4 Exploring private consumers’ willingness to become early adopters of Smart Grid technology

Madeleine Broman Toft • John Thøgersen

International Journal of Consumer Studies: Submitted

Abstract: The goal of radically increasing the proportion of electricity generated from renewable sources puts the current electrical grid under pressure and one of the solutions is to turn the grid into a "Smart Grid". One of the key elements of the Smart Grid is that electricity consumers make some of their consumption available as flexible capacity to balance the grid. Consumers’ flexible capacity is only available to the grid if the consumers adopt Smart Grid technology that establishes the link between the electric system and the consumer. This technology is new to private consumers and using it involves behavioral changes. There is a call for knowledge about who are willing to adopt Smart Grid technology and why. This study draws on innovation adoption theory as a framework for understanding consumer adoption of this new technology. We explore whether consumers who have already adopted other types of new energy technology, such as a geothermal heat pump, are more favorably disposed towards Smart Grid technology than other consumers. Also, we explore how consumers who have signed up to let their heat pump be used as flexible capacity in a test trial differ from other heat pump owners, if at all. We used semi-structured interviews with household members as well as a questionnaire to explore differences between three groups: households with (1) a heat pump with Smart Grid technology (n = 11), (2) a heat pump only (n = 7) or (3) an oil-fired boiler (n = 6). We find that the families in the three groups perceive the technology characteristics differently and those who have trial experience with Smart Grid technology are most in favor of the technology.

Keywords: Early adoption; Smart Grid technology; household study; sustainable innovation
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1 Introduction

Governments are beginning to realize that significant changes in the production and consumption of energy are needed (Edenhofer O. et al., 2014; Press & Arnould, 2009), dramatically increasing the share of renewable energy including solar heating, photovoltaic systems, heat pumps and wind turbines (Claudy, Peterson, & O’Driscoll, 2012). Integrating a larger share of renewable sources into the power system requires fundamental changes in the way the system functions to enable it to fulfill the societal demand for electricity with a much more fluctuating supply (Biegel, Hansen, Stoustrup, Andersen, & Harbo, 2014). “Smart Grid technology” with remote control of electrical equipment opens up new possibilities for balancing the supply and demand of electricity by regulating (i.e. switch on/off and postpone) electricity consumption. Since private households account for a large and increasing share of electricity consumption (e.g., 32% in Denmark in 2009, cf. Christensen, Ascarza, & Throndsen, 2013) (European Commission's Joint Research Centre, 2012), it is important that also private consumers accept that some of their power demanding appliances are made available to regulate the timing of electricity consumption and that they adopt Smart Grid technology for that purpose. In this paper, “Smart Grid technology” refers to advanced smart meters that enable an electricity supplier or distribution system operator to remotely control the electricity consumption of in-house appliances (Da Silva, Karnouskos, Griesemer, & Ilic, 2012). Hence, it is a further development of the basic smart meter, which is a digitalized electrical meter that enables two-way communication between the consumer’s electricity system and the electricity supplier, making on-site meter reading redundant (see Wissner, 2011, for further details about possible features of smart meters).

The advantages of Smart Grid technology for private consumers include digitalized reading of their electricity consumption, a possibility to become flexible in electricity consumption and take advantage of lower off-peak prices and improved feedback on electricity consumption (Benzi,
An glani, Bassi, & Frosini, 2011). However, the societal benefits are larger (Hamilton, 2010), including more effective markets, increased system security and greater integration of renewable sources into the power system (Biegel et al., 2014). Further, recent research indicates that potential adopters may perceive risks in connection with the adoption of Smart Grid technology, such as loss of comfort (Goulden, Bedwell, Rennick-Egglestone, Rodden, & Spence, 2014), violation of privacy, increased costs (Krishnamurti et al., 2012), health concerns (AlAbdulkarim, 2013), less flexibility when using electricity and difficulty performing peak shaving actions (Paetz, Dütschke, & Fichtner, 2012).

Due to their appliances and fluctuating electricity use during the day, households living in single-family houses are especially well suited to adopt Smart Grid technology. Households that have adopted some type of renewable energy technology (e.g., a geothermal heat pump), already contribute to the “new” electricity system and might also be more ready to contribute with balancing capacity. For example, households that have a heat pump have a higher flexibility and a storage capacity that can be utilized for balancing the grid.

To most private consumers, Smart Grid technology is new and unknown. Typically, such an innovation tends to be first adopted by a small group of people who perceive the potential risks relative to benefits lower than others due to their personal characteristics, needs and/or wants (Rogers, 2003). This segment of early adopters is important for the success of the innovation because they test the innovation and function as opinion leaders, who potential later adopters can turn to for advice and information thereby reducing the uncertainty that surrounds the adoption (Rogers, 2003). Hence, by identifying the customer segment or segments that are likely to become early adopters, for bigger effect can promotion campaigns be targeted at these segments in the early stage of market penetration (Gärling & Thøgersen, 2001). The current research explores who will be likely to be early adopters of Smart Grid technology.
Studies on consumers’ perceptions of smart meters exist (Benzi et al., 2011; Darby, 2010; Hargreaves, Nye, & Burgess, 2010; He et al., 2013; Krishnamurti et al., 2012; Siano, 2014), but few deal with the adoption of smart meters with remote control. The Danish E-flex project, that tested consumers flexibility capacity with smart meters with remote control, found that to a large extent private consumers were willing to let their heat pumps be externally regulated, and saving electricity costs was found to be an important incentive to do this together with environmental concern and interest in new technology (Dong Energy, 2012). Other studies found that participants are willing to allow remote control of their home appliances as long as this does not result in any loss of comfort (Da Silva et al., 2012) or they get sufficient savings on their electricity bill (Mah, Van der Vleuten, Hills, & Tao, 2012). However, what we do not know is who is willing to take the first step to adopt this new energy technology. To the best of our knowledge, this paper is the first attempt to identify a segment of likely early adopters of Smart Grid technology with remote control, a technology that has not been introduced to the market yet.

