I will elaborate on the concept of prosumers (micro-generation), which was a main concept in paper 2.

1.1.3 Prosumers and micro-generation

Within the energy and smart grid research, the notion of the prosumer has been widely mentioned. However, there have been two different interpretations of the concept. Scholars have used the concept defined by Toffler 1980 (further elaborated later in this section) and fitted it to the energy area:

> "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 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 & Eyre, 2011:346)

Within this definition, consumers become prosumers by investing in energy production, i.e., micro-generation, thus changing their role in the energy system. This definition is close to others that define the prosumer as being directly related to micro-generation, where consumers with, for instance, Photovoltaic solar cells (PVs), wind turbines and micro-CPH can produce electricity and feed it to the grid. They thus become both producers and consumers of electricity, hence, prosumers (Rathnayaka, Potdar, Dillon, Hussain, & Kuruppu, 2012; Christensen, Gram-hanssen, & Friis, 2013; Røpke, 2013), which is also the definition I apply in this thesis. Others interpret the concept more broadly and describe the prosumer thusly:

> “A prosumer is a consumer that becomes resonant with the energy market through systematic actions and reactions that aim to increase personal or collective benefits” (Bremdal, 2011; Juntunen, 2014)

Thus, the concept is here defined according to the energy market, defining the consumer as a prosumer if they have the possibility of being active. In this definition, consumers can become prosumers if they are able to turn electric devices on/off according to the price of electricity. This definition implies that all consumers in the future will become prosumers because we all will have smart metres installed (Silva, Karnouskos, & Ilic, 2012).

The background of the concept of prosumers dates back to the 1980s and, in some cases, differs from how it is used in this thesis. The prosumer, one who both produces and consumes, was coined by Alvin Toffler in 1980 (Ritzer, Dean, & Jurgenson, 2012) and has been widely used by economists. Ritzer argues that scholars and laypersons focusing on either consumption or production has been a mistake; the focus should have been on prosumption all along to capture the dynamics within the shifts between production and consumption in the production-consumption continuum (Ritzer et al., 2012). The Internet has created new potential for prosumers to simultaneously consume and produce ideas on various wiki-sites, and the service industries have continued the process of putting the consumer to work, for example, within the fast-food-industry, where consumers first have wait in line, then carry the food to the table and lastly clean up after themselves. Other examples of consumers becoming prosumers can be found within the furniture industry, where the role of the consumer has shifted. Here, one example is IKEA, where furniture is being both picked up and assembled by the consumers, processes that used to be in the hands of the producers. ATMs and net-banks are other examples of customers becoming prosumers because tasks that used to be in the hands of the banks are being moved to the hands of the customers. Ritzer argues that, in most cases, the consumers being ‘put to work’ contributes to reducing staff and maximizing profits for the company. Even the prosumers on the Internet (wiki sites and social networks) are becoming increasingly valued by companies (Ritzer et al. 2012). For this study, the prosumer ‘is being put to work’ in relation to producing electricity for the grid. Thus, the definition we rely on is highly dependent on 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, thus I refer to the definition used by Bergman & Eyre, (2011) above.

1.1.3.1 Micro-generation

The term micro-generation refers to a number of small-scale electricity and heating generation technologies that are either low-carbon or renewable, with a size that is appropriate for domestic or community use. Micro-generation technologies include PVs, solar thermal heating, micro wind power, biomass fuelled boilers and micro-combined heat and power (CPH) (Bergman & Eyre, 2011).

Dobbyn & Thomas, 2005 investigate what impact micro-generation technologies have on the users' attitudes towards energy use. They conclude that 'It seems that micro-generation provides a tangible hook to engage householders emotionally with the issue of energy use… Householders described the sheer pleasure of creation and of self-sufficiency: "It's like growing your own vegetables."' Further, they conclude that installing the devices does not have an effect on its own. The best results were achieved when householders were made aware of the benefits that could be achieved when the technology was being installed. If the residents were not aware of living in a home with micro-generation, it did not have a large effect on their awareness (Dobbyn & Thomas, 2005).

Strengers, 2013 performs a review of micro-generation, in which she investigates different studies of households that have micro-generation installed on their premises. She concludes that micro-generation has been referred to as a way of activating consumers and making them prosumers by means of micro-generation and information about production and consumption. Furthermore, micro-generation can pacify the consumer by offering plug-and play solutions that do not include any participation from the consumer side (Strengers, 2013:139).

Prosumers and the micro-generation perspective raise new questions regarding the control and flexibility dimensions to some degree. It might change the opportunities for external control and flexibility creation. If local energy production is radically developed, it might even question the idea of smart grids with centralized energy production at wind, coal or gas power plants, etc., in key roles. Micro-generation thus opens up a broader discussion of new role distributions in future energy systems.

1.2 Study design and analysis approach

This section provides a short overview of the specific research questions in the different parts of the analysis and their connection with the overall purpose. Then, the theoretical framework is described. This is followed by a section in which the methods and the process of data collection are described.

1.2.1 Aim and research questions

The main aim of this thesis is to investigate how household consumers are integrated in smart grid developments. Because the concepts and visions of smart grids have not yet been realized in practice in Denmark, the investigation of household consumers could not be completed with ordinary citizens ('normal' or real households). The closest we could get to real households in this study is through experimental projects where various smart grid technologies are implemented and investigated. Here, it is possible to investigate the interaction between the technology and household consumers in a (close to) everyday setting. Thus, this setting allowed us to investigate the household consumer in relation to the smart grid and various technological concepts that are being investigated in experimental and pilot projects.

Others have investigated household consumers in relation to smart grids where the participants have been household consumers without any (or very little) prior experience with smart grid technologies and concepts, for instance, in relation to questionnaire surveys or focus groups.

It is reasonable to argue that, in the current situation, smart grid experimental projects provide the most direct way available to study household consumer practices in everyday life in relation to smart grid technologies and concepts. As mentioned earlier, there have been a great number of smart grid projects in Denmark in recent years, making it more attractive to base research on. Because the projects provide a more realistic setting, the other methods have been excluded from this research.

The thesis includes 3 papers with individual research questions that contribute in different ways to illumination of the overall research question; see Table 1. The main aim of paper 1 was to create an overview of smart grid experimental projects in Denmark that include private consumers and analyse how consumers are being envisioned and approached in the projects. Papers 2 and 3 are based on the smart grid experimental project Insero Live Lab. Paper 2 seeks to investigate 'prosumer aspects' in Denmark and thereby investigates the smart grid vision related to 'prosumers' and micro-generation. It seeks to investigate how the demand side is responding to the particular role of prosumers. Paper 3 contributes with a study of how control aspects are being envisioned and scripted into an experimental project. It also investigates how consumers are responding and de-scripting the new issues of control in their homes.

Although both papers 2 and 3 contain 'prosumers,' the concept was not used in paper 2 because the paper focused on control aspects rather than the new role of 'prosumer.'

Paper	Overall research questions in papers	Journal & status
Paper 1	**How are private consumers represented in Danish smart grid experimental projects?**	Submitted to TASM
Paper 2	**How have the smart grid technologies been adopted 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?	Submitted to Energy Efficiency
Paper 3	**How are issues of control being scripted into the experimental project (by the project responsible) and de-scripted by the households participating in the trial?** How did the technologies and the new situation of control influence people's sense of control over their own homes?	Submitted to Energy Research and Social Science

Table 1: The table shows research questions and statuses for the 3 papers. The main research question is in bold.

1.2.2 Theoretical concepts (script and practice theory)

The theoretical foundation of this thesis is rooted in Actor network- and Practice-theory. Throughout the PhD process, the concept of script (from ANT) has been important because I found it appropriate for the investigation of how consumers are being envisioned and approached in experimental projects and later to describe the continuous change in the script of control in Insero Live Lab. Practice theory was applicable when I was studying the consumers becoming prosumers, where everyday practices were essential in relation to their new roles as prosumers.

1.2.2.1 Actor-network theory, Script and imagined futures

Actor-network theory has been referred to as the sociology of translation. The founders of ANT have claimed it to be more a methodology than a theory, offering tools to trace how material-semiotic networks stabilize through an operation called translation. The analytical framework has been proven useful in the study of science and technology in relation to the structuring of power relationships (Callon, 1986). In ANT, everything in the world is relational. John Law (2009) describes the relational aspects of ANT as follows:

> "…..if all the world is relational, then so too are texts. They come from somewhere and tell particular stories about particular relations. This implies the need for a health warning. You should beware of this chapter. I hope that it works and is useful, but it comes from somewhere, rather than everywhere or nowhere. It treats the Actor-network approach and

> material semiotics as a particular way. It proposes and seeks to enact a particular version of this animal. Beware, then, of this chapter, but beware even more of any text about Actor-network theory that pretends to the objectivity of an overall view."(Law, 2009:142)

From this passage, it is clear that every 'thing' is a part of a network and has agency. Thus, ANT does not portray anything as being disentangled. This also applies for the researchers being entangled in the actor-network that he/she is studying. Thus, there is no overhead position in ANT (Muniesa, 2015).

The metaphor of a heterogeneous network is central to ANT and suggests the existence of humans, machines and organizations as the materiality of the network. In ANT, everything is a network. One example referred to by John Law 1992 is how we might refer to 'the British government' as an entity instead of having to talk about all the different pieces that it consists of. In ANT, knowledge is considered an effect of a heterogeneous network. In relation to ANT, knowledge is embodied into material form, such as human actors or scientific articles. Knowledge is the product of work performed by the different pieces of the heterogeneous network and translated into other heterogeneous scientific products (Law, 1992).

1.2.2.1.1 Script and the imagined flexible user in the energy sector

It is within this framework that the concept of script (Akrich, 1992) originates to give vocabulary to the study of agency. The vocabulary was based on a semiotic treatment of agency and a focus on material devices. The concept of script conceptualizes that designers 'in-scribe' assumptions and visions (regarding future users) into technological artefacts. All technologies have a script, and it contains assumptions about the future (idealized) users. When the users are confronted with the artefact, the process of de-scription begins. De-scription thus refers to the users' interpretation of the technological script (Akrich, 1992).

In the following, I will give some examples of how the concept of script has contributed to research within the sustainability and smart grid area to give a better idea of how it has been useful in practice within relevant fields. Additionally, I will briefly describe how script contributed to papers 1 and 3. Furthermore, I will note some of the critiques against the concept of script.

Within the study of sustainability and the use of energy, the concept of script has been used to focus on the user side in technology developments and analyse how new technologies are introduced to users with a specific role distribution and manuscript for interaction with the technology. This research shows that the actual interaction between users and technology does not necessarily follow the visions in-scripted by the technology designers (Ozaki, Shaw, & Dodgson, 2013).

In addition, the concept has been used to solely focus on the development side of the technology. For instance, Lewis, 2015, also described in papers 1 and 3, investigates how people involved in the design, development and management of extra-care housing in the UK imagined the future users. The imagined future users were stereotypical. The study questioned the way users are being imagined by the in-scribers because the script of these extra-care homes can become extra energy-consuming when all elderly people are imagined in those stereotypical ways (Lewis, 2015). This study was conducted by focusing on how the developers were imagining future users.

Within social research and smart grids, the concept of script has been connected to imagined sociotechnical concepts. For instance, (Ballo, 2015) investigates how the public is imagined in a smart grid future in Norway. The expert imaginaries in Norway include challenges related to the energy supply system, solutions to these challenges and descriptions of the public consumers and how they are constructed within the imagined future. Within this topic, she states:

> "Ideal expectations of future users and their attributes can even be literally and materially scripted into technologies and sociotechnical systems."

Related to this, we are, in paper 1, interested in the general picture of smart grid scripts as they appear in experimental projects in Denmark. The paper identifies main themes in the scripts of the experimental projects and analyses how they have been investigated in further detail. The main themes are Economic incentives, Automation and information/visualization, which had been identified to be the means by which the projects were implementing flexible consumption. The study shows that there are many reoccurring themes and actors in the experimental projects, and we conclude that they reflect a common general script for the smart grid future in Denmark.

Paper 3 investigates control aspects in Insero Live Lab. Specifically, it explores the contrast between the in-scripted visions of control in Insero Live Lab by the designers and the actual outcome of those in-scriptions within the households. Thus, the paper investigates the designers that envision the future users in relation to control issues and the household consumers that de-script a new control situation in the households (paper 3). Others have also used the script concept to study experimental projects in niches. The concept of script allows following multiple interpretations (of a technology or experimental project) and focusing on the production of several points of view (and many de-scriptions of the technology). Thus, it has been appropriate to use it to emphasize the previously mentioned contrast between the in-scripted visions and the actual outcomes of the resulting projects and related activities (Fatimah, Raven, & Arora, 2015).

There are several points of critique to the concept of script (paper 3). The concept has been criticized for not fulfilling one of the basic approaches within the ANT field, namely the ‘symmetrical approach’ whereby technologies may have agency as well as humans. Thus, the attitude that the script is a result of designers’ visions reduces it to human activity and neglects the non-human actors’ part in the in-scripting process (Mattozzi & Piccioni, 2012). The script concept has also been criticized for being too narrow and not including vocabulary to describe the mediation between the technology and user (Verbeek 2011). Suchman criticizes the concept for over-rationalizing the designer as an actor and overestimating the ways that use can be inscribed into artefacts (Suchman, 2007). The counter critique to these points can be found in the opinion that the script does not have to be only physically defined by the designers; rather, it is sociotechnical. Following this approach, researchers have included other elements that play a role in the technological development, such as regulations and standards, in the in-scription process (Fatimah et al., 2015). In paper 3 in particular, the notion of a script being social and technical is important, as decisions made on a political level ultimately had an impact on the de-scription of control in the households (paper 3).

1.2.2.2 Practice theory and investigation of prosumers

The analysis in paper 2 employs a practice theory perspective to study the evolvement of practices in prosumers’ everyday lives. Our understandings of what constitutes a practice is mainly based on the work of the following scholars: (Shove et al., 2009), (Schatzki, 2002) and (Reckwitz, 2002:249-250). The basic idea of practice theory is that, among flows of activities, there are certain activities that are internally dependant and coordinated in a way such that it makes sense to call them entities (Røpke, 2009). Shove bases a definition of practices on Reckwitz (2002) and Schatzki (1996):

> “In this sense, practices exist as provisional but recognizable entities composed of also recognizable conventions, images and meanings; materials and forms of competence. At the same time, if they are to exist at all, practices require active reproduction and performance. In other words, people have to do them. More than that, it is through these doings that the contours of individual practices are defined, reproduced and constituted” (Shove et al., 2009:18)

Based on the definitions of practices from the above citation, we argue in paper 2 that a practice can be considered to consist of three elements: *Competences*, *images* and *materials*. *Competences* imply the knowledge the practitioners need to perform the practice, herein the embodied knowledge. *Images* covers the perceptions of the practice and the cultural meanings regarding it. The communication regarding a practice, the saying, is also included in this element. Lastly, the element *materials* refers to all the physical elements that are needed to perform a practice. With these elements, we studied the new practices that were evolving with the new role of prosumers in smart grid households. Furthermore, the competence part of the practice was especially important in this investigation of becoming a prosumer (paper 2).

Although there is no unified theory of practice, Røpke, (2009) argues that Schatzki (1996, 2002) and Reckwitz (2002) have formulated an approach that is more coherent in relation to analysing practices. Practice theory has been widely utilized in studies of consumption initiated by scholars, such as (Warde 2005) and (Shove 2003; Shove et al. 2009). The link between practice theory and consumption is found in the 'material' part of a practice. Because nearly all practices involve materials in some form, the study of consumption is linked to the study of practices, as we 'consume' materials by engaging in practices. Furthermore, many of the materials that we use in a practice also consume energy. Thus, a practice such as 'online gaming' includes a PC that itself consumes energy. Accordingly, the practices that we engage in in our everyday lives have huge impacts on the consumption of energy (Røpke 2009).

Although Actor network theory (ANT) and Practice theory have differences, they share the 'flat' structure between the social and the material. ANTs focus on agency (of human and nonhuman actors), and its detailed methodological focus on input/output is a sign of its origin among engineers:

> "…for ANT reality is constructed, but it is so in the engineer's sense (solid reality as the outcome of an organized, fragile and laborious process of material articulation) rather than in the sense usually put forward in standard social sciences (social construction considered in terms of social conventions, belief systems, mental states or collective representations)" (Muniesa, 2015:2)

Similarly, practice theory is avoiding the tendency of describing the world according to the dualism between the social and material and the body and mind (Nicolini, 2012).

1.2.3 Methods and process of data collection

This section will present the methods and data collection of this study. In addition, I will describe the process of this PhD with a focus on the collection of empirical material. The reason for this is to show the true extent of the data gathering, although some of it was not included in a paper.

1.2.3.1 Investigating smart grid projects in the Nordic countries

When I began this study approximately 3 years ago, there was not much knowledge on smart grids and consumers, as others have noted (Nyborg, 2015). Within the iPower project in wp6 (on consumer behaviour), there was a general consensus that there were a great number of smart grid projects being conducted that included private consumers. Thus, I began (together with my main supervisor) working on a report focusing on studies in the Nordic region, i.e., studies in Denmark, Finland, Iceland, Norway and Sweden. Initially, this report was part of a dual delivery, where part 1) focused on the Nordic countries and part 2) focused on selected projects in other countries. The Nordic survey report is the work completed in relation to the first part.

When identifying relevant smart grid studies, a number of databases pertaining to smart grids and to energy research and development projects were employed. On a European level, the database on smart grid projects established by the European Commission's Joint Research Centre was used (see Giordano et al., (2011), Giordano et al., (2013) and ses.jrc.ec.europa.eu). This database was established through repeated questionnaires targeted to system operators, utilities, EU member state representatives, and European associations in recent years. In addition, searches were made in the EU Cordis database for research projects funded through the EU R&D Framework Programmes (cordis.europa.eu). Moreover, the project catalogue established by the International Energy Agency's smart-grid implementing agreement was searched (ISGAN & IEA, 2013a; ISGAN & IEA, 2013b)). This was combined with searches in databases in the individual Nordic countries[i].

All information sources were accessed in 2013 or the first quarter of 2014[4]. In many instances, there were overlaps between the project information found in the international and the country-specific databases. With the chosen approach, the survey can be considered to thoroughly cover studies and projects that have received public support and funding from national and international programmes. On this point, the coverage is complete or at least close to complete (Hansen & Borup, 2014).

Through the searches, a gross list of 67 projects was established. Of these, 43 were from Denmark, 11 from Sweden, 7 from Norway and 6 from Finland. As mentioned, no projects were found in Iceland. The final list consists of 22 projects: 12 from Denmark, 4 from Sweden, 5 from Norway, and 1 from Finland. The other projects were excluded from further analysis for different reasons, e.g., lack of reporting of results, lack of consumers involved, that the results were not meant for public use, or that the project was in too early a stage of development to have a specific study design or results ready (Hansen & Borup, 2014).

This survey gave a broad picture of projects in the Nordic countries. Paper 1 is based on the Danish projects from this survey.

[4] For paper 1, some additional data was collected in 2015.

1.2.3.2 Searching for projects that study private consumers in-depth

While the survey of smart grid projects indeed made me familiar with the main concepts of smart grids and also the different approaches within the Nordic countries, it also gave me a strong idea of what the main content of the Danish smart grid vision is. While working on the survey, I began contacting projects that were relevant to my line of research to ask for contributions. During this process, there were several dead ends and time spent on projects that did not advance as quickly as imagined, or there was a change in direction regarding the project eButler where the entire electricity element was removed from the project. Additionally, the projects INCAP and Ecogrid.EU were targeted but did not work out because of different reasons. Fortunately, Insero Live Lab was launched at the perfect time for my data collection, presenting an interesting project set-up perfect for the topic of my PhD.

