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Smart grid and households: How are household consumers represented in experimental projects?

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1. Introduction

This paper investigates how smart grid experimental projects in Denmark envision the future role of the private consumers in the energy system. The smart grid development in Denmark can be characterised as compound where several diverse actors are trying to shape the future of the energy system (Nyborg & Røpke, 2011). There are many visions of the content of a future smart grid. An active role of the users of electricity is a central difference between the current electricity system and the future smart grid. Analyses have shown that users are currently getting increasing attention in smart grid projects (Verbong, Beemsterboer, & Sengers, 2013, Hansen & Borup 2014).

Denmark is the fifth most spending country in Europe on smart grids projects. It stands for around 10% of the total investments. If one considers the spending relative to the population size of the countries, Denmark also stands out: It is the country investing the most per capita (Giordano et al., 2013). In our study we identify eleven Danish experimental projects with users and analyse how the projects understand and learn about the users. As part of this, we identify what types of technologies (in contact with the users) that are investigated in the projects.

Within the general analysis framework of Strategic Niche Management (SNM), learning in demonstration projects has been pointed out as crucial for development and diffusion of new innovations (Kemp, Schot, & Hoogma, 1998, Raven, 2010). Especially they are valuable for technologies where there are great challenges of getting several components and actors to function together, as is the case in energy technologies. The learning processes in demonstration projects pave the way for the technology by preparing it to social context and applying technological adjustments. A good learning process has been suggested to be: Firstly wide-ranging and including configuration between social aspects (such as cultural meaning and user preferences) and technical aspects (such as infrastructure and technical specifications); not only focusing on techno-economic aspects and validation. Secondly a good learning process includes second-order learning[1] and is willing to change direction if the technology does not match underlying

[1] Happens when basic assumptions and values relating to the project become subject of learning (Van Mierlo, 2012)

assumptions e.g. of social values (van der Laak, Raven, & Verbong, 2007). To explore for the alignment between social and technical aspects we in our analysis investigate if the projects study the behaviour and everyday lives of the users in relation to the technology. Several scholars have earlier suggested paying more attention to the everyday life of the users in the energy area/projects, e.g. (Gram-Hanssen, 2008). To trace second-order learning we investigate the available material for discussions of the set assumptions and values of the project.

2. Methodology

The process of identifying relevant smart grid studies and projects has been interactive, with the following main steps:

1. Database search and creation of an initial gross list of potentially relevant projects.
2. Initial analysis of project material – decisions on inclusion or exclusion of the individual projects.
3. Additional search of projects through e.g. consulting of selected researchers and experts, simple online Google search and search on homepages of expertise networks, public authorities, etc. (Steps 2 and 3 are repeated.)

Several databases and sources were used in the process. The main sources were:

- The project catalogue published by Energinet.dk and Danish Energy Association (Energinet.dk & Danskenergi, 2011)
- The smart grid database by the European Commission’s Joint Research Centre (see Giordano et al., 2011, Giordano et al., 2013 and ses.jrc.ec.europa.eu)
- The EU Cordis database (cordis.europa.eu)
- The project catalogue established by the International Energy Agency’s smart-grid implementing agreement (ISGAN & IEA, 2013a, ISGAN & IEA, 2013b). (No Danish projects found here).

With the chosen method approach, the survey can be considered to be well-covering concerning studies and projects that have received public support and funding from national and international programmes. Through the searches, a gross list of 43 was found. The final list of projects consists of 12 from Denmark.

3. User aspects addressed in the projects

Table 1 shows which aspects of the interaction between the user and the smart grid technology that are investigated in the individual projects. Four main categories are used for this (column 3 - 6). The first category, 'Behaviour and everyday life', is the most broad and general. It can include a number of different aspects e.g. utility, comfort, patterns of use in practice, energy saving efforts, etc. The categories 'Economic incentives', 'Automation' and 'Feedback/visualization' are more specific and relatively narrow. The last column 'Technology' shows which specific technology areas that are addressed in the individual projects. The findings are described further after the table.