2 Theoretical background: consumer innovation adoption and temporal construal

Research on consumers’ adoption of sustainable energy technologies is sparse. Studies on the adoption of solar power show that potential early adopters value the environmental characteristics of solar power, but that widespread adoption is limited by long payback periods, high capital costs and perceived risks regarding the long-term performance as well as the products’ aesthetic characteristics (Faiers & Neame, 2006). Studies focusing on geothermal heat pumps found that early adoption depends on a variety of socio-economic characteristics such as income, age, household size, number of children in the family, education and gender as well as on investment

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1 In Denmark, are a number of ongoing Smart Grid projects testing Smart Grid technologies of various types. However, Smart Grid technology with remote control is not yet available on the market.
costs, environmental considerations, energy supply security, comfort considerations, aesthetics, and social reasons (for a detailed literature review see Karytsas & Theodoropoulou, 2014).

Over the years Rogers’ (2003, first edition 1962) Diffusion Innovation Theory has contributed extensively to research on adoption of innovations (Rogers, 2004). The theory suggests that a potential adopter goes through five stages when adopting an innovation: from first becoming aware of the innovation over being interested and attending to information about it and deciding to adopt or reject it, to implementing a decision to adopt and finally using the innovation on a continuous basis (Faiers & Neame, 2006).

The theory predicts that some consumers adopt innovations earlier than others as a result of differing innovativeness, defined as “the degree to which an individual is relatively earlier in adopting new ideas than other members of a system” (Rogers, 2003, p. 267), openness to change, and risk aversion. Midgley (1977, p. 49) integrates these three dimensions and define innovativeness as “the degree to which an individual makes innovation decisions independently of the communicated experience of others.”

Furthermore, the likelihood that potential adopters adopt the innovation depends on how they perceive the innovation on five dimensions (Gärling & Thøgersen, 2001): (1) relative advantage (i.e., the degree to which an innovation is perceived as being better than the idea/product it supersedes), (2) compatibility (i.e., the degree to which an innovation is consistent with the potential adopters existing values, past experience, lifestyle and needs), (3) complexity (i.e., the degree to which an innovation is perceived as relatively difficult to understand and use), (4) trialability (i.e., the degree to which an innovation can be experimented with or tried out), and (5) observability (i.e., the degree to which the outcome of the innovation is visible to others) (Rogers, 2003).
Both innovation and consumers’ characteristics have been found to be major determinants of innovation adoption (cf., Arts, Frambach, & Bijmolt, 2011). In a meta-analysis, Tornatzky and Klein (1982) found that relative advantage, complexity and compatibility have a consistent relationship to the adoption of an innovation. Arts et al. (2011) argue that it is important to distinguish between drivers of adoption intention and adoption behavior because they represent different “stages” in the innovation adoption process. They found that perceived compatibility is one of the most influential innovation attributes affecting intention. Relative advantage is the most important attribute stimulating both adoption intention and behavior, and product complexity has a positive effect on adoption intention while being an important barrier for adoption behavior. With regard to adopter characteristics Arts et al. (2011) found that consumer innovativeness has a positive effect on both intention and behavior (with a stronger effect on the latter) whereas consumer socio-demographics (such as age, education and income) have limited impact. Furthermore, consumers’ involvement in the product category has a strong effect on intention to adopt.

Research on consumers’ adoption of innovations typically does not consider consumers’ perceived time distance to the actual adoption decision, which has been found to affect their evaluation of the innovation and also the adoption decision (Arts et al., 2011). Hence, for our empirical study we draw on both diffusion of innovation theory (Rogers, 2003) and construal level theory (Liberman & Trope, 1998), which is used to get a better understanding of how different types of potential adopters assess Smart Grid technology prior to an adoption decision.

Construal level theory (Liberman & Trope, 1998; Trope & Liberman, 2003) suggests that consumers make judgments based on different levels of construal, depending on the distance they perceive to the actual decision. A person’s desire for something receives greater weight when it is in the distance (awareness stage), but when the adoption decision gets closer in time, feasibility considerations take over (Trope & Liberman, 2011). In the early stage of an innovation diffusion
process, some potential adopters intend to invest in the innovation in the near future (i.e., early adopters), while others do not (yet) have such intentions (Waarts, van Everdingen, & van Hillegersberg, 2002). When consumers intend to purchase an innovation in the distant future, they form a high-level construal, focusing on abstract benefits such as the ability to do new things they could not do before, while paying less attention to more concrete (i.e., low-level) feasibility constraints such as needing to change behavior to enjoy the benefits of the innovation (Alexander & Lynch, 2008; Trope & Liberman, 2003).

When consumers decide to buy the innovation (i.e., in the decision stage), the temporal frame changes from being a distant to a near event, as illustrated in Figure 1, which make them reflect more on concrete and context-specific considerations (Alexander & Lynch, 2008).