1.2.3.3 Methods used to investigate Insero Live Lab

Insero Live Lab, was the case for papers 2 and 3. Thus, parts of the material below are found in those papers. When I contacted Insero for possible collaboration, there was a sociologist employed to collect qualitative data from the participating households. Thus, to some extent, the data collection was already on track, and I could contribute to the process and obtain permission to use some of the data that had already been collected. Before we began the collaboration, 3 workshops had been held prior to the trial where Stenderup and the surrounding households had all been invited to participate (paper 3). An online survey was sent to the households in the first 6 months of the trial, providing demographic information (paper 2). Furthermore, 20 household interviews were held with the participating families after the contract had been signed but before the technologies were installed (paper 3). Although I was not present during the collection of data, I was able to benefit from it by, for instance, having access to the survey answers. Additionally, the sociologist responsible for the communication between Insero and the participants was keen on providing information regarding the outcomes from the previous activities.

The methods that I used in Insero Live Lab were based on Qualitative methods, mostly with interviews and focus groups/workshops (Edwards & Holland, 2013). The interviews and workshops were semi-structured with open-ended questions (Kvale, 2000). All interviews and workshops were recorded, and most of them were transcribed and coded in Atlas.ti based on a grounded approach (Strauss, 1987). Papers 2 and 3 were conducted as a single mixed-method longitudinal case study (Yin, 2009), chosen because different methods provide different perspectives to questions and because collecting data at different intervals would show a better understanding of the process and change that the households and project designers had gone through.

The Insero Live Lab is located in an area close to a small village, Stenderup, outside the city of Horsens, in Jutland, Denmark. The overall scope of Insero Live Lab is to use the area of Stenderup as a living laboratory, an area where new technologies can be tested in the homes of real households. In the current project, the basis for papers 2 and 3, 20 households are participating in a trial with Insero Live Lab that is set to last approximately 2 years, beginning in December 2013. Each household has had a wide range of technologies installed, and the focus for this study was PVs, HPs, EVs and information/visualization equipment. The experiment involved a subsidy to some of the technologies involved, and families may keep the HP and solar cells (PVs) at the end of the project. The electric vehicle was leased and returned after a year.

The company in charge of this live lab, Insero, brands itself as an innovative company that supports new emerging companies on their way up. The Insero Live Lab trial is part of a large-scale EU demonstration project, 'Finesce.' In addition to the one in Stenderup, there are trials in 7 European cities, including Madrid and Malmø. Insero has several areas of interest that overlap with the set-up of the trial. The overall purpose for them was to develop software to control and monitor equipment through the Internet based on different factors, such as weather conditions in the area. The developed software is supposed to be used in the aggregator role.

1.2.3.3.1 Household interviews

In the second round of interviews that were performed with the 20 households in Insero Live Lab approximately 6 months after the installation of the smart grid technologies, I collaborated with the Insero sociologist to collect the data. 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 in some cases due to work schedules. The main author of this thesis carried out 11 of the interviews and the transcription of them. The remaining 9 were conducted by the sociologist and available as sound files. Furthermore, they were transcribed by trainees at Insero Business services. The interviews included a tour of the house, where special focus was given to 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 HP, PV, and eButler (energy management equipment). All the interviews were audio-recorded, transcribed (in extenso) and finally coded in Atlas.ti based on a grounded approach (Strauss, 1987) (paper 2,3).

1.2.3.3.2 Workshops

To evaluate the implications of the technologies over the long-term, two workshops were arranged approximately 18 months after implementation (in May 2015) with the intention of discussing experiences and suggestions for future improvements with the now-experienced prosumers. Prior to the workshop, a question guide had been constructed to make sure 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 what participants had learned during the trial 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 (paper 2,3).

One workshop was scheduled by Kampstrup and Insero Business services in January 2015, and new features for the energy management equipment, eButler, were discussed with 6 informants. Although the main purpose of the workshop was evaluation and improvement of eButler, there were discussions among the participants that were highly relevant to other aspects of this project. For example, the participants were quite keen to discuss their PVs and the change of practices in their everyday lives that had occurred. The workshop was audio-recorded, and parts were later transcribed (paper 2,3).

1.2.3.3.3 Expert interviews

In relation to paper 3, a series of expert interviews were performed. In January 2015, 2 interviews were performed with Insero Software employees responsible for development of the software for remote control of the technologies in Insero Live Lab. In this round, another 2 interviews were conducted with the developers of eButler from the company Kampstrup. Furthermore, 2 phone interviews were conducted in September 2015: one with Insero software and one with Insero Energy. Before the interviews, an interview guide had been prepared.

1.2.3.4 Final comments on the process

From the ‘Methods and process of data collection’ section, it is clear that the empirical data for this thesis is diverse. The first part, the data retrieved from ‘Survey of existing studies of smart grids and consumers – Nordic countries’ (The Nordic Survey), is based on documents, such as project reports and official project webpages. From the process description from The Nordic Survey, it is clear that Denmark has a large number of smart grid projects compared to the other countries and therefor makes for a relevant case for further investigation.

Although my PhD project is part of a large Danish smart grid project, iPower, there were initially no household consumers (or field trial) connected with the project. Thus, finding a project that would allow me to take part in the data collection was not an easy task. Fortunately, the people behind Insero Live Lab started their project at just the right time and were kind enough to let me take part in their data collection.

The second part of the data collection, based on Insero Live Lab, was collected through qualitative methods, such as semi-structured interviews and workshops.

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[i] For Norway, the information based on demonstration activities and research and development projects established by the national competence centre Norwegian Smart Grid Centre and the Norwegian Centres of Expertise Smart Energy Markets were used. Moreover, through the database of the Research Council of Norway, projects in a number of research and development programmes, e.g., the RENERGI and ENERGIX programmes, were searched. For Sweden, projects in the different research, development and innovation programmes in the energy area were searched through the webpage and project database of the Swedish Energy Agency. In addition, searches were made in the project database of VINNOVA (the Swedish Governmental Agency for Innovation Systems), in Elforsk's Smart Grid Programme 2010-2014 and in SUST – Centre for Energy Efficiency in Sweden. For Denmark, the joint database of the different energy-related research, development and demonstration programmes was employed in combination with the project catalogue regarding the future power system published by Energinet.dk and the Danish Energy Association (Energinet.dk and DE 2011). For Finland, the research and development programmes administered by TEKES (the Finnish Funding Agency for Innovation) and by Sitra (The Finnish Innovation Fund) were searched; however, there were relatively few results. A number of projects were identified through personal communication with experts. For Iceland, the activities of Orkustofnun (the National Energy Agency and Energy Fund) and Rannis (the Icelandic Centre for Research) were searched, amongst other things, but no relevant projects were found.

2 Paper 1: Smart grids and households: How are household consumers represented in experimental projects?

2.1 Abstract

This study contributes a cross-going analysis of Danish smart grid experimental projects with the involvement of households. Eleven projects with real-life field experiments in households are identified. The analysis describes the scripts for the future smart grid interaction investigated in the projects and the projects' findings concerning consumers and smart grids. Four main dimensions are identified: economic incentives, automation, information/visualization, and, more broadly, behaviour and everyday life. The analysis shows that the scripts worked with for the future smart grid in Denmark primarily emphasise economic incentives and the automation of energy use as key aspects for creating flexibility in the energy consumption. Nevertheless, the project findings do not support the understanding that users are narrowly economically rational in their interaction with smart grid technology. Energy companies appear as central and leading type of actor in the smart grid development community. The analysis moreover shows that big changes can be expected at the households. There is little investigation of how these changes, and not least the automation dimension will impact the behaviour and everyday lives of private consumers.

Keywords: Smart grid; consumers; experimental projects

Authors: Meiken Hansen and Mads Borup

2.2 Introduction

Visions of smart grids as a central part of future energy systems have been on the societal and political agenda for a number of years, even for more than a decade in some countries. While the visions imply changes and smart technology in both the production side and consumption side of energy systems, most development efforts have had little emphasis on the latter. This is striking, as the visions place new demands on the consumption side that are expected to provide a substantial amount of the flexibility required by smart grids. It is opposed to the traditional order in energy systems in many industrialized countries, where the amount of energy produced follows the consumers' demand for energy (Grijalva & Tariq, 2011). Scholars have stated that because we do not have an accomplished smart grid anywhere in reality, the final form is not yet known (Niesten & Alkemade, 2015). Moreover, as the energy systems, households, and societies differ between countries to some degree and there is variation in the challenges and drivers of smart grid developments (Wang, 2014), it is not certain that identical solutions will emerge in different countries.

The majority of research and development projects regarding smart grids have thus far focused on technical aspects and paid little attention to energy users and the context and practices of energy consumption. However, In recent years, the number of smart grid projects with attention to users and consumers has grown (Verbong et al., 2013; Gangale et al., 2013). The present study offers a systematic analysis of experimental smart grid projects with household consumers in Denmark. The study identifies how the experimental projects approach consumers, what scripts for the future interplay between the smart grid and the consumers they investigate, and what knowledge about the consumer-smart grid relationship they establish. Hereby, the study identifies characteristics of both the smart grid development community and the consumer–smart grid relations. A comparison of the core dimensions investigated in the different experimental projects is made, and a cross-going analysis of the projects' findings on these dimensions is carried out.

Denmark has, for a number of years, invested significantly in smart grid research and can, in some respects, be seen as among the leading countries in the field. Amongst other things, there are relatively many projects with a focus on consumers (Catalin et al., 2014). In addition, what makes Denmark an interesting case is the special challenge the country faces due to the significant and increasing share of wind power in the electricity systems. This highly fluctuating type of energy accounts for approximately 40% of the electricity, and expansion to over 50% in 2020 is planned (Energistyrelsen, 2014; EFK, 2016). This puts special demands on the flexibility required at the consumption side.

The study complements other cross-going studies of experimental smart grid projects by systematically comparing the scripts and findings of the different projects. We focus exclusively on projects with actual real-life experiments in households over a longer period of time. Hence, they are projects that directly face the challenge of moving from visions and idealized images of consumers to real consumers. Christensen et al. (2013) earlier identified that smart grid projects have primarily placed technical focus and emphasis on managing the load on the grid from the consumption side. Similarly, Niesten & Alkemade (2015) find that 'demand side' management is the major consumption-related theme in smart grid pilot projects.

We use a common smart grid definition from the literature, namely that smart grids are enhanced electricity grids that allow a two-way flow of information and electricity between consumers and generators by means of information and communication technologies (Lunde et al., 2015; Niesten & Alkemade, 2016).

In the next section, the background for studying experimental projects and using the concept of script in the analysis of developing technologies is described. Then, a section on the methodology and how the experimental projects were identified follows. The presentation of the results of the analysis is structured with first a description of the overall findings and then a more detailed account of four main themes identified in the projects.

2.2.1 Experimental projects in the energy area, users and script

The role of experimental projects in changing socio-technical systems has been studied within theories of sociotechnical transitions, for instance, through a multi-level perspective (Geels, 2004) containing the following overall levels: The Niches, the micro-level with protected incubation spaces with experiments and learning about new radical innovations; Regimes, the meso-level, consisting of the stability of the current socio-technical systems and its set of rules and institutions; and the Landscape, the macro, background level of the wider exogenous environment of external factors, highly stable and only changing very slowly. At the Niche-level, experimental projects involving heterogeneous actors, such as users, producers and public authorities, are shown to have an important role in the development of technological niches that can challenge the existing regimes. Similarly, scholars in strategic niche management (SNM) have noted the central importance of real-life experimental projects for the development and diffusion of new technologies and innovations (Kemp et al. 1998). SNM is developed to serve the management of particular innovations that are: "(1) socially desirable innovations serving long-term goals such as sustainability, (2) radical novelties that face a mismatch with regard to existing infrastructure, user practices, regulations, etc." (Schot & Geels, 2008). Smart grid technologies fulfil these two requisitions, and real-life experimental projects with smart grid technologies can be expected to play an important role in the transition towards smart grid-based energy systems. Verbong et al. (2013) investigate pilot projects in the Netherlands using the SNM framework. They investigate the visions on user perspectives in the current and future smart grid experiments that the stakeholders disseminate through interviews with 40 stakeholders and an inventory list of smart grid projects. The study concludes that, although private users have become more central in smart grid experimental projects, the main focus remains on economic incentives and technological issues. They highlight the good opportunity for investigating users in the many experimental projects being executed (Verbong et al., 2013). Similarly, although Ballo (2015) investigates the expert imaginaries of the future smart grid with another theoretic point of departure, she uses the theoretical concepts of sociotechnical imaginaries and imagined publics. The point of departure is the national techno-epistemic network within the energy sector in Norway. Through interviews with the stakeholders from the national techno-epistemic network, issues were identified regarding the construction of the private consumer in the future imaginaries, which has an effect on the choices that are made. The results show that the visions of smart grids in Norway are rather techno-optimistic, including ideas of technological control solving social issues and uncertainties caused by nature. In addition, the Smart grid imaginaries contain a market logic where the concept of “consumer flexibility” is commodified, and consumers are to change their behaviour to accommodate this (Ballo, 2015).

Strengers refers to a Resource Man as being the imagined consumer from smart grid stakeholders’ points of view and having particular interest in managing and controlling his own energy system (Strengers, 2013). He is much referred to within industry and policy, and the ideas of the Resource Man are attracting funding and investments (Strengers, 2014). Strengers describes him as: “In his ultimate imagined state, Resource Man is interested in his own energy data, understands it, and wants to use it to change the way he uses energy. He responds rationally to price signals and makes informed decisions based on up-to-date and detailed data provided about the costs, resource units (kilowatt hours), and impacts (greenhouse gas emissions) of his consumption. For these tasks he needs information, dynamic prices, and enabling technologies, such as automated smart appliances and micro-generation systems, which allow him to transform his home into a resource control station. He is both in control of his energy consumption and assigns this control to technologies to manage on his behalf.” (Strengers, 2014:26).

Abi Ghanem & Mander (2014) investigate the active electricity demand in the ADDRESS smart grid project. The project focuses on changing households’ current demands. The study analyses how the developers within the project are imagining the consumers and their needs. Their main conclusion is that future energy consumers are assumed to act rationally in their energy behaviour, in accordance with the above-mentioned results from Strengers. The authors call for a design process within smart grids where real users are taken into account. Also studying the imagined user, Lewis, 2015 uses the concept of script (Akrich, 1992) to investigate how designers of dwellings for the elderly choose technologies based on ‘imagined users,’ leading to specific features being inscribed into the houses although the real needs of the elderly are far more diverse (Lewis 2015). Thus, the development of technologies and sociotechnical systems is based on imagined consumers and their preferences (Akrich, 1992; Borup et al., 2006). Specifically, the concept of script expresses how technology developers constrain future users and how users take part in the innovation process when a new technological system is being introduced. “A large part of the work of innovators is that of "inscribing" this vision of (or prediction about) the world in the technical content of the new object. I will call the end product of this work a "script" or a "scenario"” (Akrich 1992). The concept of script implies that, during technological development, designers have in mind specific competences and actions regarding the users (Ozaki, Shaw, and Dodgson 2013). It is precisely these imagined competences and actions that we are interested in investigating in this study. We are interested in the scenarios or scripts that the users are presented with and live within the experimental projects. We wish to investigate how the smart grid is being envisioned in experimental projects to describe the scenarios envisioned by the designers (project responsible, technology developers).

2.3 Methodology

The study employs the script perspective as methodology in the analysis of the experimental projects. It identifies what scripts are established in the projects for the future interaction between smart grid technology and household consumers and how the scripts are worked with. As part of this, it analyses how consumers are involved in the projects and which conclusions are made in the projects concerning consumers and the smart grid. The last-mentioned dimension can also illuminate reactions to the scripts and eventual descriptions by the household consumers to some extent.

The process of identifying relevant smart grid experimental projects consisted of, firstly, a database search and the creation of a gross list of potentially relevant projects. Secondly, an initial analysis of project material was completed. Thirdly, additional search for projects occurred, e.g., by consulting selected researchers and experts.

Several databases were used in the iterative process of reaching the final set of projects, and the most expedient were:

- The project catalogue published by Energinet.dk (the grid responsible organization) and the Danish Energy Association on the future electricity system (Energinet.dk & Dansk Energi, 2011)
- The database of projects funded by energy research and development programmes in Denmark (www.energiforskning.dk)
- The smart grid database by the European Commission's Joint Research Centre (see, Giordano et al., 2013 and ses.jrc.ec.europa.eu)
- The EU Cordis database on EU funded projects (cordis.europa.eu)

Through the searches, a gross list of 43 projects was found. The final list of projects consists of 11 projects[ii]. Projects were excluded because of, e.g., lack of reporting of results, lack of consumers actually involved, and that the results were not meant for public use. Our empirical study covers the period until 2014. A few additional reports from 2015 are included. The study can be considered to thoroughly cover projects that are public and, e.g., have received funding from national or international programmes. Moreover, a number of projects by energy companies are covered, but additional projects in private companies may exist.

The material used from the projects is primarily project reporting on specific contents and results of the experimental projects with household consumers. In a few cases, scientific articles were also available. General project descriptions, project webpages, etc. were used primarily in the preliminary exploration.

An assumption was made that the experimental smart grid projects can be considered, to some degree, as results of a common vision regarding the future smart grid shared by many actors in and around the energy sector, including policy- and strategy-makers. Hence, the scripts regarding the smart grid future in the individual experimental projects are not fully independent from each other but instead are elaborations and specifications in further detail of a general smart grid script.

This assumption appears to hold true for three reasons. Firstly, common strategies and roadmaps for smart grid developments are elaborated in collaboration between a number of public and private actors in the area, including an official national smart grid strategy, and the smart grid is high on the energy policy agenda in Denmark (KEB, 2012; 2013; ForskEl et al., 2014; Troi et al., 2013). Many of the experimental projects are supported by the same energy R&D funding programmes that are mutually coordinated. To obtain funding from these programmes, the applicants usually must explicitly explain the relation to the general smart grid technology strategies and policies. Finally, there are a number of actors that participate in more than one of the projects. During the study, the scripts of the projects were compared with the scripts of the general strategies and policies in the field. Considerable similarities were found. Hence, it makes sense to see the individual scripts in the project as part of a common script among Danish smart grid developers.

2.4 Results: Scripts and consumers in the smart grid projects

Two rounds of analysis were made. Firstly, in the overall analysis, core dimensions in the projects' scripts were identified, investigating which themes are addressed in the experimental projects concerning smart grid-consumer interaction. Here, project approaches and common themes overlap, and differences between the projects' scripts are identified. In the second round of analysis, the detailed analysis, the individual themes were analysed in further detail, including the projects' findings and conclusions on the themes.

The majority of projects (seven) were run by energy companies or other energy-system actors (the grid responsible organization and an association of energy companies). The four others were led by an energy industry association, a university, a consultancy company, and a technological service institute.

2.4.1 Overall analysis: Identifying dimensions

From the overall analysis, it was identified that a core element of the projects' scripts is the change of households' energy consumption to become more flexible according to the needs of the electricity grid. All projects contain this perspective. Three overall approaches for creating the flexible consumption are identified in the scripts. They are:

1. Economic incentives - consumers as economic rationally acting entities
2. Automation - automatic steering and control of households' energy units
3. Information/visualization - energy information and consumer feedback as central factors

The experimental projects have significant focus on one, two, or all of these dimensions. In addition, some of the projects address broader aspects of consumer behaviour and everyday life practices in connection with smart grid technology. Table 1 provides an overview of the projects and the addressed dimensions of consumer-smart grid interaction. More than two thirds of the projects (eight) include economic incentives for the household consumers in the script for the future smart grid. Seven projects cover automation in connection to consumers, while four projects address tools for feedback and visualization provided to the consumers. A little less than half of the projects address behaviour and everyday life aspects. The majority of the projects cover two or more of the four categories, while three projects address only one. One project addresses all four categories. Apart from the eFlex project, the categories of automation and behaviour/everyday life appear mutually exclusive.