**Figure 1.** Consumers’ temporal construal change in the adoption decision process

For example, when consumers are asked about their intention to buy green power, they often express high interest, but when the temporal construal frame changes due to entering the stage where a purchasing decision is to be made, other considerations make the potential adopters step back from adopting green power (cf., Gangale, Mengolini, & Onyeji, 2013).

In sum, the innovation’s characteristics in terms of relative advantage, compatibility and complexity as well as the consumer’s innovativeness are most likely to affect adoption intention and
behavior. Hence, the following empirical study pays special attention to these characteristics when exploring who seem more willing than others to adopt Smart Grid technology in this early stage.

3 Methodology and data

This study includes three groups of households that differ in their adoption of sustainable energy technology. Group 1 and Group 2 heat their homes by means of a heat pump and participants in Group 1 are also “trial” adopters of Smart Grid technology (SGT) for regulating their heat pumps. Group 3 consists of households using a conventional oil-fired boiler as their heating system. In-depth interviews were conducted with 42 individuals in 24 households; these also filled in a questionnaire. Hence, a mixed method was used for this research, as recommended by Sovacool (2014). The number of households in each group is shown in Figure 2.

![Figure 2. Sample](image)

3.1 Unit of analysis

Since energy consumption in a home is a social and collective process, it is advised to focus on the household as the key unit of analysis rather than the individual consumer (Hargreaves et al., 2010). Because households living in single-family houses consume, on average, almost twice as
much electricity as apartment households (Petersen & Gram-Hanssen, 2005), meaning that their flexible capacity is larger, this study focuses specifically on consumers living in single-family houses.

The few available studies on adoption of Smart Grid technology were conducted with consumers that signed up for a Smart Grid test project. Hence, participants in those studies are not likely to be “average” but rather households with a higher than average interest in the topic or in new technology, or just in being part of something new. For this study, we recruited this type of households as well, but also households that had not signed up for a Smart Grid test project in order to get a more representative sample of households (living in single-family houses) in Denmark.

3.2 Recruitment

The Building and Dwelling Register (BBR) was used to randomly choose 107 households in the Central Jutland region with either an oil-fired boiler or a heat pump. They were contacted by phone and asked to participate in an interview. Fourteen did not have a known telephone number, 25 did not answer the phone, 44 did not want to participate, or had another type of heating system than the one registered by the BBR (i.e., neither a heat pump nor an oil-fired boiler), and 11 had a photovoltaic system. Hence, only 13 fitted the screening criteria and were willing to participate in an interview.

Households with a heat pump installed with Smart Grid technology were recruited from the participants in two Danish projects testing this kind of technology. From these projects, 17 households were contacted, of which 11 were able and willing to participate. The 24 participating households are presented in Table 1.

Table 1. Background characteristics of the participating households

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2 The READY project 10757 and the Improsume project no. 2010-I-10710
3.3 The interviews

From May to September 2013, the interviews were conducted as face-to-face in the family’s home; they lasted approximately 90 minutes and were followed by a short questionnaire. The questionnaire was used to measure problem awareness and personal characteristics (especially innovativeness (Goldsmith, 2002) and value priorities (Schwartz, 2006)) that research has found to effect early adoption of innovations (Arts et al., 2011; Jager, 2006) and pro-environmental behavior (de Groot & Steg, 2010) (see the appendix 1 for measurements). The interviews were semi-structured in-depth interviews, which enables comparisons between groups (Kjeldsen, 2010). In each interview, themes (i.e., adoption of Smart Grid technology, remote control and flexibility in using electricity, and storing energy) were presented to the households using vignettes (Grønhøj & Bech-Larsen, 2010 see examples in Appendix 2). The vignettes make it possible to examine the interviewed households’ reasoning about an issue in some detail and with a shared reference point.

Note: Throughout this paper, the ID will be used to label quotations drawn from the interviews. *DNWI=Do not wish to inform

3 Nine of the households with a heat pump with SGT filled out the questionnaire online before the interview whereas the rest of the households filled out a printed questionnaire right after the interview.
(Grønhøj & Bech-Larsen, 2010). Furthermore, the use of vignettes helps the interviewees to situate the technology in their home and to imagine what it will be like to use the technology and how it will influence their everyday life; using vignettes is thus likely to increase the ecological validity of their responses (Bryman, 2008).

The vignettes were presented orally to the interviewees, followed by questions, for example, regarding perceived advantages and disadvantages, use of the technology and willingness to be flexible in their electricity consumption.

3.4 Coding and analysis

The interviews were electronically recorded and transcribed. The analysis strategy consisted of several steps. Following an inductive -deductive approach, the interviews were coded in NVivo10 based on participants’ unique perspectives, and the codes were grounded in the actual data, known as conventional content analysis (Hsieh & Shannon, 2005). Content analysis is used to subjectively interpret the content of the data through a systematic classification process of coding aiming to identifying themes or patterns (Hsieh & Shannon, 2005; Miles, Huberman, & Saldaña, 2013). The individual cases were first coded and analyzed, followed by a cross-case comparison at the group level; the groups were defined by their heating system (i.e., heat pump with SGT, only heat pump, or oil-fired boiler). The coding process started with attribute coding, such as the interviewees’ gender, age, group affiliation, marital status and other background information. Then followed an open coding of the interviews and a systematic grouping of the open codes under themes that were relevant for the analysis using hierarchal coding (Gibbs, 2007). In practice, this means that the open codes were sorted into themes relevant for answering the research questions. Along the coding, memos were used to write down ideas for relationships between codes and a summary of the analysts’ reflections on the data from each household interviewed.
4 Results

4.1 Some characteristics of the families in the three groups

The families in all three groups scored high on Problem Awareness \(^4\) (mean scores at least 6 on a 7-point scale) and on Universalism (mean scores 4.5 on a 6-point scale) and low on Achievement (mean scores between 3 and 4). Hence, the results indicate that there are no differences between the groups as regards Problem Awareness, Universalism, and Achievement values. However, there is a significant difference (p<.05) in Innovativeness with regard to alternative energy technology between the group with a heat pump with SGT (mean score 5.4) and the oil-fired boiler group (mean score 4.04). As expected, the mean score for the heat-pump-only group (4.9) was in between the other two groups.

These results suggest that participants in all three groups are highly aware of the threats that energy consumption poses on the environment and that they value protecting the welfare of people and nature more than personal achievements. The participants’ choice of heating system reflects their innovativeness with regard to alternative energy technology.

4.2 Potential adopters’ perception of Smart Grid technology

According to the diffusion of innovation theory, the innovation adoption process starts with potential adopters becoming aware that the innovation exists. The first vignette explained what

\(^4\) Problem awareness and innovativeness were measured on a scale from totally disagree (1) to totally agree (7). Universalism and Achievement values were measured on a scale from: Not similar to me at all (1) to Exactly like me (6). For more details, see appendix 1.
Smart Grid technology is and how it works\(^5\) (see appendix 2, vignette 1). Then followed questions probing what they thought about this technology.

As expected, the participants with a heat pump with SGT had more knowledge about this technology than the other two groups. However, it was evident that even in this group, not everyone was certain about how it worked, as illustrated by this quote:

\[\ldots \text{after he [the electrician] had left, I felt a bit like … well, what do I actually need this for. And then I suddenly started to worry that he had installed something that would enable to them to turn off my heat, and that the house would be left without heating. SGT10 (male)}\]

However, knowledge and interest in Smart Grid technology was found among participants in all three groups. It appeared that it is usually a male responsibility to take care of the heating system and technology related to it. Men tended to be most interested and had most knowledge about the technology and how it worked. Some of the interviewed women expressed that they found neither the heating system nor Smart Grid technology interesting.

\[\ldots\text{I don’t find it particularly interesting. I just think the heating should work and then everything is fine. So it’s more my husband’s responsibility. SGT2 (woman)}\]

One man said that even if he thought that his wife had more technical skills than he, he was the one responsible for things related to the heat pump.

\[\ldots\text{in fact, it doesn’t make sense that I should deal with these things because in fact it’s Charlotte, who is .. She is much more technically minded than I am." SGT9 (male)}\]

However, in spite of men having most of the responsibility and knowledge, both men and women expressed that it was a joint decision to have a new heating system and technology installed.

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\(^5\) The group with heat pumps with Smart Grid technology was not presented with this vignette. Instead, they were directly asked about their expectations of the technology.
4.2.1 Perceived relative advantage

The consumers’ perceived value of an innovation is the benefits that they expect from the innovation relative to the costs of adoption (Waarts et al., 2002). In the following, the main findings regarding participants’ expected benefits and costs or disadvantages related to the adoption of Smart Grid technology are reported.

4.2.1.1 Benefits

After introducing the Smart Grid technology to the participants, they were asked what they thought were its advantages and disadvantages. The participants with a heat pump with SGT valued that Smart Grid technology gives them more insight into how their heat pump works. They use it to check that the heat pump works as it should and to control the amount of consumed hot water and electricity consumption, as expressed in this quote:

"...to check that your heat pump performs okay, I mean that you get the optimum benefit or whether you’re looking at excessive spending. Or whether I can save some money; if I save electricity, then I’ll save some money, and that’s always interesting." SGT1 (male)

The majority of households in this group (7/11) also mentioned the prospect of reducing their electricity bill. Many also expected that this technology would contribute something good to society and the environment.

Participants with a heat pump only did not expect that many advantages from Smart Grid technology. It was mainly two of the seven households in this group that talked about the advantages. These two families expected that they could save money and contribute to society and the environment.

"Well, firstly, of course, that we can save on our electricity bill, but there’s also something more overall – I want to support the use of renewable energy, and we’ll do that in this way."
Our CO2 emission will be lower by using wind power and solar energy and by being able to exploit it better. I want to be a part of that. But having said that, our primary goal, if we’re want to invest in this, is that we must be able to see some economic benefits.” HP4 (male)

Participants with an oil-fired boiler also mentioned being able to save on the electricity bill, in addition to having the newest technology on the market, as expressed in this quote:

"I imagine that if we want to replace our heat source, then we’ll want to find something up-to-date, something that can monitor the entire system, right?” OFB4 (male)

Participants in this group also mentioned contributing to society and the environment.