Project title:	**ID**	**Economic incentives**	**Auto-mation**	**Information/ visualization**	**Behaviour and everyday life**	**Technology**
Automation systems for Demand Response	1	X	X	X	-	Electric heating; automation
Dynamic grid tariff - Charge stands	2	X	-	-	X	EVs; charge stands
Demand as Frequency-controlled Reserve	3	-	X	X	-	Automation to control individual loads ('smartbox'), electric heating
ECOGRID-EU	4	X	X	X	-	HPs, electric heating, real time signals
EDISON	5	-	X	-	-	EVs and charging functionalities
Energy Forecast	6	X	-	X	X	Indication of electricity price
From wind power to heat pumps	7	X	X	-	-	Automatic control of HP; measure consumption
IFIV	8	X	X	-	-	HP; automation; sensors
Prøv1elbil	9	X	-	-	X	EVs
Test-en-elbil (ChooseCom)	10	-	-	-	X	Charging; EVs
The e-Flex Project	11	X	X	X	X	HPs; automation; consumption visualization

Table 2: Consumer-related aspects addressed in the projects and major technology elements involved. Heat pump = HP

Another main finding of the overall analysis is that the scripts of most experimental projects integrate a major new electricity-consuming component in the household. The majority of the projects involve HPs or electric cars (EVs). Moreover, electric heating is central in some of the experiments[5]. The new components imply considerable changes in the energy consumption in technical terms and enable an increased consumption of renewable energy sources, extending the households' electricity consumption. Both EVs and HPs increase flexibility in the households' electricity consumption, allowing them to consume more electricity.

In the following, details of the scripts with respect to each of the four dimensions (economic incentives, automation, consumer interfaces and consumer behaviour/everyday life) are described, firstly concerning the project approaches to these dimensions and secondly concerning the project conclusions.

2.4.2 Detailed analysis: Investigating the projects according to themes

2.4.2.1 Economic incentives

The majority of projects assume economic incentives to be a central element in the script of the smart grid future and a key factor for creating flexibility for the electricity grid from the consumption side. In practice, this is established through electricity prices that vary over time (dynamic prices). Here, the main variation between the projects is in the complexity of the price structure and in when prices are communicated to the consumers. The majority of projects use the prices from the electricity spot market (Nord Pool[6]). The wholesale price represents less than 20% of the electricity price in Denmark, and several other components (net tariffs, taxes, and costs for net and supplier subscriptions) appear as part of consumers' total costs for the supply of electricity[7]. Some projects [2, 4, 11] use dynamic net tariffs to increase the variances of electricity prices. Here, fixed categories (cheapest at night and most expensive at daytime) of dynamic net tariffs were applied, while the electricity price is announced the day before it occurs, increasing the price variation compared to the projects where the only varying component was the spot price component. Data on precisely how large the price variations are have not been available for analysis.

With this combination of dynamic net tariffs and spot market prices, the complexity is also increased. The most complex pricing system uses 'real-time' pricing, where users obtain a signal with the price of electricity 5 minutes before it occurs, i.e., a very short notice compared to users on spot contracts and net

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[5] Photovoltaics and micro-generation apart from HPs are not technologies that are focused on in the analysed experiments. An overview of areas of household consumption and technologies addressed in smart grid activities more generally can be found in (Christensen et al. 2013).
[6] http://www.nordpoolspot.com/#/nordic/table
[7] http://www.dongenergy.dk/privat/El/vores_elpriser/om_elprisen/Pages/om_elprisen.aspx

tariffs [4]. The simplest approach to economic incentives was achieved by giving the participants (with a flat rate contract) a 50% discount per kWh between midnight and 6 o'clock in the morning [9].

In some projects, the specific price variations are not communicated continually to the consumers but instead appear afterwards when they receive the electricity bill. In these projects, the users are not expected to keep track of the prices in detail. Instead, the varying prices are used as a parameter to control specific units in the households, e.g., HPs [1,7,8].

It is a more or less unquestioned assumption that dynamic pricing for households shall be an integrated element in the smart grid. All but one of the projects applied it to all the participating households. Only one project tests if dynamic pricing is beneficial at all. Here, 100 (out of 558) participants are given a contract with price variation according to the spot market. The remaining participants receive information on the electricity market and prices without a spot contract [6].

2.4.2.2 Project conclusions regarding economic incentives

The projects' conclusions regarding economic incentives are ambiguous. In a number of projects, the results disprove the assumption that economic incentives should be the dominating and decisive factor for integrating household consumers with smart grid technology. The consumers often react differently than prescribed by the smart grid script on this point. Although an increased degree of flexibility appears in a number of projects, it is found that there are other means causing this change. For instance, two projects find that economic incentives and automation in combination can lead to increased flexibility in the energy consumption. In another project, changes were observed in the households' consumption patterns because of a combination of price incentives and visualization of price information [1,2].

A number of projects identify that household consumers are positive about the idea of dynamic prices in principle. In practice, the situation is more complex. For instance, one project [11] concludes that the users' participation and motivation for contributing to flexible consumption are not connected merely to economic incentives. The participants' rationales are complex and diverse, and *"a relatively large segment of customers is not sensitive to variations in electricity pricing, and other incentives may play a more influential role in customers' procurement behaviour"* (Dong Energy Eldistribution 2012*)*. While a number of projects do not investigate other potential incentives than economic, consumer interest in being more environmentally friendly and in reducing energy consumption is identified in some of the projects. Moreover, technical interest in the new energy technologies and in how they can be employed appears [1,11 a.o.]. In addition, interest in supporting responsible development in the local community and energy systems is observed as an important incentive [4].

2.4.3 Automation

Seven of the eleven projects include automation in the smart grid scenarios and investigate different types of technologies for automatic control of households' energy units in the experiments. The primary purpose of the automation is to serve the needs of the power system and create the flexibility on the demand side. Consumer benefits of automation are usually not the primary purpose. In many of the projects, it is assumed, however, that automation in the sense of little or no interaction with the energy equipment is in the interest of the consumers. It is the understanding that the consumers shall not experience any loss or change in comfort level with the automation equipment and that the technology shall be as unnoticeable and discrete as possible.

At the same time, new control possibilities appear for the consumers in some of the projects. They typically consist of opportunities for setting comfort preferences, e.g., for temperature and maximum temperature variation in the rooms in connection with electric heating and HPs or for preferred normal or maximum charging time in connection with EVs. The users have the ability to enter specific settings into the installed automation equipment once and for all and then leave the technology to itself, at least for a period. In this way, the projects seek to integrate flexibility preferences by the consumers and by the power system. The project 'Demand as Frequency-controlled Reserve' deviates by including a 'smart box' where steering and communication technology is combined with an opportunity for the consumers to connect additional electric devices. In practice, for example, freezers and pumps are connected. After problems with the automatic control resulting in, e.g., flooding of a basement and loss of the contents of freezers, smaller and less energy-consuming devices such as lamps, radios and toasters have also been connected.

The automatic control is normally designed to take place outside of households with electricity system actors managing and controlling the local flexibility. Of the seven projects, five automate on the basis of price signals, alone or in combination with energy forecasts and technical signals about the state of the power system (e.g., frequency variations). The remaining projects use technical parameters only as a basis for the automation. In these, the households are expected to accept the script of automatic, remote control and switching on and off of the electric devices without receiving special economic benefits or compensations.

The remotely controlled automation implies changes in the role distribution and relationship between household consumers and energy system actors. The experiments differ on this point, for example, with respect to whether a new 'aggregator' role is established and how the relationship between general grid-responsible organizations and energy suppliers is[8]. How exactly the role distribution will change cannot be generally concluded from our analysis. However, it is clear that the smart grid script with remotely controlled automation implies substantially expanded and more complex technical interactions between the households, the energy companies and other actors of the electricity system.[9] This implies a surrender of control from the consumers to the system actors. Much more information about the households' energy systems and electricity consumption is communicated to the system actors. The new role distribution appears through the technical smart grid devices, redeploying the relation between electrical devices, consumers and electricity suppliers. Issues of data security, privacy and access rights to data are addressed in some of the projects, primarily as a technical issue. A broader discussion of access rights and ownership of the information, etc., is usually not undertaken.

Few projects establish experiments that directly compare smart grid scenarios with and without automation. There was one exception [4] that assumes that automation together with customer choice is a key feature. It investigates this by comparing different technology combinations. One group will receive price signals but will have to adjust their level of consumption manually. Two other groups will test two different types of automation equipment, where the difference amongst other things consists of the presence of an aggregator control or not and the degree of customer choice in connection to the automation.

2.4.3.1 Project conclusions regarding automation

Not all projects report specific conclusions regarding the automation aspect of the experiments with consumers. From those that do, we see that the general findings are, firstly, that the comfort level of the consumers can be maintained in most cases. It is not significantly reduced by the automatic control. Secondly, the automation is a key aspect for moving the consumption and creating flexibility (as mentioned above a.o.t.) not only in combination with price incentives but also in other cases. Thirdly, it is found that many of the involved consumers are positive about having automation equipment and, to a large degree, accept it, including it being controlled by an outside actor.

Automation does not necessarily imply passive users. The picture is more complex than this. A number of the projects identify active engagement in the technology use and in the experiments among the users,

[8] "Aggregator control is a solution that aggregates the participants' consumption/generation and influences the behaviour (e.g., new temperature set points) of the connected appliances – depending on the flexibility of the individual participants on the one hand and the requirement of the power system on the other hand. In this way, the available flexibility in the aggregated set can be strategically operated to maximise the financial yield"(EcoGrid EU 2013)

[9] The current relationship is already relatively complex, with separate economic relations to suppliers of the net connections as such and, in many cases, different suppliers of electricity, heat, gas, etc.

even after severe problems in some cases, e.g., malfunctions of pumps and freezers as mentioned above. There are differences among the consumers, though. One project concludes that, in general, the consumers are neutral to moderately positive about the automatic control [4].

There is a tendency for the most promising results to appear in set-ups where a combination of user control and automatic control is established. This is, amongst other things, observed in the direct comparison between two automation systems. Having a number of options for setting the room temperature is perceived as positive and useful by the consumers. The possibility of overruling the automatic control, e.g., concerning temperature levels or the fastest possible charging of electric cars, appears as an advantage (even if it is not used often) [4].

Automatic control is found to work most smoothly with energy components, such as HPs, electric heating, and EV chargers, while automated control over other devices, such as freezers, fridges, dryers and pumps, entails problems for the participants. Nevertheless, the participants often remain positive towards the experiments.

2.4.4 Information/visualization

A minority of the projects, five, include new tools for consumer information as part of the smart grid script. In some of the experiments, the tools also involve the possibility of consumer feedback to the smart grid system, e.g., in the sense of an opportunity for setting preferences for control and comfort (for example, concerning temperature levels) or control of individual devices' electricity consumption. The information given regards the state of the electricity grid (often the prices) or the state of the household's energy consumption and energy equipment. None of the projects offer detailed information to the consumers about the automation and control from outside. In addition to written text and numbers, graphically oriented visualizations and signals are employed in some projects. Many different media are used for the communication, ranging from in-home boxes and displays, web-based systems accessed by the consumers' own computers or smartphones, text messages (SMS) and e-mails, to social media and mass media (TV broadcast).

Two projects [11,4] contain the most complex information and feedback systems. In one of them, the consumers have a home automation portal installed on an iPod or computer, enabling them to change settings related to their HPs, heating systems, and electric vehicles, and monitoring devices attached to the 'smart plugs' that are part of the system. Furthermore, they have the choice to optimize their energy consumption according to a) price signals; b) the amount of wind energy in the energy mix in the grid ('environmental signal'); or c) a balanced combination of the two. Furthermore, the participants are joined in a Facebook-like social media platform where they can get technical support from professionals and each other [11]. The second project seeks to test 4 groups, where 3 groups have access to price information, consumption data and bonus calculation through a web portal. In addition, two of the groups have advanced home automation and information systems, each including yet another web portal with access to tailoring and pre-programming of the preferred balance between comfort, consumer flexibility and cost savings [4].

Two projects worked with an 'Electronic Housekeeper' box with hardware and software to control the attached appliances automatically or manually based on displayed price signals. The simplest visualization tools consisted of, firstly, the variation of the electricity price, delivered daily by e-mail or text message, and secondly, visualization of the coming 36 hours of spot market prices to the users on a website and in local TV weather reports or TV spots; in addition, 100 households get a box in the home with a clock-like display indicating the relative electricity price for the coming hours using three different colours.

2.4.4.1 Project conclusions regarding Information/visualization

In most cases, the projects primarily report conclusions regarding changes in energy consumption and only to a smaller extent address the users' interactions and experiences with using the information and visualization tools. Though it is found that the tools do not typically create a change in consumption patterns by themselves, they are among the important contributing factors.

The most positive and unambiguous results are found in connection with relatively simple information and visualization tools, such as the clock-like light signal display and the e-mails/text messages. Most of the consumers are positive towards these tools. They use the information and understand it, and they frequently make changes in consumption behaviour based on this input. Information through mass media (weather/energy forecasts and TV spots) also showed positive results [1,6].

Compared to this, the conclusions regarding the complex consumer interfaces and information tools are less clear. The web-based solutions are typically used by a smaller share of the consumers (in the ECOGRID-EU project [4], for example, the share is approximately 25-30%). Moreover, the satisfaction with the use of the websites varies. Similarly, there are mixed opinions among consumers about the advanced in-home boxes, such as the Electronic Housekeeper. Boxes and websites had flaws and were not fully ready at the start of the experiments in some cases, and it is difficult to conclude how much of the dissatisfaction can be related to flaws and beginner problems and how much is due to the chosen working principle in general.

2.4.5 Behaviour and everyday life

Five projects address consumers' everyday lives and practices in relation to the new smart grid technology more broadly than the three previously mentioned dimensions. These projects view the consumers and the social configuration around the technology as being as important in the smart grid learning process as the technical set-up. The domestication processes at the households are typically investigated not only to assess the effects of the smart grid technology but also to identify constructive suggestions for further development of the technology, relevant consumer incentives, and consumer advantages and disadvantages in the suggested designs. Three of the five projects have focused on use of electric cars and smart charging. Only two have a main emphasis on in-house practices and equipment [11, 6]. The approaches of the projects are, in many cases, attentive to the fact that there can be important differences between consumers. They do not only seek to describe the average consumer.

The projects on electric cars address how the electric cars can fit into households' everyday lives, either in terms of specific use patterns, practical issues (e.g., range, charging, and safety), and pros and cons compared to normal combustion-engine cars, or in terms of values, such as flexibility, freedom, spontaneity, confidence and environmental considerations.

2.4.5.1 Project conclusions regarding behaviour and everyday life

The home automation-oriented projects in particular make conclusions about the variation between consumers. Some of the projects identify that users react differently to the smart grid technology and are motivated by different factors. A segmentation of the users into groups with different profiles is made on this basis; see Table 3. For example, the 'Technicians' are motivated by experimenting with new technology and participation in technological development, and the 'Symphathetics' are engaged in societal issues and motivated by the 'good cause.' One project finds that the most significant incentive across all groups is related to the environmental effects of energy consumption [11]. Other projects find that economic incentives are among the most important [6, 1].

eFlex	**Automation systems for Demand Response**
The Technician	The Knowledgeable
The Economist	The Price-conscious
The Sympathetic	The Socially responsible
The Comfortable	The Uninterested
The Curious	

Table 3: Consumer profiles identified in two projects (our juxtaposition of categories; right column: our translation).

The projects conclude that, if the willingness towards smart grid technology is to be advanced, then the diversity of the users should be considered in the technological systems. The technology must be open to diversity and include other incentives in addition to economic ones. In one project, it is further concluded that the new technology changes the roles within families [11], and it is identified that some of the experimental set-ups are more family-oriented than others that target individuals. The point here is that the new technology must be seen as an intervention in the households.

If a distinction is made between necessities (cooking, heating, etc.) and luxurious practices (hobbies, social life, etc.), the participants are mostly willing to change their consumption practises related to necessities. In one of the projects, it is found that approximately 40% of the households do not, in practice, have the ability to act flexibly with regard to energy consumption despite initial interest in doing so. This is due to the nature of their appliances and heating systems. Those that do change their consumption use the price signals and have primarily economic and environmental reasons for doing so [6].

A number of projects show that a learning process takes place in the households. Two projects identify that the level of knowledge regarding one's own consumption, the electricity markets, prices, and the load of the electricity systems increases considerably [11, 6]. The home automation equipment functions as a 'mediator' between the abstract 'electrical world' and the 'real world' in the home. The interaction with the equipment advances the willingness for flexible consumption. Learning processes also appear in relation to electric cars, and it is identified that many consumers are more focused on their energy consumption and acting in an environmentally friendly manner after the project [10]. There is some divergence between other conclusions on electric car use. Parts of the analyses conclude that electric cars and flexible charging are not easily integrated into the social practises of users' everyday lives, as core values within families regarding flexible use and confidence are not fulfilled [2, 9].

2.5 Discussion and Conclusions

To sum up, the experimental projects in Denmark show a picture of scripts for the future smart grid that implies major, additional electricity-using components in the households and that emphasizes economic incentives and automation of energy use as key aspects for creating flexibility in the consumption. These two dimensions are in focus in the majority of projects and it is primarily through these the demand of the grid and of the electricity production shall be met. The economic incentives alone are not sufficiently important for the consumers to make a change in consumption. However, they can play a role in accepting automated, remote control of, e.g., HPs, and through this support the creation of flexible consumption. In this sense, our results are in accordance with studies in other countries that have identified that dynamic pricing is important for acceptance of smart grid systems (Fell et al., 2014). However there are variations on this point. In the Danish case, participants reacted with indifference to economic incentives to some extent, emphasizing other motivations, such as the environment and the community. In addition, studies in the US and UK have found that dynamic pricing is considered unfair by parts of the population (Murtaghet al., 2014). This is not the case in any of the Danish projects. There is need for additional comparative studies across different countries to understand these variations better.

Most of the five experimental projects addressing behaviour and everyday life aspects focus on the use of electric cars. Only two projects are attentive to other behavioural and everyday-life aspects of smart grid technology in the homes, indicating in general a low interest in household consumer's everyday practices and opportunities to learn from these. The question raised by smart grid developers has more often been whether the consumers will accept and align with the smart grid scripts they are presented to, rather than how the consumers' experimental use of the technology can lead to new insights, constructive suggestions and, new perspectives for smart grid development. Households are considered more as passive consumers than as active participants in the development process. This resonates with findings in Norway and UK (Skjølsvold & Lindkvist, 2015; Abi Ghanem & Mander, 2014). The passive role ascribed to consumers goes beyond energy consumption technologies and continues to generation of energy. Thus, micro-generation in households has largely been omitted from smart grid experimental projects in Denmark. None of the analysed included micro-generation and the related possibilities for smart grids developments.[10] A broader smart energy perspective that includes micro-generation and is less one-sidedly focused on the needs of the grid and grid optimization would be fruitful to investigate further.