4.2.1.2 Disadvantages

The participants who had adopted Smart Grid technology for a trial period perceived several disadvantages of the technology, including loss of comfort in terms of too low indoor temperature and not enough hot shower water:

“...if this is going to work in a family, then you have to take into consideration that the family includes two teenagers who can easily spend 20 minutes each in the shower. So when it’s mum’s and dad’s turn to shower afterwards then there’s no hot water left and if it doesn’t resume working until two or three hours later – not good. Plus if there’s a spell of cold weather then I don’t want to enter a cold bathroom and it doesn’t switch on before the temperature is below 17° – that's not good enough.” SGT3 (male)

Other disadvantages mentioned were the risk that the utility would increase the price for a kWh (SGT9, SGT10) and an increase in electricity consumption due to the additional communication and regulation equipment, as expressed in this quote:

“who’s going to pay for the electricity that the control unit is using? My measurements tell me that the three boxes – there are two out by the heat pump and one at our Internet – and they use about 6-7 watst each, that is 20 watts, which runs into 160-170 kW per year and we’re paying about 2 DKK per kW, right” SGT6 (male)
All the interviewees in the heat-pump-only group anticipated high installation costs and also emphasized the importance of the return on investment or length of the payback period. It was unclear to them how much it would cost to install Smart Grid technology and whether the savings would cover the investment costs, as expressed in this quote:

“....I doubt that it will involve any real saving for us. It depends on how much the price of electricity is going to fluctuate; if it’s only 2 or 3 øre or 5 per kWh then it isn’t that interesting. If there were real savings in it, something with a real impact, but I doubt that is the case”HP1 (male)

Some families in this group reasoned in much detail about what it would be like to live with this technology in different situations, asking questions about how it works and what happens if it breaks down when they are away on holiday, and who would then come in to repair it?

“...it may break down or something. Like in the holidays, if it crashes or something, who’s there to ensure that it’s up and running again? And if you’re done out in that period, how is that sorted? This is what I’m thinking, with technology something is bound to happen.”HP6 (female)

Some of the families in this group had already invested in heat pump gadgets, such as a secondary meter, showing the electricity consumption of the heat pump. One family had installed their heat pump with a steering system regulating the room temperature in each room and lowering it during nighttime and when they went to work or on holiday. This family was concerned whether the two different technologies were compatible:

“I can see some negative aspects – we’ve invested heavily in geothermal heat and new ??? – if I’m to invest in something new again, which probably isn’t compatible with the other systems – that would be a downer. It’s the same as having three phones that don’t work together or having three remote controls for your TV set or stereo. An all-purpose thing would be neat.” HP7 (male)
Two thirds of the families with an oil-fired boiler mentioned the costs of adopting Smart Grid technology. One family said that they did not want to invest in a heat pump and Smart Grid technology because they thought it would be too expensive. In general, participants in this group expected a lot of extra installations, did not perceive a heat pump as a good heating system, and did not like to fully depend on electricity as a heating source, as expressed in this quote:

“I know a lot of people who have geothermal heating and in the winter time they are cold, so they have to have another energy source. Geothermal heating is not enough when it’s cold. So it’s a big investment. And there’s the control box and everything, it all runs into money. I truly don’t believe that even if the electricity is cheap that you’ll get a return on investment” OFB1 (male)

4.2.1.3 Similarities and differences across groups

When comparing the three groups, it is clear that they all expect both benefits and disadvantages from adopting Smart Grid technology. Participants in all groups mentioned the benefit of being able to save money and energy and contribute to society and the environment.

The groups differ more as to what the participants stress as being the disadvantages or risks. Participants with a heat pump with SGT tended to emphasize, more than other participants, the benefits of gaining control over the heat pump’s electricity consumption and control over their electricity consumption in general. They also focus more on the risks of comfort loss and increased electricity consumption. The technology was already installed in this group’s homes at the time of the interview so the purchase and installation costs were not an issue to them. The participants in the two other groups focused more on the costs related to adoption and use of the technology. However, some participants in the heat pump with SGT group stated that the incentives to continue the use of the technology might be too small. There was even one household (SGT11) in this group where the Smart Grid technology was not properly installed because, as the male in the family
expressed it, they could not get a contract with their utility company based on time-variable pricing. Therefore he did not see the point in buying the extra cord that was missing to properly install the Smart Grid technology.

NVIVO enables a quantification of how much participants elaborate on various aspects, such as advantages and disadvantages, by counting the number of “coding instances” that are labeled within a certain category. In NVIVO, a coding instance is the number of times text has been coded under a specific node (e.g. under the parent node advantage or disadvantage). The analysis of the average number of coding instances for each group shows that participants with a heat pump with SGT elaborate relatively more on the advantages than on the disadvantages of Smart Grid technology (see Figure 1). Participants in the two other groups talked more, and equally much about disadvantages. Of the three groups, the heat-pump-only group talked the least about benefits.

In sum, this analysis indicates that when households are ready to adopt Smart Grid technology, they tend to focus mostly on the risks and less on the potential benefits, whereas households that have already adopted it on a trial basis focus mostly on the benefits and less on risks or disadvantages.
Figure 3. Perceived advantages and disadvantages of Smart Grid technology in the three groups measured as coding instances corrected for sample size, \( N = 24 \)

4.2.2 Perceived compatibility

The adoption rate of an innovation depends on its fit with the target market (Waarts et al., 2002), that is, compatibility with the potential adopters’ needs, values, lifestyle and past experience (Arts et al., 2011; Tornatzky & Klein, 1982). To explore how participants perceived the fit of Smart Grid technology with their lifestyles and needs, they were introduced to a vignette (see appendix 2, vignette 2) explaining the need for switching off appliances in periods of high demand and two vignettes (see appendix 2, vignettes 3 and 4) with examples of how Smart Grid technology work with a heat pump and a washing machine.