The experimental projects addressed household consumers primarily on the level of individual households and not on a community level, as has been seen elsewhere in a few cases, e.g., in the Netherlands, where the Cloud Power project on the island Texel is organized as a cooperative and set up with a 'cloud' system that allows the inhabitants to exchange energy. In addition, the Flexines project in Groningen includes an experimental element of transactions in a network between users (Verbong et al., 2013). There are many different opportunities for working with communities as a context for individual behaviour, through which the household users are considered not only as individual consumers but also as citizens and part of a community (see Heiskanen et al., 2010). Pointing out the interest in contributing to the community's

[10] Christensen et al. (2013) included micro-generation as a relevant dimension to look into in smart grid development, but found only one project addressing the topic in Denmark. (The project is not included in our study as there is no real-life household experiment reported.). One recent example is the Insero Live Lab located in Stenderup outside of Horsens, Jutland. It started too late to be a part of this study.

development as one of the rationales for engaging in using smart grid technology observed in our analysis, supports the view that further studies in this direction could be useful.

Interestingly, the analysis shows that it is the experiments with relatively simple information/visualisation tools that obtain the broadest uptake and acceptance by the consumers. The experiments with advanced and complex information/visualisation equipment, sometimes using several communication platforms, do not report much usage, raising the question of whether the information/visualization systems are becoming too complex and not matching consumers' interests and every day practices.

The topic of remote control in everyday life should be investigated further. Our analysis shows that automation with remote control of home devices is a core element in the script for the smart grid future and that change in energy consumption can be made without changing comfort levels for the consumers. It is also clear that the automation projects in Denmark do not address behavioural and everyday-life aspects in a broader sense. It seems relevant to establish new experimental projects that to a larger extent can address such perspectives. Other studies have found that implementation of remote control over home devices might be connected with the feeling of losing control potentially creating resistance towards the concept (Fell et al. 2014). Our finding that the consumers are more positive towards systems that combine household control with remote control than to systems with 100% remote control seems to support this. Trust and mutual support are part of this and one should be aware that missed receptiveness and openness from the consumers' side can challenge not only the smart grid future scripts as they appear in the households, but also the prevailing understanding in the actor network behind the scripts. The question is whether the actor network is ready for such a challenge.

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Project title:	**Project duration (years)**	**Duration of field test (months**	**Number of households**	**Quantitative data**	**Question-naires**	**Qualitative data (other)**
Automation systems for Demand Response	3	24	500	X	-	X
Dynamic grid tariff - Charge stands	n.a.	6	18	-	-	X
Demand as Frequency-controlled Reserve	3	11	28	X	X	X
ECOGRID-EU	3	36	1800	X	X	X
EDISON	n.a.	3	13	X	-	-
Energy Forecast	3	5	558	X	X	X
From wind power to heat pumps	2	24	300	X	-	-
Intelligent remote control of individual heat pumps (IFIV)	2	2	4	X	-	-
Prøv1elbil	3	3	80	-	-	X
Test-en-elbil (ChooseCom)	n.a	3	1578	X	X	-
The e-Flex Project	n.a	12	119	X	-	X

Size of the experimental projects' field tests with household consumers and types of empirical data collected in relation to the consumers. (n.a. indicates that no information was available).

3 Paper 2: Prosumers and smart grid technologies in Denmark; Developing user competences in smart grid households

3.1 Abstract

This paper explores and describes residents' experiences with an energy intervention in Denmark during 2014-2015 that was performed with 20 households and the effect of the intervention on people's energy-related practices. The intervention involved installation of solar PVs, an HP, energy management equipment, an EV with a charging station enabling remote control, and a smart metre. Long-term studies on such comprehensive energy interventions and derived changes in domestic energy practices are exceptional. The paper thus 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. Qualitative data from the participating households, collected 6, 12 and 18 months after the start of the intervention, show that people relate to their natural environment in new ways and have constructed new practices according to the movements of the sun; that they gradually become skilled practitioners and prosumers; and that they also increase consumption (rebound effect) 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; prosumers; practice theory; competences

Authors: Meiken Hansen and Bettina Hauge

3.2 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). Although the visions for and the contents of the 'smart grid'[11] vary depending on the context (Hadjsaïd & Sabonnadière, 2011: 471-4), a common

[11] 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

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 & 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 & 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 practical 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 a more practical experience with producing energy has had any impact on the use of energy or on common practices and habits[12] within the household.

The notion of a prosumer (Bergman & Eyre, 2011) suggests a new role for consumers where they not only consume but also produce power. The prosumer concept covers the situation where a consumer produces

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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, 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.

[12] The two concepts are often used when analyzing and identifying structural dependency (micro- and macro-level analysis) because a habitual practice naturally evolves from an interaction between the two. In this paper, we suffice to address the micro-level and, to some extent, the meso-level (represented by Insero Live Lab and eButler). The concepts share similarities yet are also different. Some similarities include that both are reproduced by the individual (through imitating actions and attitudes of peers/social classes) and that both are embodied and often performed based on tacit knowledge. Barnes, 2001, describes how it is through interaction with fellow practitioners, while at the same time both cognizant of and disposed to move in the direction of their practice, that one becomes a practitioner who contributes to sustaining the shared practice.

something and consumes it later in time. This is the case in many businesses in the modern world where the consumer participates in the production of products, e.g., collects and assembles furniture from IKEA (Ritzer, 2013). In this paper the focus is on prosumers in the energy sector and the transition from being consumers of electricity to also producers, viz. prosumers.

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 & 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" (2011). However, focusing on individual (male) users of smart grid technology and assuming that they are rational men who need only 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[13]. 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 (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 a short review of selected, relevant pilot projects and main findings in the literature and, based on this, delineate the current knowledge gap and our research objectives. Then, the actual intervention, the methods used for the study and the main theoretical concepts used in the empirical analysis 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.

[13] 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 & Energinet.dk, 2010; KEB, 2013). 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).

3.2.1 Studies of prosumers in the energy sector

There are two reasons behind 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. 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, in-depth knowledge of precise residential responses to comprehensive interventions seems to be lacking, as well as what happens to people as a result of the intervention and the new practices. 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).

3.2.2 Smart grid and practices

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, a.o. a study by Hargreaves et al, 2013, showing 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 (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 (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 (Wood & Newborough, 2003; Darby, 2006) for teaching consumers to be more responsible energy-wise: Trials of informative electricity billing in Norway (Wilhite & Ling, 1995) and trials 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 solely interested in economic incentives (Nyborg & Røpke, 2013). The challenge of realizing the smart grid thus 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.

3.2.3 Micro-generation and practices

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. They also purchased micro-generation technology to increase convenience and cost efficiency (Juntunen, 2014a). Bergman & Eyre, 2011, included a range of results from PV (photovoltaic) trials in the UK, showing that consumers living with micro-generation have shown various behaviour changes after having micro-generation installed. Dobbyn & Thomas, 2005, report that households motivated by new technologies or by the self-sufficiency were showing greater behavioural change than those motivated by the environment. They also 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 & Eyre, 2011). Consumer motivations for the adoption of micro-generation have been investigated (Balcombe et al., 2013; Palm & Tengvard, 2011; Schelly, 2014; Snape & Rynikiewicz, 2012; Vasseur & Kemp, 2015), but little research has been carried out on micro-generation using a practice theoretical approach.

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. The study also showed that consumers preferred to control their washing machines manually instead of using the automated equipment that was available (Kobus et al., 2015). Previous scholars have focused on prosumers as stakeholders in smart cities. Karnouskos, 2011, and Timmerman & Huitema, 2009, have described the need to design services to help the prosumer in his/her new role. Juntunen, (2014b) has investigated prosumers with solar thermal collectors, micro-wind, ground-source HPs and wood pellets. This research thus includes prosumers in the current energy system.

Strengers (2013) investigates micro-generation in her book 'Smart Utopia,' focusing on 'the role that micro-generate energies play in everyday practice, where energy-as-material meets with constellations of other materials, meanings and skills' (Strengers, 2013: 135). She refers to many investigations of users and micro-generation (a.o. 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). Despite the fact that this view reflects an integrated way of understanding and using energy and that the above studies include investigations of practices, they pay little attention to an aspect that may be particularly interesting when designing future trials and smart grid technology that require some sort of actions by people: competences. We shall further elaborate on this in the following section.

3.2.4 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 in a practice. The competence perspective may have disappeared in the interventions because practical competences, over time becoming practical knowledge[14], are developed in the doing – meaning that skills are learnt and bodily

[14] '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

incorporated in the process of performing the practice (Wallenborn & Wilhite, 2014). In turn, these competences are transformed into embodied practical knowledge that quickly becomes tacit: a habit carried out as routine, with no particular reflection[15]. Investigating 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 in this 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 objective, rational, and codified, while tacit elements are subjective, experiential, and often dynamically created (Leonard & 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 & 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

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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.

[15] Studying habits is important in understanding energy consumption. Maréchal (2009) describes that the concept of habits is essential in analyzing the determinants of domestic energy consumption, as it sheds light on why it keeps rising despite awareness and concern about energy-related environmental issues, such as climate change.

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, studying them on the micro-level because little research seems to have been performed on this level.

To our knowledge, this is the first qualitative study on households based on a large combination of technologies (solar PVs; HPs; electric vehicles (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 practice theory 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[16] at play, asking the following questions: How have the smart grid technologies been adopted 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 trial, 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.

3.3 Study design, methods and theoretical concepts

Because we wished to analyse practices and competences developed over time, we chose an exploratory study design to keep the study open in case interesting aspects turned up during the trial. 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 trial was going on in people's private homes and because we wished to discuss and potentially observe embodied practices (Kvale, 2000).

3.3.1 Specific research site and methodology

20 Danish households, all living in detached houses, form the basis for this paper. Starting in December 2013, they all jointed a two year long trial. The trial is organized by Insero Live Lab, an experimental lab

[16] 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.'

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 keep the HP and Photovoltaics solar cells (PVs) after the project ends. The electric car is leased and was returned after one year. The households acquired technologies were partly subsidized. The company in charge of the live lab, Insero, wanted to develop software to remotely control the smart grid technologies based on different factors, such as weather conditions in the area. Their interest in setting up the trial was connected with their work on software to be used for external control of electric loads, as is vision-connected with the development of the smart grid related to the 'flexible loads' mentioned earlier. The equipment can be controlled and monitored through the Internet. Table 1 shows details of the families participating in the trial, such as the high degree of 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.

The following methods for collecting empirical data were chosen: 1) an online survey sent to the households in the first 6 months of the trial, providing demographic information; 2) semi-structured interviews of all 20 households, as well as photos and observations, providing rich data for thick descriptions and thorough analysis, conducted approximately 6 months after the installation; 3) one workshop performed 12 months after implementation, discussing new features of some of the technology with the participants; 4) two workshops performed 18 months after implementation with the intention of discussing experiences and suggestions for future improvements with the now-experienced prosumers[17].

[17] 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. They 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 HP, PV, and eButler (energy management equipment). All the interviews were audio-recorded, transcribed (in extenso) and finally coded in Atlas.ti based on a grounded approach (Strauss, 1987). 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 trial 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 after a long trial period. Based on the audio recordings, the workshops were transcribed and coded in the

The long period for gathering data was to ensure that the experience of becoming a prosumer had in fact settled. Naturally, field notes provided information as well.

ID	PV feed-in tariffs: Old / New[18]	Gender and age	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) M (10-14) M (10-14)	Wage earner Wage earner	College Lower secondary school	Hybrid Air/water HP with gas boiler. PV; EV
F7	new	M (45-54)	Wage earner	College	Hybrid Air/water HP

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software programme Atlas.ti using previously identified thematic codes, such as: Consumption – Keeps track of; EV-charging - Remote control; Remote Control - Trust. 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.

[18] 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 and bought back in the evening at a price of 2.20 DKK/kWh.

		F (45-54)	Self-employed	University education	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)	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

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

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. Before presenting our findings on these aspects, we shall briefly introduce practice theory and the concept of competence used in the analysis.

3.3.2 Theoretical approach: Practice theory and the concept of competence

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 & 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 habitual practices, and as described above, making long-lasting transitions in habits 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 on a micro-level.

What constitutes a practice is defined by a.o. 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. 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 & 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[19]) - 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 constituents of the energy-related practices, the CIM, among the Danish families seemed to involve the following: regarding *competences*, people performing practices relating to, e.g., the solar PVs needed to know about the direction and availability of the sun if they wanted to get the most out the prosumption.

[19] We have chosen ´image' rather than 'meaning.' In content, we regard them as highly similar, but there are some differences nonetheless. 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, often visual or expressed as a 'brand,' which in turn requires a strategic adaptation to the specific culture. In our view and approach, 'meaning' is more of an individual matter and may be more dynamic, depending on the situation, which is the ethno-practice oriented where 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' would be more correct in this trial, where many elements are visual and a certain image was originally expressed text-wise ('join this trial and be an energy innovator'). 'Image' has also been chosen for pragmatic reasons: CIM is easier to say than CMM.

They also required some knowledge about the control panel to know how and when to use it. Some *images* in the intervention reflected how the notion of being a participant in a trial focusing on green energy was socially and culturally constructed through continuous meetings and workshops but also reflected how people viewed the participation and how the image of being controlled or not controlled by others seemed gradually to become an issue. One example is how one family could not accept having the charging of their EV remotely controlled since they were retired and did not have a fixed schedule. They would rather control the charging themselves according to their production of their PV and agenda. Because they had always been preoccupied with their consumption, they did not feel that it would be more sustainable if someone else was in control. Thus, the image of prosumption practices was here closely related to self-regulation. Naturally, *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. Other elements in the practices that took place in the intervention involved 'rules and regulations' and 'understandings.' Formal rules and energy-related regulations were described regarding what was required from the house in terms of being connected to the grid in new ways and regarding being observed by others with respect to their energy consumption. Some informants also referred to 'understandings' that involved both keeping themselves updated on the technology part and on the communication with some of the stakeholders.

However, becoming 'a skilful practitioner' involved more than the specific CIM related to the energy technologies alone. A new type of competence appeared, a 'competence of the environment,' 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, 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 knowledgeable citizens. The results of performing the practices, the knowledge-shaping, are illustrated in the following.

3.4 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 a rebound effect; secondly, the section 'Getting more competent' describes how users became more competent 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 trial.

3.4.1 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 to make their modern, often hectic, lives as bearable as possible. 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:

> 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" (L1x)

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.

3.4.1.1 Changing practices: Rescheduling the energy load

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[20]. 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 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

[20] 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.

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.

3.4.2 Changing practices: Micro-generated rebound effect

As noted by many other scholars (e.g., Caird & Roy, 2006; Frondel, 2004; Greening et al., 2000; Strengers 2013), micro-generation can cause increased energy use in households, known as the 'rebound effect' [21] (found by Greening et al, 2000, although it is mostly low to moderate). Rebound appeared here as well: 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 type of rebounding discovered 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 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." (L1x)

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:

[21] 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.

> 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 rebounding 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 & 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 spending electricity: users were spending more than they rationally 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 trial (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.

3.4.3 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. 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 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. 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." (L1x)

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 (L1x). 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)

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].” (L1x)

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.

3.5 Conclusions and recommendations

In this paper, we set out to investigate the changes in energy-related practices in homes with multiple smart grid technologies installed. By studying everyday energy practices related to smart grid technologies, we found that micro-generation in some circumstances implies a change of everyday energy practises. Practitioners changed their daily rhythms according to the generation of electricity from the PV. Additionally, some returned to less energy-consuming practices when they were not producing energy, for instance, using the broom instead of the vacuum cleaner. Similar findings have been noted by, for instance, Strengers (2013). The focus on using energy when the sun was shining also caused an overuse for some (the rebound effect). In this case, the rebound was mainly rooted in increased comfort and frustration in relation to giving the energy away to the energy company. This resulted in increased engagement in new renewable ideas, for instance, there was great interest in getting battery banks and small joint windmills to become increasingly self-sufficient and avoid the energy company. In addition, the frustration resulted in suggestions pertaining to having the right to donate surplus electricity to local public buildings to contribute to the local area instead of just delivering it to the grid.

In this longitudinal study, it was clear that the consumers were becoming increasingly more competent throughout the trial. For instance, the participants were very interested in changing the heating practice of the HP to be in sync with the production from the PVs. The participants also started questioning the set-up of the HP and were aware of the functions of the HP and questioning the fact that there were no settings available to fulfil their needs. Participants' most valued achievements from participating in the trial covered the following: realizing that they did in fact get cheaper heating (usually); reduced energy consumption (although this was not the end result for all and required more system adjustments for some); appreciating that the system could manage itself when they were away; appreciating being independent of oil/gas and hoping that the house would be easier to sell; and getting a better energy label. However, not all learnings were positive. The vast majority of participants were confused and annoyed about contradictory experiences and "completely incomprehensible" electricity bills: "It's not ok with the bill, I can't understand that our energy consumption in the last couple of months has increased, compared to last year."

Throughout the trial, it became apparent how complex the reality for prosumers is in DK. For instance, some of the participants realized that their generated electricity was divided onto the three electrical phases in the household, meaning that they had to consume each phase equally if they wanted to consume their own produced electricity. Thus, the complexity of changing the practices to accommodate their own generation of electricity increased for the prosumer during the project. Being a prosumer in Denmark with smart grid technologies is a complicated task that requires competences and a great deal of DIY skills in relation to the electricity system and the technologies to fully benefit from the generated electricity. This is the case despite the fact that the tested technologies, the EV, HP and the automation system, supposedly should be able to contribute to energy efficiency via efficient usage of the generated electricity.

3.5.1 Policy recommendations

Based on the findings in this study and those supported by other research (such as Fischer, 2007, Martiskainen, 2007; Maréchal, 2009), it seems that policy-makers may benefit from specifically addressing the performance context of habits and the competences required and developed by people if they wish to reduce domestic energy consumption through co-operating more and better with prosumers. It follows from our analysis that features represented by the CIM of people's energy practices should be addressed and accounted for prior to designing measures aimed at reducing domestic energy consumption. From the perspective of habits, greater effectiveness in combining feedback information with social influence might be obtained, such as providing people with options to send their prosumed energy to community sites rather than back to the grid.

Evidently, the prosumers in the Insero Live Lab had difficulties understanding the full extent of circumstances relating to the PVs and 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), and include common options for participants to pass on the prosumed energy to energy-demanding community institutions. The latter may be controversial in the sense that the overall idea of the intervention was precisely to send energy back into the grid; however, participants seemed more motivated by the thought of helping their close environment. Donating the prosumed energy to specific institutions would also 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 this time, 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 proceeds from the sale of electricity. While this suggestion from the participants in the trial seemed to gain much support, 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. 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 "there is probably not "the" perfect feedback for everybody." We wish to underline this too: there is no "one size fits all" trial, so naturally effective interventions must match the characteristics of the targeted group (e.g., norms and motives, consumption profiles, social lifestyles & practices, etc.) and preferably integrate participants' needs and ideas upfront.

Based on the research, we would recommend policies to consider the frustrations that the prosumers experience when delivering energy to the energy company and that this in some cases could be the cause of the rebound effect related to micro-generation. A way of avoiding the prosumers' rebounding could be through encouraging technologies, such as HPs, to be easily adjusted in accordance with the sun's shining or an option for the complex possibility of including a 'local area benefit' to policies on the area. Consumers are not merely motivated by economic incentives. On the contrary, motivations for participating were multiple: staying updated, having a house that would keep its value, being on the forefront in terms of technology, being part of a trial together with others and thus sharing something that might bring people closer together, seeing the participation as something fun for the family, being independent of the energy companies, and the possibility to save money. This seems to call for new ways of facilitating - 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. In relation to this, there should be further research to investigate if the micro-generated rebound effect could be avoided if prosumers were able to deliver their surplus of energy to area-specific initiatives or institutions. With a view to consumer rights, such research would involve a discussion of 'prosumer rights' and the need for developing such rights.

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4 Paper 3: Smart grids and private consumers: Issues of control on the household level

4.1 Abstract

This paper investigates control aspects related to smart grid devices and elaborates how different types of control were envisioned and designed in a smart grid trial in Denmark. We show how private participants are de-scripting the new situation of control when an extensive combination of smart grid technologies is installed in their homes. The paper contributes a longitudinal study of a smart grid trial performed with 20 private households adapting to everyday use of new types of control. In Denmark, there has been a trend towards an aggregator function within smart grid research, where aggregators trade flexibility achieved by remotely controlling appliances, such as HPs and chargers of EVs. This was supported in the trial, where households produced electricity for the grid during the daytime and accepted being remotely controlled during the night. The way remote control was initiated may push values and norms in society towards those of 'passive consumers' within the smart grid. This brings us to questions of how users in smart grid development are envisioned and configured. With the current development in this area, there is a risk that those consumers that invest in PVs and EVs will lose interest in contributing their energy at the system level.

Keywords: Smart grid; households; control; Script

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4.2 Introduction

Across the world, electricity systems are in for dramatic changes in the near future. In most countries, the reason for change is closely linked to environmental reasons: to increase the amount of renewable energy sources in the energy system and to increase energy efficiency (Fadaeenejad et al., 2014) to reduce global warming. Because the renewable energy sources with the largest potential fluctuate, there is a need for structural changes within the electricity system. One way to imply such change is to implement smart grids[iii]; increasingly intelligent electricity systems with a two-way flow of digital communication between supplier and consumer (European Commission, 2011). For a number of years, Denmark has had an ambitious plan for substituting a large part of the technology in the energy system, which has led to large investments in smart grid research. The Danish vision of smart grids is linked to a new aggregator role that will remotely control specific technologies within households (Schick & Gad, 2015). Smart grids will imply changes on many levels of the electricity system, but according to experts in the field, the new energy system will depend on a highly different consumer role than the current one (Lunde, Røpke, & Heiskanen, 2015). Danish stakeholders in the energy field seem to envision (and prefer) consumers as passive in the energy transition, where technologies and price incentives are considered to initiate the appropriate and required system-wise behaviour (Nyborg & Røpke, 2011).

As highlighted by Lunde ét al. 2015, smart grids need consumers as partners to consume energy when there is abundance. If the smart grid vision is to be realized, consumers thus need to act according to the system's needs and enter into a different, more active, role in relation to the system compared to the current situation (Lunde et al., 2015). Other scholars connect the new role of the consumers with flexible demand, thus the consumers shall become flexible by investing in 'flexible loads,' such as electric vehicles (EV) and heat pumps (HP). This flexibility connected with new monitoring and control tools will ensure stability of the grid (Moura, López, Moreno, & Almeida, 2013).

Balta-Ozkan et al. (2014) identify two conflicting visions for consumers in smart grids. Either the main occurring change is purely technological with a passive consumer, or the consumers come to inhabit an active role through technology as part of the solution (Balta-ozkan et al., 2014). Goulden et al., (2014) argue that the second vision may ensure a more effective smart grid, where intelligence is utilized from devices as well as users (Goulden et al., 2014).

This new situation with either passive or active consumers will entail new control situations in relation to the consumer, aggregator and technologies, which will change people's homes.

Although smart grids offers a new situation of control for households, little research has focused on these issues of control over a household (Hargreaves et al., 2015). To fill this gap, we investigated a smart grid trial with 20 Danish households, all equipped with smart grid technologies. From December 2013 until May 2015, we investigated how issues of control were being scripted (Akrich, 1992) into the trial by the project responsible and trial initiator, the company Insero, and how the technologies and the control elements were de-scripted by the households participating in the trial. Additionally, we investigated how the new situation of control and technologies influenced people's sense of control over their own homes.

'Control' related to smart grids and households has different meanings: it can relate to automation and technologies, such as when consumers are in control of the settings of their own devices (internal control), or it can relate to aggregators controlling electrical devices remotely (external control). Thus, households become arenas where new situations of control materialize (Wilson, Hargreaves, & Hauxwell-Baldwin, 2014)[iv]. This study thus contributes rich empirical research on how control gets adapted in households equipped with a large combination of smart grid technologies. Research on smart grid households and issues of control is scarce (Hargreaves et al., 2015), which makes this contribution relevant for the field.

4.3 Methodology

A smart grid trial called 'Insero Live Lab' is the source of this research, and a number of actors are involved; see Figure 1.

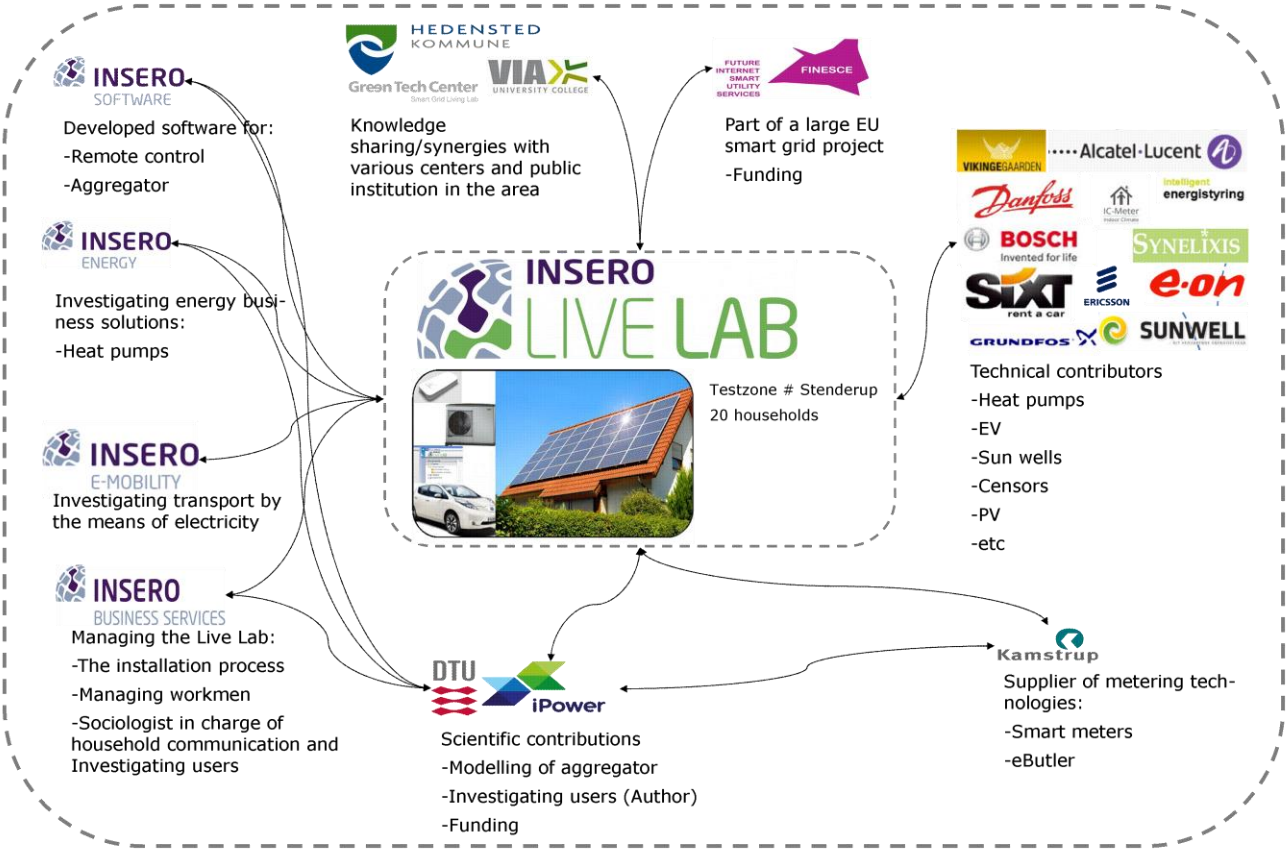

Figure 1. Actors related to Insero Live Lab. The arrows show relations between actors and actor groups.

Insero Live Lab is located in the village of Stenderup in Jutland and was set to last 2 years, beginning in December 2013. 20 households have been equipped with a range of smart grid technologies, such as Photovoltaics (PVs), HPs and a home energy management system, eButler. Because a number of households had PVs prior to the trial, they were on the 'old' regulation scheme and receiving the same amount of money for their produced electricity as when purchasing, approximately 2 DKK/kWh. The remaining households were on the new scheme, receiving 0.6 DKK/kWh. The households are connected in a smart grid, thus specific equipment (charging stations, HPs and sensors) can be monitored and controlled by Insero Software through the internet. There was high diversity among the families in the project regarding age, gender, family status, and educational level[v]. To ensure confidentiality, the families have been anonymized.

For this study, we used a combination of different methods: a small survey among households, ethnographic methods (semi-structured interviews, photos, videos) and workshops[vi]. See Figure 2 for more information about the data collection process.

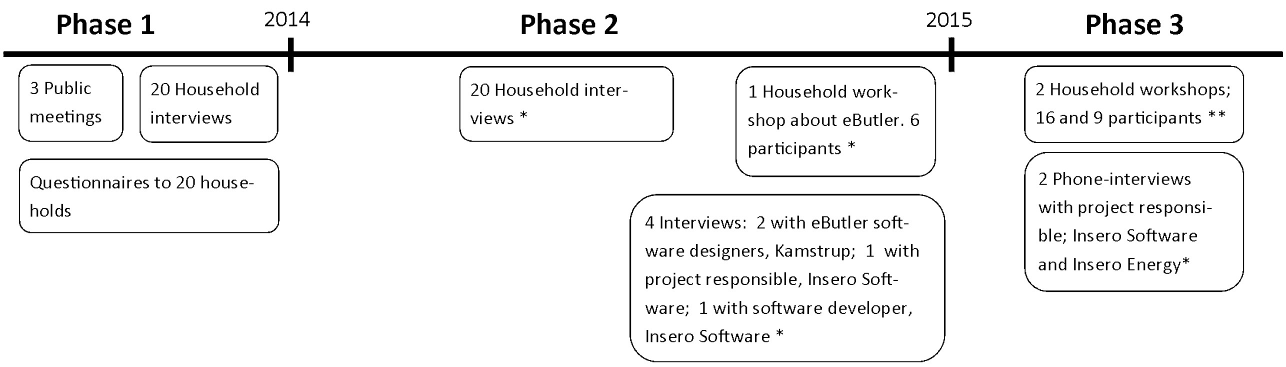

Figure 1. Timeline illustrating the application of methods; *: Main author involved in the activity, **: Both authors involved.

Phase 1 included public meetings prior to the trial. They are further described in the results section. When enough interested participants had committed to joining the Live Lab, the first round of interviews was scheduled[vii]. To obtain demographic data, the informants were required to answer an online questionnaire in the same period.

In phase 2, interviews were conducted with the households. They took place in the homes of the informants and lasted between 50 and 90 minutes[viii]. In most cases, the informants demonstrated the use of the displays connected to the HP, PV, and eButler (energy management equipment) in a tour of the house. The main author participated in one workshop in January 2015 to discuss new features of eButler. In the same period, interviews were conducted with relevant actors (see Figure 2).

In phase 3, workshops were arranged: one occurred in the home of a participating family, and the second was arranged in the local community hall. The locations were chosen to create a familiar atmosphere, inviting participants to talk openly. In September 2015, two phone interviews were conducted.

Before all the arranged interviews, a semi-structured interview guide was prepared with a range of open-ended questions (Kvale, 2000). All interviews and workshops were audio-recorded, transcribed[ix] and finally coded in Atlas.ti based on a grounded approach (Strauss, 1987). Research questions were based and refined through an iterative analysis and continuous data collection. Codes were developed from general themes but also developed inductively from the interviews, first organized in a flat structure but later, after analysing the data, organized hierarchically.

The purpose of the chosen methods was to gain rich data from studying issues of control in their real setting. We regard the empirical data as a case study that may lead to new insights, whether of a social, cultural, philosophical or technical nature, by examining how the smart grid technology affects human life and how people attempt (or do not attempt) to take control of the technology. In the current trial, we investigate how smart grid technology installed in people's homes affected the residents. A major element of the trial involved 'control,' not only in the form of 'technological control' relating to the integrated part of the technology but also the idea of being controlled. What 'control' signifies to people living with it and the implications of being controlled seem to have received little attention research-wise in relation to 'living the vision of the smart grid' referred to above (Hargreaves et al., 2015). We will present empirical data on how control was embedded in the technology, practised, perceived and lived with by the residents, but before presenting the analysis - which to a large extent evolves around control issues relating to the smart grid technology - the concepts used in the analysis will be discussed. The following section thus briefly describes the concept of script (Akrich, 1992) and the nature of control; it highlights essential characteristics of the concepts and situates 'control' in the context of homes. By explaining the significance of the home to people, it is illustrated why it is particularly important to residents to have control there.

4.4 Conceptual framework

The conceptual framework for investigating the value of smart grid technology to trial participants is the concept of script and that of control. We shall briefly describe each in turn to allow for a clearer understanding of how these concepts have been identified and used in the empirical analysis.

4.4.1 The notion of script, in-scription and de-scription

Madeline Akrich and Latour proposed the concept of script to describe technical objects (Akrich, 1992)(Akrich & Latour, 1992)(Mattozzi & Piccioni, 2012). The concept was coined by Akrich:

> "Thus, like a film script, technical objects define a framework of action together with the actors and the space in which they are supposed to act". More specifically she claims about the designers and their role in defining the artefact "[…] Designers thus define actors with specific tastes, competences, motives, aspirations, political prejudices, and the rest, and they assume that morality, technology, science, and economy will evolve in particular ways. A large part of the work of innovators is that of "inscribing" this vision of (or prediction about) the world in the technical content of the new object." (Akrich, 1992)

To Akrich, the script is the end product of the designers' activity of inscribing a vision of the potential user and of the world in which the artefact will eventually work. All the focus is on the designers, and the artefact is the last element of this assemblage; it has only to accommodate the script stemming from the designers' ideas. This view seems somewhat limited, and the need for a more precise picture of the designers' view of the user and a view of the technology as being more ambiguous has been suggested (Suchman, 2007). Others have also criticized the concept of script as being too narrow (Verbeek, 2011) (Fallan, 2008). Verbeek asks for a rich vocabulary to make use of the concept in consistent and broader ways and further claims that the notion of script deals too little with the mediation between artefact and user, suggesting that 'delegation' and 'in-scription' should be seen as a much more complex, reciprocal exchange between artefact and user. Non-human entities can also delegate tasks to human beings, as is indeed the case with this trial, and technological mediations may be the result of specific forms of user appropriation. Seeing script only as the product of in-scriptions makes it reducible to human activity, which is not in line with the symmetrical approach Latour initially had in mind (Mattozzi & Piccioni, 2012). Akrich's initial script concept suggests that scripts are the product of in-scriptions, but the eventual script is the result of an interaction going on between many: designers, who inscribe particular forms of mediation; users with their interpretations and forms of appropriations; and the technological artefacts themselves, which sometimes give rise to unexpected forms of use and mediation. On the one side, there is the scripting of the technology by the designers, and on the other side, there is the de-scripting of the technology performed by the users: "*Once the artifact is displaced into sites of use, she (Akrich) argues, the work of the user becomes one of "de-scription" of recovering from the object a coherent program of action."* (Suchman, 2007). To fully understand the co-evolvement of objects by using a script analysis method, the aim is to move back and forth between the designers and users (Fallan, 2008). The concept has been used for studying user-representation and to evaluate the compliance between user behaviour and the technology developed by designers. The main focus has been on the layout of technologies in relation to the actual users, with emphasis on mismatches between intended and actual use (Konrad, 2008).

To advance sustainable products, the concept of script has been investigated to create moral technologies, i.e., technologies that better align to the goal of sustainability. The morality of a technology's script can be investigated by three dimensions: force, scale and direction (Jelsma, 2003). The force of the script refers to the extent of the constraint that the script applies on the user's relevant behaviour. The weaker the script is, the more choices the user has in complying with the script to achieve a set goal. One example of a goal could be to change the timing of the charging of an EV to periods when the electricity is generated from wind. A strong script would not allow charging in periods without 'wind-electricity' on the grid, while a weaker script would allow the user to charge at other periods as well, which could be accomplished by an override function. The scale of the script refers to at what level the technological system is being re-designed. The script might become more moral, more sustainable, if the technology is changed at a higher level. Using the previous example of matching the charging of the EV with wind power, this could be conducted at a household level: the households could have technologies that they buy and program themselves to react to the amount of electricity from wind in the system. In principle, they could use a timer, check the weather forecast and be able to time their charging accordingly. On another scale, the aggregator, a new actor in the energy area, can offer to control the users' charging according to different goals. His/her motives to control the charging are related to gaining flexibility in the grid, which can be traded. This is thus on a different scale at a higher level, where the goal of charging when the wind is blowing can be met more systematically. The last dimension, the direction, refers to the how the script pushes behaviour according to the values and rules in the occurring socio-technical landscape. Consequently, the script can work along different rules and values in the socio-technical landscape, slightly changing the morality in society (Jelsma, 2003). Within the notion of the smart grid and all the new technologies that are at stake, this is a highly relevant discussion.

The idea of the designers of technology carefully planning the future of the users has left room for discussion. The comparison between 'the use of a technological object' and a 'film script' has been regarded as not fulfilling because the role of the user is not completely defined as it would be in a film script. Thus, developers cannot be as farsighted as described by Akrich (Suchman, 2007). To counter this critique, others have stressed that the script does not have to be purely psychical (and defined by the designers) but also socio-technical. Akrich stresses in her de-scription that links of interest to us are both technical and social (Fallan, 2008). Fatimah et al. (2015) highlight, referring to (Joerges, 1999), that not only designers shape new technologies or designs. Other elements, such as standards, policies and regulations of technologies, may play an important role in the outcome and the use of a technology, and designers thus include these external elements in the in-scription of technologies. Furthermore, they emphasize that script allows for an investigation from multiple points of views from the involved actants. The concept allows a study of multiple de-scriptions of a project and multiple in-scriptions of entities to sustain one full project (Fatimah et al., 2015); it is this perception of script that we have used when analysing our empirical data, combined with the notion of control.

4.4.2 The nature of control

The interest in 'control' and particularly control over 'technology,' including considerations of 'out-of-control' situations, is age-old: Plato feared that writing technology, as a form of persuasion, would change Greek culture significantly and for the worse (Slack & Macgregor, Wise, 2014: 52). Philosophers, human scientists and engineers have thus long discussed the role of artefacts as a mediator between humans and the world. Still, a philosophy of technology as a recognizable philosophical specialization only emerged in the second half of the 19th century (Reydon, 2012). In the philosophy of technology, the crux of the matter precisely relates to technology and control over it (Scharff & Dusek, 2002). Technology is seen as instrumental, not only in the sense that technological objects are means by which we can achieve particular ends but also as more than the devising of instruments for practical purposes; it is a way of knowing by uncovering the hidden natures of things (Heiddeger, 1977). As a way of knowing, technology has taken on a new character: older technology imitated nature, and this imitation was inseparably connected to uncovering the hidden nature of the natural entities; contemporary technology, however, places nature in the position of a supplier of resources controlled by humans but is nonetheless often intangible and complex without an observable direct causality. When we imitate nature, we examine entities and phenomena that already exist, but technology today, such as electrical energy provision or a nuclear power plant, differs from existing natural objects. “Forcing nature to deliver energy (or another type of resource) whenever we ask for it cannot be understood as objects made by man in a mode of imitating nature” (Reydon, 2012). The new character of technology is not only fundamentally different from old technology, it further alienates people from nature and separates technology from culture. In Heidegger’s words, nature only reveals itself to us on its own terms, and all that humans can directly control is our orientation to the natural world. What we need to determine is how we, as human beings, stand in relation to technology. Once we realize that our own orientation to the world is the essence of technology, once we "open ourselves" (Heiddeger, 1977:26) to this essence, an opportunity to establish a free relationship with technology will arise.