All households with a heat pump with SGT were positive towards having their electricity consumption regulated by a utility company. They perceived this as something they could adapt to in their everyday lifestyle. It appears that the type of heating system is a matter of importance for this group’s willingness to have their heat pumps regulated. Seven of these families’ houses had
floor heating, and they did not expect loss in comfort because floor heating reacts slowly and the heat accumulated in a concrete floor would heat the room for quite some time if the heat pump is switched off.

Four of the 11 participants in this group (SGT7, SGT8, SGT10, SGT11) also expressed an interest in new technology, as expressed in this quote:

“But generally I find new electronic gadgets and stuff like that fascinating. That’s why I also thought it was fun having a control box fitted to the heat pump which enabled me to check our consumption and perhaps even when I was out of the house, or that I could fiddle with it even if I was not at home.” SGT10 (male)

Four of the seven households in the heat-pump-only group were positive towards having their electricity consumption regulated, expressing that their lifestyle fitted with the remote control (i.e., doing the laundry at night) and that they would regulate the consumption themselves if the utility did not do it for them. The adverse households in this group lacked trust in the utility company, as expressed in this quote:

“It starts looking a bit like banking and interests and what have we. You really have to have confidence in your utility company to leave it to them. In principle they can fleece the consumers if they want to.” HP5 (female)

Also, some families expressed reluctance to changing their laundry habits, as expressed in these quotes:

“What if they switch the thing off in the morning, say at 10, and that’s when I want to do the laundry because I’m going out later. Then I have a problem. Or perhaps it’s in the afternoon – I’ve been at work all day and when I get home I want to get three machines done before dinner – and I get can’t do that either. That would upset me, I’m telling you. There’s not so much laundry to do as before. It would really be a nuisance if I was kept from deciding when to do the laundry” HP2 (female)
“If I’ve been outside fixing something and my clothes are soiled, then I’ll toss them in the washer – let’s say at about 5. Then I’ll want to start the machine straightaway. Otherwise I would have to wait until 8. If so, we’d want a timer that would start it then. But the machine wouldn’t be done until a quarter past nine and then I’ll need to remove the clothes and hang them and you know. We might have gone out in the meantime so it would cramp our room to maneuver.” HP3 (male)

Other participants in this group (HP1, HP2) had reservations with reference to the value of being in control and having the freedom to decide when to use electricity.

Five out of the six households with an oil-fired boiler were positive towards having their electricity consumption regulated by the utility company. They believed that they could adapt their lifestyle, doing the laundry at other hours, and that it was clever to have the utility to do the regulation because doing it themselves would be time-consuming. The household (OFB1) that was opposed to Smart Grid technology did not perceive it as useful. They did not find it safe having the washing machine run at night and did not trust the utility company to regulate their consumption, and in general they did not see renewable power sources as a good alternative. Four out of the six households in this group stated that they found the technology interesting and one family said that without a doubt they would like to try it (if it was for free):

“If somebody wants to give it to us for free, then we’re game, absolutely. We’re in” OFB4 (male)

4.2.2.1 Differences and similarities across groups

All the households with a heat pump with SGT were positive towards having their electricity consumption remotely controlled, and all except one of the oil-fired boiler household. However, almost half of the families in the heat-pump-only group were opposed to having their electricity consumption remotely controlled.
In general, all groups perceived washing machines, dishwashers and especially their heating system as suitable for Smart Grid technology because it would be possible to adjust habits and lifestyles with regard to the use of these appliances. Computers and TV sets were mentioned as examples of equipment not suitable for Smart Grid technology as it is inconceivable that you would stop watching a football game just because the utility company wants to reduce electricity consumption at that point in time.

Interest in new technology was mentioned more by participants with an oil-fired boiler (4/6) compared to the other two groups (heat pump w. SGT 4/11, heat pump only 1/7). Participants with an oil-fired boiler often mentioned structural reasons for not having more sustainable technologies installed. One family (OFB2) had thought about installing solar panels on their house, but the roof faced in the wrong direction, and trees were in the way of the sun. Another family (OFB4) had thought about different alternatives to their oil-fired boiler, but was waiting for the village to decide whether district heating should be installed in all houses. A third family was renovating their house and had not gotten as far as to changing the heating system, but their plan was to have a solar heating system. Financial reasons were also mentioned for not yet having invested in any kind of sustainable energy technology.

4.2.3 Perceived complexity

An innovation’s complexity has been found to be an important barrier for adoption (Arts et al., 2011). With regard to Smart Grid technology, the complexity relates to the product itself as well as to the use of the technology (i.e., having appliances remotely controlled by the technology).

The families with a heat pump with SGT found it difficult to grasp how the setting of the minimum temperature worked and how Smart Grid technology would operate with a washing machine (for instance, when the washing machine would be switched off). Some of these families
found it difficult to understand how the remote control would work in practice, who would be in charge of the remote control, and for how long the appliances would be switched off. Mainly they were uncertain about how it would affect their heat lacked information about how to overrule the remote control.

Some of the families in the heat-pump-only group did not understand the need to be remotely controlled and they were also uncertain about how that would be done in reality and for how long, about which appliances could be connected to Smart Grid technology, how it worked with fluctuating prices of electricity, and how that was linked to the demand for electricity. Some were also uncertain about how the heat pump’s production of hot water would be affected, whether they would need a buffer tank to allow regulation of their heat pump’s electricity consumption, how their heat pump was switched off, and when the remote control would take place. How to overrule the remote control was also an issue.

The families with an oil-fired boiler were mostly uncertain about why they should be remotely controlled, how that would happen in practice and how the technology functioned connected to a washing machine. Some families in this group also had questions about the technicalities of the signals being sent via the Internet to the Smart Grid technology.

4.2.3.1 Similarities and differences across groups

Across groups, families perceive several uncertainties and difficulties when trying to picture themselves adopting and using Smart Grid technology in their everyday lives. The complexity also made the participants in the two groups with no Smart Grid technology experience (i.e. the families with a heat-pump-only or an oil-fired boiler) uncertain about why they should have their electricity consumption remotely controlled. Participants with a heat pump with SGT mainly had questions about details such as how to set the minimum temperature, how Smart Grid technology works with
the washing machine, and the information it provides. The quantitative analysis of coded instances of expressions of complexity shows that the least uncertainty is expressed by those who have experience with the technology (i.e., the heat pump with SGT group) and those whose heating system is not yet ready for Smart Grid technology (the oil-fired boiler group) whereas the most inquisitive group as regards the technology and its use is the one that is ready for it but which has no experience (the heat pump only group; see Figure 3).

![Figure 3](image)

**Figure 3.** Perceived complexity of Smart Grid technology in the three groups measured as coding instances corrected for sample size, N = 24

5 Discussion

Early adopters are crucial for the further diffusion of an innovation (Rogers, 2003). Hence, knowledge about who are more willing than others to adopt an innovation in the early stage is valuable to producers and marketers. Furthermore, understanding why some consumers are more willing than others is useful when trying to convince potential adopters. This study has contributed
insight by showing that not all potential Smart Grid technology adopters are equally willing and by suggesting why this is likely to be the case.

As expected, this study suggests that households that have a heat pump and that have adopted Smart Grid technology on a trial basis are more willing than others to adopt Smart Grid technology. According to innovation diffusion theory, these consumers have reached the “confirmation stage” of the innovation adoption process and will either continue towards full adoption or reject the innovation after the trial period. According to construal level theory, the fact that the households perceive the adoption decision as an imminent one makes them focus on concrete details related to the technology adoption. Consistent with this prediction, they mentioned potential risks, such as loss of comfort, and details about how the technology works (e.g., the setting of a minimum temperature). However, due to their trial experience, they focus more on benefits than on disadvantages, perceiving a higher level of relative advantage than participants with no experience. This also indicates that they have overcome some of the obstacles perceived by other segments, such as investment costs and not understanding why remote control is necessary. They may also have gained new insights as to the private benefits of Smart Grid technology, for example, useful knowledge about their heat pump’s electricity consumption and function. Prior research found that many consumers find heat pumps difficult to grasp and operate (Antropologerna.com, 2012). Smart Grid technology gives these consumers a tool to better understand their heating system. Hence, trial might reduce their perceived uncertainty and the complexity of the innovation.

The participants with an oil-fired boiler appear to perceive Smart Grid technology as relatively more advantageous and less complex than participants with a heat-pump-only. This is also in line with construal level theory. It can be assumed that families with an oil-fired boiler perceive the decision about adopting Smart Grid technology to be an event in the distant future whereas the families with a heat pump only are ready to adopt (because of the heat pump) and
therefore perceive the adoption decision to be imminent. According to construal level theory, families with an oil-fired boiler focus more on the benefits and rate the compatibility higher exactly because they are further away from the actual adoption decision, whereas families with a heat pump focus more on the concrete consideration and risks because they are ready to make the final decision.

5.1 Limitations

Smart Grid technology as defined here can be classified as a really new innovation because there is no similar product on the private consumer market. Hence, when interpreting the findings of this study, one must keep in mind that when an innovation is really new, it is difficult for consumers to judge its usefulness (Alexander & Lynch, 2008). This adds an unknown amount of uncertainty and randomness to information and judgments provided by participants. Possibly the interviewer may affect participants’ judgments more in an interview conducted in an early stage of an innovation’s diffusion process due to lack of personal experience with the innovation. However, the use of a semi-structural interview guide and vignettes reduces the possible variation in interviewer influence across participants.

5.2 Conclusions and implications

The objective of this study was to explore consumer willingness to adopt Smart Grid technology in the early stage of its diffusion. This was achieved by comparing three groups of households that vary in their adoption of sustainable energy technology: (1) Households with a heat pump and Smart Grid technology, (2) households with a heat-pump-only, and (3) households with an oil-fired boiler. Besides their adoption of sustainable energy technology, these three groups of households do not differ significantly on their background characteristics (Table 1).

The results show that the families in the three groups perceive the technology’s characteristics differently. The families with a heat pump with SGT appear to perceive the technology as having
higher relative advantages and as being less complex, and they seem more willing to have their electricity consumption remotely controlled than the two other groups. Families with a heat pump only are the most hesitant of the three groups. The families with heat pump with SGT also have the highest level of energy technology innovativeness of the three groups and the families with a conventional oil-fired boiler the lowest.

For companies and organizations promoting Smart Grid technology to private households, the study suggests a segmentation of potential adopters in terms of both structural and personality characteristics. It is relatively easy to identify the households whose structural characteristics make them most “Smart Grid ready”. These would include households with a heating system or other equipment with a high electricity consumption and service flexibility, such as a heat pump. In terms of personality, the study shows that it is indeed possible to identify the consumers with the highest willingness to try the new technology using a well-established instrument to measure domain-specific innovativeness. By combining these structural and personality characteristics, it is possible to identify a well-defined target segment for promotion campaigns in the early stage of the development of the Smart Grid technology market.