This vision of establishing such a ‘free relationship’ somehow contradicts the notion of the script and the inherent power that may be found in technology. Even the ways in which we would ‘open ourselves’ would be contextualized and influenced by our access to and positions in the world. While it may be true that humans are alienated by technology and that technology is separated from culture, in an STS perspective, technology holds power, and this outset may in fact precisely bring technology back into culture, power being ontological and embedded in any society and at all levels (Foucault, 1975). This brings us closer to the issue of control: according to Bacon (in (Reydon, 2012)), knowledge of natural causes gives people power over nature that can be used for the benefit of mankind, such as implementing this knowledge in technology. Applying Bacon’s idea of knowledge as power for technology means that technology is power and hence that technological control becomes similar to power. Such a view makes technology not only instrumental but with a power of its own; simply stated, this means that being in control of technology is identical to being in power.

How technology and technological control are viewed reflects one's stand within a spectrum ranging from 'cultural determinism,' believing that technology is developed only in accordance to cultural needs and that culture shapes and defines and thus controls technology, to 'technological determinism,' where technology is seen as beyond the control of people, and technological change is the primary cause of societal change, thus defining culture (Slack & Macgregor, Wise, 2014). Our position is that technologies do not in themselves determine effect; they have scripts of course because technologies are created by people, and through use they are de-scripted, which may change the intended effect. Although this interaction certainly involves a mutual impact and effect, particularly in the long run, as shown for instance with the appearance of the freezer resulting in entirely new eating and food preparation habits (Shove & Southerton, 2000), technologies none the less need to be imagined, designed, developed and administered by people. Control elements may of course be more or less integrated in the technology. However, we believe that it is from a prolonged interaction between technology and people who we may best identify who is in fact controlling who and when, as well as potential shifts. Investigating control naturally involves the question of identifying the controlling part or controlling elements, as well as what or who is being controlled and the purpose and extent of this control. In early industrialization, these questions were easier to answer than today because technology was commonly developed and used in more centralized contexts. Today, society is characterized by complex technological interactions and transactions across the world, where technology may be co-created through development processes and technological regimes have the form of complex hybrids (Latour, 1991). This makes questions of identifying control an intricate, entangled matter. In the light of an increasing societal need for energy reduction and the expectations placed on the smart grid for this matter (Darby, Strömbäck, & Wilks, 2013), we believe that issues of control require more focus and that special attention needs to be given to the setting for this control: the home.

4.4.2.1 *Control – at home*

Research has shown that having a sense of control over one's home and its appliances, products and technologies is important to residents; such control includes, for instance, being able to open the windows at home for airing out and controlling the solar influx and indoor heating (Hauge, 2015). This not only relates to residents' need to feel empowered and able to act based on a sense of responsibility for the health of the family, it also reflects special characteristics of the setting, i.e., the home.

Residential well-being largely depends on controlling the indoor climate and cannot be isolated from the notion of 'home,' described as a place to rest, a haven, a 'family project,' and an arena for activities (Aune, 2007) and for establishing and negotiating not only relations (Gram-Hanssen & Bech-Danielsen, 2004) but also practices (Hauge, 2013). Identity, control, freedom and self-determination are vital ingredients of a home (Blunt & Dowling, 2006). All these aspects are particularly important for the home precisely because the home is the counterpart to the unstable, unpredictable world outside (such as working life or uncontrollable nature).

The reason that we highlight the significance of the home is to underline how important it is for residents to feel in control precisely because the setting is their home. Often, the sense of feeling in control at home rests on well-known technologies and routines, and despite the fact that Akrich (1992) may have shown that man-made technologies prescribe the behaviour of human users, such prescriptions are often ignored, and technology is appropriated and domesticated in ways that counteract designers' intentions (Lie & Sørensen, 1996). As we shall show in our empirical analysis, in-scriptions were made during the entire trial as a result of extensive interaction between many parties. We use the script concept precisely to show this iterative process, and we combine this with a focus on control issues. Placing focus on the dynamic interaction, inscribing process and specific control issues means that we will not use the categories given by Latour (Bruno Latour, 1992), which otherwise could have been applied for showing in- and de-scriptions in technology. Instead, we show the process empirically in three tracks identified in the results: How did the designers in-script control?; How did the users de-script control?; and How did the designers respond to the de-scription?

4.5 Results

We analyse script and control issues on two levels: among designers and project owners (in-scribers), and on the household level (de-scribers). From the analyses of how control was in-scripted in the Insero Live Lab, we found that a certain collection of technologies was of particular interest to the project responsible because this set of technologies allowed for remote control of the residential energy consumption. We analysed the script related to control issues in smart grid households, specifically investigating remote control of HPs and the charging of EVs in relation to PVs. We found 'the need for being in control' to be an individual phenomenon, and participants had some difficulties in adapting to the needs of the system. A common discontent was found in the de-scription of the control technologies because they did not always function as the participants expected; once residents realized that the control they knew to be part of the set-up did not in fact fulfil their overall purpose of being controlled, viz. to reduce energy or alert them in situations where the energy consumption was remarkably high, they expressed frustrations and dissatisfaction, indicating a mismatch between in- and de-scription.

4.5.1 How did the designers in-script control?

The initiator of Insero Live Lab, Insero, includes four subsidiary companies; see Figure 1. The Insero Live Lab was constructed to support all four[x]. The initial purpose of Insero Live Lab was to work with software development to design and develop remote control in smart grids. Insero Software was the key actor in this task, responsible for development, implementation and management of the IT infrastructure to control specific technologies (HPs and EVs) with the purpose of offering flexibility to the grid, i.e., moving the energy consumption from peak periods. Insero Energy was interested in the control from a practical point of view, being interested in new business models for HPs or PVs in Denmark.

4.5.2 The initial idea in the trial

The initial package to be introduced included: an air/water HP; an EV, including a charging station that could be remotely controlled (both EV and charging station were to be leased for 2 years); and 6000-kW Photovoltaic solar cells (PVs). These technologies were the core and would be installed in people's houses[xi], allowing Insero to test flexibility in real-life energy consumption. To the project initiators, different issues of control were at stake: initially they planned remote control of the charge stations and HPs so they could be optimized dynamically according to electricity market fluctuations and to aggregate flexibility and trade it on a new flexibility market. This included a change in the way energy is being used within the households.

Carefully chosen technologies were to be tested in combination in a smart grid, where all households could be monitored and externally controlled: "We wanted to create a system that we could monitor while at the same time take into account their preferences. We wanted to control the flow temperature but based on certain criteria that the participants had pre-defined. They could say: 'I want 21° C in the living room and the hot water to be 48° C.' and whatever they would define we would respect. Nevertheless, it was important for us to be in control of the system." (Project responsible, Insero). By focusing on already developed technologies, they avoided most risks related to functionality that novel technologies entail[xii].

4.5.3 Modification of the package; showcasing the blurred boundaries of who is in control

To create awareness of the project and to attract participants, Insero arranged 3 public meetings in the village of Stenderup to investigate the interest among the villagers to invest in these technologies. It became clear that the inhabitants would not settle for the suggested packages. People were not satisfied with the EV and asked if it could be excluded. The HP and PV are technologies that are often related to renewal or modernization of the home, thus many of the participants already had a clear idea of what type of new technologies they preferred to be installed. They were more interested in a process of negotiating what was possible and why. There was great interest in ground HPs and less in the preliminary air/water

HPs that Insero had an interest in. The choice of technologies was opened up again, and several new opportunities were discussed. Some of the households that initially wanted a ground HP did not succeed because of barriers such as too small a garden and insufficient access to the basement. A new alternative was included in the range of possible technologies: the hybrid HP (air/water and gas)[xiii]. A few families were keen on getting solar wells[xiv] instead of ground HPs, and so two households had solar wells drilled on their premises.

The changes in the technology portfolio had consequences for the overall setup and the related issues of control. Several technologies needed reconfiguration to enable remote control, and the new type of HPs (the hybrid form) had not been tested before in Denmark. The solar wells and ground HPs were not suitable for achieving flexibility because of the lower electricity consumption and other technical reasons. Because of the participants' resistance to leasing an EV for two years, the period was changed to one year instead. Because of the legislation being changed regarding the PVs, the participants could only get 4000-kW PVs installed. Additionally, they were promised a price of 1.3 kr/kWh for the electricity delivered to the grid because this was the price that was reasonable to expect at the time.

Because Insero Software, developing the software to remotely control the EVs and HPs, did not have any experience in developing interfaces for the consumer side, Insero opted for an existing home energy management system, eButler, which would give the consumer an overview of their energy consumption and the means to manage it[xv].

The in-scription process at Insero Live Lab was dynamic and included negotiations between the residents and project-responsible. The designers of the Live Lab had a specific vision of control that involved a certain type of technology and a feed-in tariff structure. This vision did not materialize because the participants were decisive in relation to what technologies they wanted to have in their home. Simultaneously, the feed-in tariff structure for the PVs changed, causing difficulties in remote control. In other words, the final script of Insero Live Lab was not merely a product of the designers' visions but can be described more as a negotiation process between designers, participants and political decisions in the energy area.

4.5.4 How did the users de-script control?

In this section, we investigate how the private consumers de-script the new issues of control in their homes. Firstly, we investigate the information/visualization equipment in the process; secondly, we investigate how the participants considered being remotely controlled; and thirdly, we explore remote control and how it was de-scripted by the participants.

4.5.4.1 *Information/Visualization equipment*

In this section, we show how information/visualization was part of the process of gaining control over the technologies[xvi]. The participants were engaging in changing their consumption patterns according to their own production of electricity[xvii]. In the process of load shedding, information/visualization equipment[22] was used to impact the consumption by providing immediate feedback to the residents. The families had different types of visualization equipment installed at home, and all had access to eButler (fig. 2), accessible through the internet.

Figure 2. Online access to eButler (with courtesy of Kamstrup, eButler)

Furthermore, in-home displays were connected to the newly installed technologies (Fig. 3). The information/visualization equipment had different designs, and the information that can be gained from them varies according to the technology they were connected to. For instance, the HP display shows the consumption of electricity (and gas for the hybrid HP) used to heat the house and water. In addition, it visualizes the available settings for the HP: the temperature-curves and nighttime-drop setting. The smart metre shows the purchase of electricity since the metre was installed, how much electricity has been delivered to the grid (utility company) and lastly the current use of electricity.

[22] We include all the equipment that in some manner informed participants of or visualised energy consumption and production in this term.

Figure 3. The available displays installed among the 20 households. Pictures retrieved from: http://inserolivelab.dk/instruktionsvideoer/ (with courtesy to Insero).

The PV inverter visualizes how much electricity has been produced (in kWh) the last day, week, and in total since the installation. Some used the PV inverter to gain increased knowledge about the production of electricity. It functioned as a signal of when to begin charging the car:

> ”We read what it (inverter) says when we come home, and if there is any electricity being produced then we might as well plug it in”(L13)

In this case, the inverter display was used as a signal for when to plug in the car. The actual number on the inverter display (kWh) had no significance to them, which is in accordance with other work reporting that the amount of energy in kW has little meaning in everyday life to many people (D’Oca, Corgnati, & Buso, 2014). The information on the display was used simply to see if the PV was producing energy, and if it was, they would then start charging the car. The immediate availability of the smart metre display contributed information during activities within the home:

> “W:…when we are doing some activities, we look at the metre, ‘what happens out here?’, it is really great when it says 0 (zero), and the washing machine and oven are running, and the car is plugged in” (L13)

This family used the ‘current electricity purchase’ on the metre as a sign of electricity savings: when the metre said 0, they knew that they were getting all the consumed energy for free. By looking at the metre, they adjusted their consumption, using the metre to control the amount of devices they could switch on/off according to how much electricity they were producing from the PVs. Although they had great interest in being oriented about the current state of production and consumption, they did not use eButler to keep track of their overall energy situation because eButler was only available on the PC and they only sat in front of a PC once a week to conduct practical chores, such as paying the bills; they were not interested in spending additional time there. Therefore, the displays on the inverter, the HP and the smart metre were more frequently used.

Many of the families expressed distress about the fact that, apart from seeing their consumption and production, they were also confronted with information regarding how much electricity they were donating to the energy company:

> M: ”we can see here what we produce during the day. Here we see how much electricity we buy, here we see how much electricity we sell. We are on the new billing account[23]… we have to pay 1000 DKK to the energy company in administration fees. That’s a bit annoying.” (B2xx)

> ”M: This is how much we produce (looking at eButler), this is how much we deliver to the energy company. It’s far too much.” (P3)

Here, a dilemma regarding feedback was revealed: the participants were informed by the equipment about the consumption and production of electricity, but not all of them had the ability to make any energy-related changes. Thus, this information was highlighting that they did not have control over what their produced electricity was used for.

After 18 months, some of the participants found it a waste of time to scrutinize the data. This was especially the case with busy families, who did not seem to find spare time to spend on eButler.

> “… I have used eButler 5 times, I think. It doesn’t interest me at all.. I don’t have time nor interest to use eButler.” (F6)

eButler enabled participants to investigate the consumption of specific devices in more detail. One example was the consumption of the EV and investigating specific issues, such as calculating the COP value for the HP to make sure that the settings were optimal:

> “.. I have checked eButler every month to see how much I have produced and how much I have used. Also I have figured out that my HP has an average COP-value[xviii] of 3 over a one year period.” (P7)“Yes, and I have used night-time drop, and used eButler to see if it actually made sense.”

[23] See note iii for a description of the new/old billing account.

This feedback occasionally resulted in frustrations where families became aware of the HP having unwanted use-patterns:

> M: “eButler told us that our HP runs during the night.” F: “Between 4 and 6 am I think it was.” M: “And that’s not right. Why does it start then, ‘cause if the water is 45 °C it is more than enough for us to shower. At 10 am the sun is shining, then it can begin heating…we think that in the summer it should shut down and not use electricity when there’s no sunshine..”(B2xx)

Thus, the displays were used to give information about current production and consumption. They were used actively and more regularly than eButler because they were available at all times without having to log-on. The families were acting on the information being presented on the displays by turning technologies on/off according to the production from the PV, thus the de-scription of the information/visualization equipment was used to control the consumption according to their production from the PV. Thus, a de-scription of eButler mainly occurred among the technologically interested participants and involved a deep interest in controlling the technologies by themselves, while others rejected the script and had no interest in it. The de-scription of eButler also entailed frustration because it presented the participants with facts about their lack of control over their consumption and technologies.

4.5.4.2 *Thoughts regarding remote control*

When asking about the concept of remote control, the participants had different ideas regarding what control meant for them:

> ”the more the devices are controlled by others the less it becomes something that we feel a sense of ownership of. And there’s something about having these devices yourself, I think there’s something in that, that there are some technologies you have and that you can provide yourself with energy and that you would like to control how it should work.” (L15)

This family had the time to control the temperature in the house on a daily basis; they were keen on changing settings in the house to accommodate the new system, highly interested in the environment and determined to control their consumption and be ‘green.’ Others were living busy family lives and could not find the extra time and energy to comply with environmental goals. As one family man stated regarding being remote controlled:

> M: “..The more the technologies can control themselves the better; they (automatic technologies) are better at it. That is why it’s called automatic.” (P3)

There were great differences in how much time different families could invest in the control of their own heating system. Most of the families were of the opinion that, as long as the comfort settings were accounted for, they did not mind if someone else was controlling their devices. As one of the participants said:

> "..I don't consider it any different if it's a computer at home that controls the temperature, or if this control is placed with Insero. As long as the temperature is 23° C, which they promised, then it is ok." (B2xx)

Participants also discussed who had the control. If you as a person in the household define the temperature, are you then in control, or is the energy company acting within those boundaries in control?

> "The question is if they are going to control it, or who is in control? If you can change the setting in periods as you wish, are you then the one in control?" (S2)

Thus, the script including the setting of the boundaries seemed to give many of the participants the feeling of being in control because they were setting the boundaries. Many families believed that it did not matter if the controlling unit was placed at home or with the energy company. The idea of being controlled externally gave some informants a sense of safety. They reflected on the fact that having external control could help maintain a correct indoor temperature when they were away and also make it possible to get the house heated up before they arrived back home after the holiday. The increased level of control and talk about control related to the data from the household made the participants question their advantages in this set-up:

> "M: I have been wondering, since we are talking about control, is anyone keeping track of our consumption? Are they saying, 'this looks all wrong'? Right from the beginning I had the feeling that we were really being 'watched' with the different technologies, but as my mum says, if that was the case then the technologies should have worked" I: "So you would have liked more focus on finding the problems?" M: "Otherwise, what are all the measuring devices for?" (B2xx)

Some of the participants were disappointed in the lack of feedback from the results of the surveillance. They were wondering if they were missing information from all the data collected from the household. Others had experienced their HP malfunctioning and felt disappointed that they themselves were the ones discovering the problem:

> “It was pure luck that he (a technician) came that day. Because if 2-3 weeks had gone by and the HP had been running on the heating element during all that time, then we would have received a huge electricity bill. It would have been nice if someone surveilling the system would pay attention to when we all of a sudden used the double amount of electricity.” (P7)

The promise of remote control had apparently made them feel safer in relation to such problems. They had confidence in the company also checking the system for malfunctions. Thus, there was a difference between what the informants expected from the concept of remote control and what Insero provided. Where the participants were greatly motivated by reliability in relation to remote control, Insero was more focused on flexibility issues, showing a mismatch in the script regarding control. How the participants de-scripted the notion of control and what it should include is illustrated in the following citation:

> “..We have those sensors in the rooms; then I see it as natural that they (project responsible) look if it runs alright….Or are they just letting everything run without even keeping an eye on what is going on? There must be a reason for why we have sensors in various rooms.” (P7)

Some participants reported that providing themselves with energy was connected to a wish to control the devices themselves; they thus were rejecting the script of remote control. Others had more faith in the technologies and the actors performing the remote control than in their own abilities and time to learn how to control these devices according to best practices. Most participants did not seem to be considerably concerned with whom the control was located; as long as they were able to apply their settings, they did not care about the physical location of the computer. The external control also made them feel safer because others now also could locate problems within the household. De-scripting the technologies and new situation of control revealed that the participants’ notion of control did not equal Insero’s notion of control. While the participants found it expected to have increased safety as a part of being increasingly surveilled, they found that this had not necessarily been the case, resulting in frustration.

4.5.4.3 *Living with remote control*

As part of the project, the households had agreed to let their EV and HP be remotely controlled. The remote control of the EV began slightly more than one year after the technologies had been installed. Some of the households did not notice when the remote control began:

> ”I didn’t realize that it’d been remotely controlled until I checked eButler.“ (L13)

Others had experienced plugging the car in and having it stop without finalizing the charging. This made some of the informants slightly nervous:

> ”In the beginning I was kind of nervous. We had some problems with the charger when it just got installed. It wasn’t easy to figure out if it was because of the same problems that we had experienced earlier or if it was because they had begun controlling it” (P7)

There was great interest in charging the EV when the sun was shining, and this was not following the original idea of the project, where the EV and HP were to be turned on during the night when electricity was cheap and the electricity produced during the daytime was to be fed to the grid.

> “..We ended up using a lot of extra money on the charging of the EV. We actually plugged the car in while the PVs were producing electricity. But you see, they were postponing the charging until the night” (S4)

The informants were dissatisfied with this issue of not being able to control the EV according to the PV’s production of electricity. Because the informants had changed their routines to use as much of their own produced electricity as possible, they felt annoyed when Insero began to externally control their EV, although it was a part of the initial project plan and agreement. Some found ways to work around it by turning the plug on and off a couple of times until it began charging again:

> ”It didn’t work a couple of times, but then I figured out that I should just leave it turned on when I pulled the plug out…and when I re-plugged the EV, it started charging again” (S2)

Additionally, the remote control of charging had failed in few cases, which made the informants suspicious. They took precautions when they had important plans:

> “Sometimes in the morning it was only charged to 24-25%. Some mornings when I had to leave early I pulled a cable pool and charged with the guest charger during the night to make sure that it was charged” (F15)

Although there was an override function, many of the informants did not use it because it was too much work. When asked about the override function, one replied: “Well it was such a hassle. It was in eButler you could access it, but I never got around using it.” (D22). They tended to use other methods to control the charging if they needed to. In general, the participants did not approve of the idea of having their EV remotely controlled. This was partly linked to the driving range of the EVs:

> ”If you drive an EV with a range of 130-140 km on a fully charged battery, then it mustn’t occur that it’s only charged 30-40% when you want to use it. So when you plug it in, it has to charge up to 80%. Otherwise it needs to be a Tesla with a range of 400-500 km” (F15)

It was also connected with the time schedules of the families. Some families were under pressure time-wise such that it was impossible to avoid charging during peak hours in the grid:

> ”I couldn’t live with the EV not being charged between 4-6 pm. Because I’m often at home an hour before I have to pick up the kids from football practice. Then, it needs all the electricity it can get.” (F6)

Because the families were living in the countryside, they were all entirely dependent on their cars and could not use public transport if the car did not function. Thus, they had to be certain that their car was working. The script of remote control during the nighttime was unwanted by many of the participants because they were more interested in controlling the devices themselves to be consuming when the sun was shining. There were examples of the script changing in the de-scripting process in the households. People found ways to adjust the charging to avoid the remote control when they really needed the EV the next morning.

4.5.5 How did Insero respond to the users’ de-scription of control?

There were several learning points reported from Insero when Insero Live Lab ended. The results spanned from user involvement to implications for the electricity grid. According to the control aspects, Insero reported the consumers as being more interested in having their HP externally controlled than their EV because participants reported feeling safer when experts were controlling their HP. The remote control of the EV, however, was not seen as an increase in reliability, rather the opposite – it decreased it. Here, consumers felt they lost control over something they were entirely dependent on. Thus, the results reported from the project report were aligned with the results retrieved through the interviews and workshops as the basis of this paper.

Insero reported that their choice of technologies, the PVs, had caused problems[xix] that conflicted with the original visions of the Live Lab:

> “There were some big challenges connected with the fact that the earnings from the PVs were so low. And that is why they [participants] wanted to control the HP, and run the dishwasher in the middle of the day. That was for sure not what we intended because we went out to optimize according to an electricity price on the spot market and not what was privately economically feasible. ” (Insero project responsible)

The change in the script by another actor, through governmental regulations, thus changed the de-scription by the consumers in relation to the control. They wanted to use electricity differently (than Insero had originally anticipated), and this made the smart grid visions for flexibility collapse, which had not been expected before the project was initiated.

Insero Energy chose on the basis of the Live Lab to create a new business focusing on the least engaged customers, stating the following about the new business and the results of the Insero Live Lab:

> ”It is important that consumers do not control and monitor the HP themselves, they must simply regard the HP as black-boxed, so it’s important to us to get that particularly kind of consumers, and those types we did not have in the Living Lab” (Insero project responsible)

Because of the combination of technologies and the fact that the participants wanted to control their devices according to their PVs, they did not turn out to be the type of consumers to base a new business on given the current situation in Denmark.

4.6 Concluding remarks – Script

By studying in-scription and de-scription of control in a smart grid trial, we have encountered control on different levels. In the in-scription process, we discovered how remote control was related to the choice of specific technologies to be installed in the households. In the de-scription process, the participants were actively controlling their appliances according to their own needs and dealing with remote control, by an aggregator, that took some control aspects away from the participants. In this study, remote control was apparent in all levels of the in-scription and de-scription process, and there were many controversies related to it: from the choice of technologies to passing of the control over certain devices to an aggregator.

The residents did not seem to expect to be autonomously in control of their technologies. The question remains: Were the participants thus empowered through the de-scripted technologies in relation to remote control? Did they even want this empowerment, and if so, for what purpose? Some families resented the idea of being remotely controlled; others welcomed it, mostly for reasons of convenience.

Consider Jelsma’s (Jelsma, 2003) dimensions of the script concept to investigate the morality of the concept of remote control: when considering the *force dimension*, it was apparent that the force of the script relating to remote control in Insero Live Lab can be considered strong, i.e., the consumers could not easily avoid changing the timing of the remote control. They had the ability to override the remote control of the EV via eButler, but the function was too complicated. In general, the information/visualization equipment provided the households with information that they could use to control their own devices. Thus, some became more aware of what could be done to consume their own generated electricity, which enforced the wish to be in control of the timing of the consumption. This worked against the main idea of the concept of remote control and the aggregator in Insero Live Lab, for whom it was important to have consumers that were not so concerned with their energy consumption. For them, the users should preferably be un-engaged in their energy system, having a strong script where the consumers mainly set some temperature boundaries and leave the control part up to the aggregator. As mentioned before, *the scale of the script* related to remote control in Insero Live Lab can be considered to change on a high level in relation to sustainability because it requires both changes within the devices and a new actor, the aggregator, for it to function; compare this to situations where flexibility should be achieved through feedback to the consumers. The *direction* that the script of remote control in Insero Live Lab is pushing values and rules in society can be connected to the values of the 'passive consumer' within the smart grid in Denmark. This brings us to the subject of how we envision and configure users in relation to flexible energy consumption and remote control. The results show that the active energy consumers - active by investing in PVs and EVs – do not have any incentives to contribute on a system level in Denmark in the current situation.

Following Jelsma (1997), we too suggest that "we need to move from the de-scriptive to the in-scriptive level," a move required because society needs 'moralizing' products and design strategies that seek to change environmental behaviour that go beyond nudging or simple encouragements. "Retrospective de-scriptions of how residents react in particular situations are only useful if it is possible to identify malleable conditions that may be used in the design of new technology for shaping users' behaviour in societally desirable directions." In this trial, the script appeared as a product of dynamic negotiations, and parts of the technology were redesigned according to comments from users that precisely showed different ways of taking control. We thus suggest that the move from the descriptive to the inscriptive level requires an explicit focus on control and that control issues should be dynamically discussed and developed with users, making them able to take control of technologies at home by allowing for individual adjustments via simple methods.

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[iii] 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, 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 and the embedded/decentralized intelligence and a reliable means of communication. The intelligence may be deployed at various levels of the network.

[iv] A distinction seems in place: one thing is being physically in control of the technology, able to manage the settings, while another is the sense of control. According to Langer (1975), people may have an illusion of control, believing that they have more control over end results when they have the possibility of being actively involved in the process. Feeling in control may thus provide people with a sense of empowerment precisely through technology that allows for some kind of active involvement; likewise, a lack of control and a sense of being disempowered may be felt by people when they are not able to administer the technology as intended.

[v]

ID	PV feed-in tariffs: Old/New*	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) M (10-14) M (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

Information about participants: * PVs in Denmark became especially favourable after the 'solar agreement' in 2012, which included a lucrative deal for the prosumers, with the state paying them for delivering electricity to the grid. The agreement 'Netto-måler-ordningen' (net-meter-scheme), referred to as 'the old agreement,' included a yearly settlement of accounts regarding the produced electricity and the stipulation that capacity not exceed 6 kW/household. Because of this lucrative deal and the decline of prices of PV panels, many households purchased PVs, 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, the surplus of electricity from solar panels up to 6 kW are sold at the fixed price of 0.6 DKK/kWh for PVs installed after September 19, 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 and bought back in the evening at a price of 2.20 DKK/kWh.

[vi] A sociologist employed by Insero Business Services had the tasks of primary communication with and evaluation of households.
[vii] Before the interviews, an interview guide had been prepared, covering the following general areas: overall use of the house (residents and their practices related to the home), digital behaviour, energy technologies, and car usage/practices. These themes were important to gain knowledge of the informant and their relation to both relevant technologies and energy use. This interview round was also important to inform the informants of their roles in the trial and to create a first connection between the informants and Insero employees.
[viii] Mostly both the husband and wife were interviewed, although it was not possible in some cases.
[ix] The sound files for the four interviews conducted with two eButler software designers and two Insero employees were unfortunately lost. Therefore, they could not be transcribed and coded.
[x] In addition, the trial was also part of the FINESCE European smart grid pilot project.
[xi] Each participant would receive a subsidy of approximately 50% of the price of the PV and the HP. The EV and charging station was to be leased for 2 years.
[xii] The control of the air/water HPs was building on 'Control Your Heat pump' (StyrDinVarmepumpe, (Intelligent Energistyring AmbA et al., 2015)), a tested platform that can be used to control HPs externally. The project was thus building on a pilot project where 300 HPs have already been remotely controlled to investigate the potential of HPs in relation to flexibility (Intelligent Energistyring AmbA et al., 2015). This study was also the reason for the choice of particular brands in the initial package.
[xiii] For instance, one family explained how they were more confident in having more than electricity as a source of heating because of the tax system on electricity in DK and how they could never be sure if it would be heavily taxed all of a sudden.
[xiv] This paper does not include any investigations of the efficiency of solar wells (or other technologies), as that is beyond the defined scope.

[xv] eButler had been developed for utility companies and was meant as a platform to serve communication between utilities and their customers. The program needed to be changed to fit Insero Live Lab. Thus, there were some functional limitations from the beginning; some were improved during the process.

[xvi] Other studies have focused on visualization and feedback. Some studies have critically assessed the role in energy feedback when it comes to reducing households' consumption (Van Dam, Bakker, & Buiter, 2013; Hargreaves, Nye, & Burgess, 2013). Nevertheless, energy feedback has also been shown to, in some cases, have an empowering effect on the residents (Buchanan, Russo, & Anderson, 2014).

[xvii] Detailed description of the practices in Hansen & Hauge, 2016 (Hansen & Hauge, 2016)

[xviii] Coefficient of Performance

[xix] The fact that the price for delivering electricity to the grid was low gave the participants incentives to use all the electricity they produced within the hour because, when doing so, they would receive approximately 2 DKK for each kWh instead of 0.6 DKK.

5 Discussion, perspectives and further work

In the preceding three chapters, I have analysed private households in smart grid projects with a focus on household consumers' future energy practices and interaction with energy equipment. The purpose has been to explore their integration and participation in smart grid scripts that are currently being explored. Such inquiries shed light on some of the future expectations from smart grid developers and provide knowledge about how private households are actually responding to smart grid technologies (HPs, EVs) and concepts (flexibility, remote control).

The three papers in this thesis have focused on understanding the private households' representation in Danish smart grid experimental projects. Paper 1 provides an overall analysis of the scripts that the households are presented with in Danish smart grid experimental projects. In the subsequent research, I chose to focus on the everyday lives of participating households in one experimental project, Insero Live Lab. Papers 2 and 3 investigate the private households and analyse central aspects in the smart grid discussion, namely issues of control and prosumers.

It is reasonable to argue, based on the conclusions from paper 1, that the empirical knowledge regarding the effect of the smart grid technologies and concepts is rather narrowly focused on the technical specification and that the households are considered as more of a barrier than an area of study. Therefore, there is a need for research on smart grid households' everyday lives. Such research is relevant for a number of reasons. Mainly, consumers might choose not to change their behaviour according to the smart grid visions and thereby lower the chance for a successful implementation of the smart grid.

The findings from the papers point in the same direction: if private households are to be flexible, great changes are going to need to take place in their homes. Moreover, the Danish smart grid development community has not fully acknowledged the level of change that the smart grid will imply in households.

This chapter briefly presents key studies, research gap and contribution for this study and furthermore recapitalizes the three papers and discusses the findings regarding flexibility, control and prosumers.

5.1 Key studies, research gap and contribution

I will briefly summarise key studies, research gap, and main contributions of this study before continuing to a more detailed discussion of the results in the sections 5.2 – 5.6.

Among the key studies for this thesis are studies of the energy area and private consumers in relation to feedback of electricity consumption. Some of these studies are carried out by Sarah Darby and others from around 2000 until 2012, with a focus on feedback of energy consumption in households.

These studies include an investigation of roll out of smart metres in the UK and reviews a number of trials in which the main purpose is to implement smart metres along with other technologies for displaying information about energy (electricity and gas) consumption. The study compares tests and evaluations of the implemented feedback technologies of the four different trials (Darby et al. 2011). Furthermore, these studies include a comprehensive review of the effectiveness of feedback where consumers are informed of their energy consumption in different ways (Darby 2006). At the time, one assumption within energy research seemed to be that if the consumers were informed of their energy consumption they would also optimise their consumption and behave rationally. These studies were thus investigating the advance of smart grid-related technologies such as smart metres and direct displays and questioning some general assumption on the area.

While these projects mainly focused on reports and experimental projects as sources, others focused on the household level, investigating how these new feedback trials in fact were affecting the families living with the technologies. Hargreaves, Nye, and Burgess (2010) investigate, on a household level, how smart energy monitors are being used in a field trial with 15 UK households. What was especially interesting for this project was the way they investigate the use of the monitors in their everyday lives and how feedback changed the consumption behaviour in the households (Hargreaves et al. 2010). Furthermore, they conducted a follow up study of the same project 12 months later to investigate how the participants were using the technologies after a longer period of time (Hargreaves, Nye, and Burgess 2013).

Among the key studies that had an impact on the theoretical approach of this project were the study of the introduction of new energy-producing equipment by Akrich (1992) along with the study on script and morality by Jelsma (2003). Furthermore studies combining social practice theory and energy consumption such as Shove, Trentmann, and Wilk (2009) had an impact on the design and execution of this project. Along this line one study analysed the peak demand according to a practice theoretical approach moving the focus from the individual consumers, their attitudes, behaviours and choices, towards a focus on technological-mediated social practices (Strengers 2012). This topic was continued in the book "Smart Energy Technologies in Everyday Life - Smart Utopia", also mentioned previously in this thesis. This book was entirely dedicated the consumers and households in smart grid with a practice theoretical approach. The study captures many interesting topics that are essential to investigate the future energy system. The study is particularly critical towards the typical visions found among leading developers within the smart grid area on how the consumer role is envisioned in smart grid, applying the previously mentioned concept 'resource man'. This concept is highly inspired by the image of consumers as behaving rationally economically speaking.

Another project that is supporting the trend of positioning the consumer in other ways than 'economical rational' is the ISHMAG project. Particularly for this project, the IHSMAG project is of interest as it argues for a practice theoretical approach to be integrated in smart grid research. The researchers also acknowledge the necessity of a focus on the prosumer area within the smart grid and the rights that this new role should entail (Christensen, Gram-hanssen, and Friis 2013). Furthermore, the project seeks to inspire the debate about practice theory and that it can become more usable in design of smart grid solutions (Christensen 2014). This can be seen as a reaction to the simplistic view of consumers in smart grid development previously mentioned as the 'resource man'.

Goulden et al. (2014) study two scenarios of the future consumer in smart grid, with a practice theoretical approach, by initiating focus groups with consumers without any prior knowledge of the subject. In the focus groups smart grid concepts/technologies such as: In home display and automated control were discussed based on previously watched films about smart grid and technologies. They use the concepts 'energy consumer' and 'energy citizen' to consider two forms of engagements that can take place based on: a centralised system with current institutional arrangements and an alternative system in which decentralisation of generation and control is central. This study is central in the framing of this project and in the discussion of the visions of the household consumers.

Furthermore visions in smart grids are central in a study by Verbong, Beemsterboer, and Sengers (2013) who use a SNM approach to investigate the visions for consumers in smart grid. They interview relevant stakeholders (no household consumers were included among the stakeholders) from experimental projects and the energy sector for their opinion concerning the visions of the smart grid. This study focuses on smart grid experimental projects in the Netherlands and is connected to the research in this thesis.

Another two key studies for this thesis, which were based on experimental projects, were based on the eFlex project. The eFlex project was initiated by DONG, one of the analysed projects in paper 1 and had a rather unique focus on the household participants compared to the other Danish smart grid projects. Anthropologists were in charge of an investigation of how the households were reacting to the project-set up and the installed technologies (Koppel et al. 2012). The first study investigated what can be learned from such smart grid projects (Nyborg and Røpke 2013) while the second focused on user innovation in smart grid experimental projects using social practices theory and domestication theories to shed a light on the topic (Nyborg 2015).

This study seeks to build on this knowledge about smart grid and consumers from the key studies above and to extend the investigation to include experimental projects in Denmark and their participating household consumers to give an overall view on the visions on households and how they respond to them.

Currently there is a lack of studies that investigate the visions of household consumers in smart grid experimental projects in Denmark on a detailed manner. Furthermore studies of how the household consumers and how they are reacting to this proposed reality are scarce. This is the research gap that this thesis is addressing.

The scientific contributions of this thesis contribute to excessive knowledge about household consumers in real life smart grid experimental projects in Denmark. This is relevant because of the previous mentioned extensive smart grid activity present in the country. The thesis contributes to the stream of academic literature regarding social science and smart grid. Due to the choice of retrieving data from real-life experimental projects, it offers in-depth knowledge about what is currently being researched on the smart grid area and how the household consumers are being envisioned and how they are responding towards these visions in their everyday life.

The thesis contributes with a description of the scripts for the future smart grid interaction investigated in the projects and their findings concerning consumers and smart grids. Results show that visions concerning the household consumers' roles in smart grid in Denmark are emphasising economic incentives and automation to achieve flexible energy consumption. Nevertheless, little investigation has been conducted on the changes that such concepts can entail in the household consumers' everyday life. This thesis contributes with knowledge on this area by investigating the in- and de-scription of control in a real-life experimental smart grid project.

Control is, in many facets, a central concept in smart grid. Nevertheless, there ceases to be a comprehensive study of how control is envisioned by the system developers and interpreted by the households in smart grid households. This thesis also contributes to fill this gap in literature.

Studying smart grid experimental smart grid projects in Denmark revealed that one often mentioned concept in smart grid literature, the prosumer, has not been studied in real-life smart grid settings.

Furthermore, within the stream of academic literature there is a growing literature on the role of consumers but a lack of studies focusing on how prosumers' energy consuming practices are affected by other smart grid technologies such as EVs and HP, simultaneously. Such a comprehensive research of prosumers in smart grid households - that this study offers - is new within the field. The analyses of prosumers with the use of a practice theoretical approach contributes with better understanding of how micro-generation can induce awareness of energy related practices but also give rise to 'malleable practices'. Furthermore, the focus on competences contributes with a better understanding of households within the energy area and the resistance they can meet when technologies are part of such comprehensive network as the installed PVs, heat pumps and EVs are. These types of technologies often require competences beyond the average person to be able to be consumed their own generated electricity.