For the next stage, focus should be on those that are structurally ready but less innovative, in this study represented by families with a heat-pump-only. From innovation diffusion research we know that this group is influenced by the earliest adopters, both as regards advice (in the close network) and, more importantly, in terms of demonstration and “vicarious learning” (Bandura, 1977). The current study also shows that this group would benefit from more information and from a possibility to experiment with the technology; this would enhance their readiness because it would help them understand the technology (cf., Arts et al., 2011).
Acknowledgements

We gratefully acknowledge funding from Energinet.dk for the realization of the READY project (no. 10757) and the Improsume project (no. 2010-1-10710) in which this research has been conducted.

References


QSR International Pty Ltd (Producer). (2012). NVivo qualitative data analysis software, version 10


Appendix 1. Questionnaire measurements

Domain-specific innovativeness (Goldsmith, 2002)

1. Compared to the people I know, I have invested more in alternative energy
2. In general I am the last one in my social circle to invest in alternative energy
3. In general I am among the first one in my social circle to acquaint myself with alternative energy technology
4. When I hear about new alternative energy technology, I’m interested in finding out whether it’s my sort of thing
5. I know about new types of alternative energy before others do

Strongly agree - 7. Strongly disagree

Problem awareness (de Groot & Steg, 2010)

1. The use of electricity based on coal, oil and natural gas creates problems for society
2. By having a smart meter with remote control in my home, I can help balance the supply and demand of electricity.
3. If more electricity is used in off-peak periods rather than in peak periods, it will benefit the environment.

Strongly agree - 7. Strongly disagree

Basic human values (Schwartz, 2006), males received a version with “him”, females received a version with “her”

1. He believes that it is important that everybody is treated equally. He wants justice for all, even for people he does not know. (Universalism_humans)
2. It is important for him to listen to people who are different. Even when he disagrees with them, he wants to understand them (Universalism_humans)
3. He believes that it is very important to prevent the polluting of nature (Universalism_environment)
4. He has it at heart that you should protect nature. It is important to him to take care of the environment (Universalism_environment)
5. It is very important to him to demonstrate what he is capable of. He likes that people admire what he does (Achievement)
6. It is very important to him to be successful. He likes to impress (Achievement)

Not similar to me at all (1) to Exactly like me (6).
Appendix 2. Vignettes

Vignette 1

In this interview I would like to describe some situations that may arise in a family in connection with the development of an intelligent energy system that Denmark is working on. The family I want to depict is a fictitious family consisting of dad (Søren), mum (Helle) and their two children, Christian and Freja aged 16 and 10 respectively.

The family’s heat pump has been fitted with an automatic control device – a so-called smart meter with remote control. Energy consumption of the heat pump is regulated by means of signals that the smart meter receives from the Internet. The utility company sends out a signal when it is time to lower the energy consumptions. In future the price of electricity will fluctuate round the clock according to the force of the wind and the general situation of the power system.

The smart meter with remote control ensures that the heat pump is working mainly in off-peak periods and when prices are low, e.g. when it is windy or at night. It switches off the heat pump when it is important to reduce energy consumption when the price of electricity is high. The household defines the minimum temperature they want in their house, meaning that the remote control device only switches off the heat pump if the temperature keeps above the fixed minimum temperature. If the temperature drops below the minimum temperature, the heat pump is activated no matter what.

Example: Søren and Helle have set the minimum temperature at 19°C. So if the temperature is 21°C and the electricity price is high, a signal is triggering that it is important to reduce energy consumption, then the heat pump will switch off automatically. It will resume working when the price drops or the temperature falls below 19°C.
Having an smart meter with remote control installed on to their heat pump allows the family to keep abreast of the energy consumption of the heat pump in kWh and DKK on a homepage or a smartphone. Both the costs and the saving derived from the optimized heat pump are shown.

Vignette 2

Søren and Helle have allowed their utility company to monitor their high-electricity appliances, e.g. the heat pump [the participants were shown an example of a homepage illustrating how the family could allow the utility company to remotely control the electricity consumption of the heat pump by checking a box stating: Optimize my electricity consumption. I wish to have my heat pump be optimized so that its electricity consumption will be reduced for short periods when the electricity price is high.]

This implies that the utility company can switch off the heat pump when it is important to reduce electricity consumption. The household can cancel the utility company’s remote control if they need to heat the house at a certain point (e.g. when having guests).

Vignette 3

In the morning, when the family is having breakfast there may be only 19°C, i.e. to or three degrees colder that during the day. Freja is not quite awake yet – she’s still in her nightie and she’s feeling cold.

Freja asks “Can’t we turn up the heat?”

Freja’s dad (Søren) “Sure we can”

Freja’s mum Helle does not agree “No, I don’t think we should. Electricity is expense right now. Go and get dressed instead.”
Vignette 4

Helle has come home from work. She starts filling the washer while Søren does the cooking. She fills the washing machine and pushes the start button, but nothing happens. The display tells her that the machine will start at 22:00 when the capacity on the power system allows it.

Helle wants to hang their clothes to dry before going to bed so she pushes the ignore-button and the washing machine starts.

Later she thinks that she perhaps could have postponed washing her laundry.