5.2 The script of flexibility

From the cross-going analysis of experimental projects in paper 1, it is clear that, within smart grid experimental projects in Denmark, there is a common smart grid script, with one coherent development community, dominated by energy system actors in the leading roles. The common script includes flexible consumption, which is one of the main changes for the private consumers going from the 'conventional electricity grid' to the 'smart grid.' Overall, the consumers are expected to provide flexibility by means of changing their energy-consuming practices to some extent.

Flexibility has been created by means of economic incentives and automation. One common assumption in the Danish experimental projects is that the consumers behave economically rationally according to their energy consumption. Thus, in many cases, projects focus on variable electricity prices (where the price of electricity changes during the day) and price signals to change the energy consumption according to the availability of energy. Nevertheless, the results show that economic incentives alone are not sufficient to make a change in consumption. Other incentives, such as environmental concerns, engagement in taking up the technology, and responsibility in the local community, appear but are excluded or only receive limited attention in many projects. Thus, there is a contradiction within the research. There seems to be a need for a mix of incentives instead of solely focusing on economic ones. Although the price incentives have been shown to have an effect in the initial phases, to get people on-board in these projects, other incentives might matter more in the long run (paper 1). Papers 2 and 3 supported this finding that incentives do not necessarily need to have financial benefits on a household level if they can contribute to the community. As also found by (Späth & Rohracher, 2010), the support of the local community can be a strong motivation.

Furthermore, automation of electric devices is commonly used in combination with variable prices to create flexible consumption. The majority of the Danish projects included new devices, such as HPs or EVs, (along with variable prices) to obtain more flexibility. Combined with the new technology, some projects also included information/visualization equipment to show the price and/or consumption of electricity of devices. Thus, big changes have been applied in the households in the majority of projects. This also contributed to tensions within the script since, in many projects, the participants were busy de-scripting the technologies. Thus, when other smart grid concepts were added, tensions were seen (paper 1).

This study shows that energy information/visualization equipment can affect the way the households think about energy and also have an effect on the consumption itself. From paper 1, it is clear that there is a great difference between the complexities of the signals in the visualization equipment in the projects. Nevertheless, the most simple information/visualization equipment was also gaining the most attention. In the projects that had a more complex set-up, with both information/visualization tools and automation, there was not much use reported. Thus, it seems reasonable to question if the level of complexity is actually matching the households' needs and interests (paper 1). To some extent, this pattern, where the simplest equipment was reported to be the most frequently used, was also confirmed in Insero Live Lab. The participants in Insero Live Lab were actively engaging with the different displays (PV inverter, HP displays and smart metre) to consume according to the shining of the sun. The engagement with the displays (available at all times) with rather simple information was used the most by the participants. eButler (an energy management system), which required a log-in from a PC, was less used overall but was important in gaining more detailed knowledge about the consumption (papers 2, 3). Research on visualization and information equipment has previously focused on how specific visualization tools may affect the energy consumption (e.g., D'Oca, Corgnati, & Buso, 2014)(Darby, 2006)(Darby, 2010). Scholars have highlighted that several pilot projects in Europe have included smart metres and Smart Energy Monitors to investigate how increased information (regarding consumption) affects the consumption. Usually, increased information results in little or no savings of electricity among the households. Rather than dismissing such informative technologies because of the absent savings, they argue that such informing technologies are contributing to energy citizenship. With these devices, citizens can be informed and contribute to more sustainable energy consumption. Thus, the devices can be seen as engaging and with a performative effect (Throndsen & Ryghaug, 2015). In papers 2 and 3, we found that the information/visualization equipment can be considered to act as an 'engaging device' (Throndsen & Ryghaug, 2015), informing them about the energy situation in their own home but also about how much electricity was delivered to the grid with little revenue, giving them energy citizenship and making them energy system participants rather than energy consumers (Goulden, Bedwell, Rennick-Egglestone, Rodden, & Spence, 2014).

From paper 1, we find that studies of everyday life in Danish smart grid projects have been lacking. We found that the majority of the experimental smart grid projects that did include a study of everyday life were EV projects with one exception, the eFlex project. This is striking because the new technologies can have dramatic changes on households' lives. Finding flexibility in everyday life is not a simple matter, as it implies changing the rhythm of everyday practices. Additionally, some practices are more socially dependent than others. Practices such as cooking and dining are more socially constrained compared with laundry and dishwashing (Powells, Bulkeley, Bell, & Judson, 2014). Furthermore, the more actors there are in a household, the more difficult it is to achieve flexible consumption, mainly because of children and pets (Nyborg, 2015). Thus, the changes of practices to obtain flexible consumption can also have different effects on parts of the population. In relation to issues of inequality, there are several issues at stake in this development of flexible households. Depending on the type of variable pricing mechanism (how much cheaper/more expensive) implemented, some parts of the population will not be able to change their everyday practices to accommodate variable electricity prices (Nicholls & Strengers, 2015). Furthermore, to benefit from variable pricing, there might be the need for purchasing new (expensive) technologies, which might prove difficult for certain segments. Thus, one important aspect in these considerations is if the smart grid is creating inequality in the population and discriminating against certain social groups that are capable of neither changing their consumption nor investing in new technologies.

5.3 Control in smart grid experimental projects

As mentioned previously, there are different aspects of control in smart grid households. Within the households, the control over specific appliances might change if concepts such as price signals are implemented. Furthermore, the households are in some cases expected to leave the overall control of devices to an outside actor (the aggregator) and lose control to some extent.

From paper 1, we found that automated control is an essential part of gaining flexibility within the smart grid. The automated control includes two versions: automatic control where appliances react to signals and also the remote control managed outside the household by an aggregator. The results from paper 1 showed that the two types of automation were applied in general because it proved difficult for the household consumers to react to price in a manual fashion. The Danish projects generally reported that there was no loss of comfort level having heating devices remotely controlled. Because there was little investigation of remote control and its impact on the everyday lives of the consumers, I wish to draw on a project from the previously mentioned Nordic survey of smart grid experimental projects. The project 'Pilotstudie i Vallentuna' investigated how comfortable users were in relation to the new technology (remotely controlled HPs). The comfort was in relation to the indoor temperature and also in relation to managing the device. The investigation focused on the trust of the users towards the new heating system. Unlike the previously mentioned projects, which included remote control and HPs, 'Pilotstudie i Vallentuna' reported negative results on the acceptance of the automatic system. The project reported that there was a great difference between how much an exact comfort level meant to the different house owners. Furthermore, an increased level of reinsurance in relation to the HPs was required by some of the participants. The participants varied in their level of insecurity towards the new technology (Persson, Fernlund, & Lindbom, 2012). The findings from 'Pilotstudie i Vallentuna' concerning the issues of trust (or the lack thereof) in relation to remote control were also found in papers 2 and 3 in relation to the EV. Some of the participants were either constantly checking if the EV was indeed charging or they found ways to work around it by charging the car with an extension cord instead of using the installed charging station. Thus, the participants were (occasionally) finding ways to by-pass the system by using other solutions that fit their own routines better and made them feel more secure (paper 2). Thus, users can have rationales that were not expected by the project designers and technology developers, and the urge to change the settings or work around them is stronger in some than in others (Nyborg & Røpke, 2015). Remote control requires a high level of trust between the households and the actor responsible for the remote control.

There has been an international rise in studies that include aggregators, which can benefit financially from flexibility (Niesten & Alkemade, 2015). This is also the case in the newest project, Ecogrid EU, reviewed in paper 1, where private households are to offer flexible consumption by having some of their devices remotely controlled. In this case, the 'traditional' functions and roles of the household consumers will be transformed. Paper 3 began with an interest in this new situation that emerged in the particular experimental project and these new issues of control that followed. The analyses focuses on control aspects related to smart grid devices, elaborating how issues of control were envisioned and designed in a smart grid trial in Denmark.

Paper 3 showed that households do not consider the remote control of EVs and HPs equally. The household consumers articulated resistance against remote control of the charging of their EV and expressed the need be in total control themselves (paper 3). Contradicting these results, a study from Germany reported smart charging of EVs to be acceptable and usable for the participants. In this study, 10 drivers each drove an EV in the Berlin metropolitan area for 5 months (Schmalfuß et al., 2015). Thus, these two studies point in different directions regarding the acceptance of remote control in the everyday lives of household consumers. One possible reason for this difference of opinion among the users of the EVs can be the location of the trials. Where Insero Live lab is situated in a rather remote area concerning public transport, it could well be the opposite case for the Berlin metropolitan area. Because the participants in Insero Live

Lab were so dependent on their EVs functioning, they were reluctant to let the charging be controlled by anyone else. Thus, in outskirt areas, other measures (than those currently studied) for smart charging could be necessary. Such research is of importance in relation to the stability of the grid. Thus, intelligent charging of EVs has proven to be more important to implement than that of HPs (Hedegaard, Morthorst, Münster, & Detlefsen, 2013). According to our results in paper 3, the participants are more likely to endure remote control of their HP than that of the charging of their EV because of the reasons mentioned above. However, the participants also showed great engagement in changing the consumption from the HP to fit with the production from their PV. The general consensus seemed to be that the remote control of the HP should include the production from the PV in the program, followed by the needs of the electricity system, to benefit from the increased use of wind power (paper 2).

5.4 Prosumers, engagement, and control

From paper 1, it is clear that none of the included projects in the survey included micro-generation. To some extent, micro-generation can be in conflict with the more centralized energy system that is embedded in the smart grid scripts in Denmark. Thus, as has been shown in this thesis, there can be a conflict between the internal practices in the households with micro-generation and the energy system's interests.

Paper 2 adopted the practice theory perspective to understand the everyday practices of household consumers with micro-generation. The findings show that micro-generation can change consumers' energy-related practices and also increase their awareness of other renewable energy sources. Furthermore, micro-generation had the effect of changing the practices to become more sustainable in some cases. For instance, it made sense to use the broom rather than the vacuum cleaner on a rainy day because they then were not consuming their own energy. Thus, micro-generation gives sense to sustainable practices. A similar result was found in a Dutch study (Naus, van Vliet, & Hendriksen, 2015).

The findings from paper 2 confirmed that practitioners (on the new agreement) changed their daily rhythms according to the generation of electricity from the PV, and some returned to less energy-consuming practices when there was no power being generated. The participants would mostly vacuum and charge the EV when the sun was shining and go back to less energy-consuming practices when it was not.

Thus, they were in fact (following(Walker, 2014)) showing an example of how a natural-social form of synchronization is becoming integrated in smart grid scenarios, where the energy consumption can become synchronized to the availability of energy in many ways. In the Insero Live Lab, the synchronization according to PVs was obvious. Walker, (2014) suggests paying attention to the rhythms (of the energy consuming practices) and finding the practices less malleable (and more sustainable). The reason for paying attention to the rhythm is that much of the energy consumption of everyday life happens in rhythms. Thus, the change of rhythms can have an impact on the timing of energy consumption.

Findings also showed that the households in Insero Live Lab were changing their rhythms to include less malleable practices. However, malleable practices were also induced with the installation of the PV. The results show that the participants were considering the energy from the PV as being 'home-grown' and 'green.' Thus, they felt less guilty performing practices, such as driving, because now they could drive using their home-made energy. Thus, the households reported using more electricity than they actually needed (the rebound effect). Another reason for the extended use was to avoid delivering the electricity to the energy company in exchange for little revenue. The frustration related to delivering electricity 'for next to nothing' resulted in increased engagement (in the local community among the Insero Live Lab participants) in becoming increasingly self-sufficient by buying a shared windmill and/or investing in battery banks to avoid the energy company.

As Insero Live Lab progressed and the prosumers became increasingly competent, they also realized how far they were from spending all the electricity that they generated. To succeed in this, comprehensive DIY skills were needed, skills that the majority of the participants did not have.

Interestingly, quite opposite the experiences from the Insero Live Lab, Schick & Gad, 2015 quote 'The Head of the Alliance for Intelligent Energy' in their study of household consumers in relation to the Danish Smart Grid Strategy:

> "The ones who are most progressive are the 85.000 owners of solar panels. Because they can read their electricity production they start changing their behaviour. They actually turn off the light and such things because they are inside a kind of game" (Schick & Gad, 2015:7)

He is here comparing the change of energy consumption to hours where they are producing electricity as a game (Schick & Gad, 2015). From papers 2 and 3, we learned that the reality for prosumers in Denmark is rather far from being game-like. There are several areas where prosumers in Denmark are struggling, making the task of consuming their own energy a complex matter (papers 2, 3).

Another aspect in the prosumer role that is worth discussing is the effect it has on the system level and one other particular envisioned smart grid concept: remote control. As mentioned before, flexibility and remote control have been envisioned to together play a key role in the smart grid (Lunde, Røpke, & Heiskanen, 2015). From the results from Insero Live Lab, it is clear that the role of prosumers today is in opposition to this vision. In this connection, I will cite a lead actor from Insero Live Lab about his take on this matter:

> "Well I think that the new PV agreement is all wrong in the sense that it encourages to opposite of what the electricity system needs. The electricity system needs that we produce electricity or save electricity when the electricity prices are high. The prices are high in the middle of the day when the sun is shining, therefore we should not use electricity in the middle of the day but instead deliver it to the grid… there are some moments where the sun is shining so heavily that the electricity prices fall but in reality it is not the case. It is the Germans and Norwegians that decide the price of electricity in Denmark, so the new model is senseless if we want PVs to assist the electricity system…it is really difficult to get PVs to be a part of Smart Grids or an intelligent control of the electricity system. I do not believe that is possible with this accounting system…it is contradicting…" (Insero project responsible)

Thus, the results from Insero Live lab show that micro-generation is indeed making the participants active in the sense of changing their consumption to when the sun is shining. Because the prices are high at this time of the day, it in some ways goes against the needs of the electricity system and the vision of smart grids. Thus, the prosumers will actively change their consumption according to their production, which can be argued as contradictory to the current Danish smart grid vision, which includes remote control to maximize the use of electricity when the wind is blowing.

5.5 The docile user

Based on this contradiction between how the prosumers behave and the electricity system's needs, the roles of future energy-consumers or energy-citizens is worth discussing. In paper 3, we showed how the participants are de-scripting the new situation of control when an extensive combination of smart grid technologies was installed in their homes. Analysing the dimensions (Jelsma, 2003) of the script of remote control, it was apparent that the information/visualization equipment (eButler, PV inverter- and HP displays) was providing the households with information about what could be done to consume according to their own generated electricity, enforcing the need to time the consumption. Thus, the behaviour was contradicting the in-scripted vision of remote control from Insero Software, for whom it was important to control the devices without interference from the consumers. Drawing on the discussion regarding energy citizenship and energy consumers, the control in-scriptions from Insero Live Lab can be considered to push values in society towards continuing the current role of the energy consumer "..from whom energy is simply a good to be expended in pursuit of personal goals" (Goulden et al., 2014:24) because they preferably would not interfere with the system. The de-scripting from the participating households was showing signs of energy citizenship, where they were engaging with energy in a meaningful part of their practices.

One could even argue that the set-up of the Insero Live lab, with households and the introduction of new electric equipment, is akin to the original text by Akrich 1992, where she uses the concept of script to investigate energy-producing equipment (photoelectric Lightning Kit and generators) introduced to rural areas in developing countries. She there studies how the technologies materialize in new settings. Several issues that were not thought of before the actual displacement appeared when users were de-scripting the new technologies. In her conclusions of the photo-electric-kit, she concludes:

> "So it was the technical object defined the actors with which it was to interact. The lighting kit (and behind it the designers) worked by a process of elimination. It would tolerate only a docile user and excluded other actors such as technicians or businesspeople who might normally have been expected to contribute to the creation of a technico-economic network" (Akrich, 1992:211).

This particular phrase is indeed interesting in relation to many of the results obtained by studying the household consumers in smart grid projects in Denmark. The presented view that the green technology is not allowing the users to actively de-script the technology to fit their world is remarkably alike many of the results retrieved in this thesis.

This thus brings us to the subject of how we envision the household consumers in Denmark in relation to flexible energy consumption, remote control and micro-generation. Results from paper 3 suggest that consumers investing in both PVs and EVs are becoming increasingly focused on their individual needs because of the current tariff structures, not having any incentives to contribute on a system level. At the same time, they are struggling to fulfil their own needs, as observed above. A recent report on the energy sector in Denmark expects that the installations of PVs in Denmark will increase because of declining prices[24]. They estimate that, until 2020, the expansion will primarily happen in the private sector, but after 2020, commercial PV plants only producing electricity for the grid are expected because at that point it is valued to be profitable (Danmarks Energi- og Klimafremskrivning 2015, 2015). The participating households in Insero Live Lab mentioned other assistive technologies that might make the consumption of their own generated power easier. One example was batteries, which seemed to make a lot of sense for several of

[24] Electricity from wind power is expected to cover 53-59% of the electricity consumption in 2020 and close to 53-65% of the electricity consumption in 2015. Electricity from PVs is expected to cover approximately 5% of the electricity consumption in 2020 and close to 8% in 2025 (Danmarks Energi- og Klimafremskrivning 2015, 2015).

the households. The question of what consequences such solutions will have on a system level then remains.

In a discussion with a project responsible from Insero Live lab, I asked him about what he expected to happen in the future with PV owners in Denmark. He replied that several solutions are appearing in the market that can benefit PV owners; as an example, he mentioned the combination of PVs and batteries, which Tesla is currently selling. Furthermore, he said that it will make economic sense for the households to invest in such technologies, but from a system perspective it does not.

There are systems being developed to facilitate a path where households become continuously self-sufficient, but how this will impact the development of the smart grid is unclear. With a rise of PVs being installed in the private sector, along with the prosumers experiences from the Insero Live Lab, measures should be taken to investigate the prosumer role further. Many issues and discussions on the interplay between household and energy system developments, which is also a regulatory matter, can be expected in the future.

5.6 Final remarks/further research

This thesis has increased our understanding of the visions of the smart grid and household consumers and of how they are actually responding to smart grid technologies and concepts. Particular attention has been given to the overall visions in experimental projects, the new emerging practices related to the new role of being a prosumer, and lastly the issues of control.

There is a need for further studies on what it means to be a flexible consumer, including in households without micro-generation, and how it affects households' everyday lives. In relation to this, further investigation is needed on the different types of pricing mechanisms and on who will be able to benefit from variable electricity pricing. If only new technologies can be remotely controlled, will it demand a complete new collection of devices to benefit from variable prices and an aggregator?

The research conducted in this thesis has also contributed to understanding of the consequences that implementation of smart grid technologies can have in private households. Thus, the study of the HPs combined with remote control and PVs has contributed knowledge regarding how the combination of HPs, EVs and PVs can affect the everyday lives of consumers. Furthermore, this thesis has contributed knowledge regarding EV drivers in the countryside and remote control of the charging. Contradicting other research, the EV drivers in Insero Live Lab did not find the remote control to fit with their everyday lives. Further research on this area is needed.

This research has noted some interesting aspects in relation to how households in one community can begin to increase in interest in renewable energies. We observed an interest among the participating households in Insero Live Lab in supporting local institutions with excess electricity. Furthermore, they expressed an interest in shared windmills and battery banks to increase the use of renewable energy. This thus calls for more research on how communities and possible micro-grids (matching the local generation to consumption (Moura, López, Moreno, & Almeida, 2013)) can accommodate an interest in supporting the community while increasingly basing the consumption on renewable energy.

Moreover, there is a need to study how the role of the prosumer 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.

This thesis has noted some contradictory trends in Denmark, namely the prosumers' current circumstances and the visions of the smart grid and remote control. Further research should investigate how the prosumers can provide benefit to the system level instead of striving for independence.

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