	Project title	Behaviour and everyday life	Economic incentives	Auto-mation	Feedback/visualization	Technology
DK	Automation systems for Demand Response	-	X	X	X	Automation; electrical heating.
DK	Charge stands[2]	X	X	-	-	EV's; charge stands
DK	Demand as Frequency controlled Reserve	-	-	X	-	Automation (to control individual loads)
DK	ECOGRID-EU	-	X	X	X	RT-signals; consumption visualization; automatic control
DK	EDISON	-	-	X	-	EV's and charging functionalities
DK	Energy Forecast	X	X	-	X	Energy forecast; Indication of electricity price
DK	From wind power to heat pumps	-	-	X	-	Automatic control of heat pump; data collection; measure consumption
DK	IFIV[3]	-	X	X	-	Heat pumps; automation; sensors
DK	Prøv1elbil	X	X	-	-	EV's
DK	Test-en-elbil (ChooseCom)	X	-	-	-	Charging; EV's
DK	The e-Flex Project	X	X	X	X	Heat pumps; automation; consumption visualization

Table 1 User aspects addressed in the projects. The table shows: 1) if the projects include an investigation of the everyday lives of the user in relation to the new smart grid technology (column 3). 2) The initiatives used in the projects to change the user's consumption of energy (column 4, 5, 6). 3) The main smart grid technologies and concepts in the projects (column 7).

The category 'Behaviour and everyday life' in table 3 covers an investigation of, if/how the projects incorporate a study of the new smart grid technology, in relation to the everyday life of the users. Smart grid technologies impose changes in the energy consumption in the households. Since energy consumption is related to everyday practises, an implementation of smart grid technologies in the households will have an effect upon the user's everyday lives and routines. For example, there are differences in the everyday routines when driving an electric vehicle compared to an internal combustion engine vehicle. Likewise, homes equipped with smart grid technology have an effect upon the people that occupy them.

The categories 'Economic incentives'; 'Automation'; and 'Feedback/visualization' cover the types of concepts applied in the projects to investigate or change the users' consumption of energy. The category 'Economic incentives' includes different types of pricing initiatives, typically different types of dynamic pricing (price consisting of: spot-price and dynamic net tariff; or real time pricing). The category 'Automation' shows if the projects included automation of equipment in order to change the user's

[2] Subproject of 'test-en-elbil'

[3] Short for: Intelligent remote control of individual heat pumps

consumption. For example, in connection to use of electric vehicles, the automation category covers automatic charging of the vehicle, the relationship between the users plugging in the car when arriving at home and when the charging occurs (when circumstances are right; according to stability of the grid, price of electricity, etc.). In similar ways automation can also cover control of heat pumps and water boilers.

The category 'Feedback/visualization' shows if the projects include feedback and/or visualization to the users of the energy consumption; peak periods; or price signals between the energy supplier and the household user. The category hence covers by which methods the energy consumption; peak periods or price signals are communicated. The methods are e.g. peak periods; in-home display; different PC and email methods.

3.1 Behaviour and everyday life

Table 2 shows that five out of the total eleven projects include investigation of the user's everyday life and practices related to the new technology.

Some projects had a strong focus of how new technology affected the daily lives of the participants. Among these was the 'eFlex project'. The 'eFlex project' investigated the changes in the user's lives that the home automation system caused. The investigation was conducted by anthropologists. This approach gave a different view where the users and the social configuration became equally important in the learning process as the technical set-up. The domestication process of the new technology, i.e. how the new 'wild, unknown' technology gets 'tamed' by the families was studied in diverse families and provided with information of how the families behave differently when using the technologies. Among the dimensions investigated in the 'e-flex project' are economic concerns and environmental concerns of users in their smart grid interaction.

Three out of the four projects including electric cars paid focus on how the new technology fit into the users' everyday lives. The project 'Charge Stands' used an analytical framework to specifically understand the change in social practices in everyday life. The project focused on how the electric cars fit into the participants' daily lives in terms of flexibility, freedom, spontaneity and confidence. The project 'Prøv1elbil' explored the attitude towards electric cars in families, and if electric cars can fit into the everyday lives of the families. In this connection the project investigated what aspects of electric cars were perceived positive or negative (compared to a combustion engine car) in the families. The project 'Test-en-elbil' is a project building on 'Prøv1elbil' and has continued investigating the everyday settings around the electric vehicles and the users. 'Test-en-elbil' investigated how frequent the users prefer charging stations to be available. Furthermore the project has explored how safety issues in electric cars affect the users, and how the non-existence of noise in the electric cars affects the drivers' behaviour in traffic. Also the project investigated how the usage of an electric vehicle can affect the overall consideration for the environment and energy consumption.

3.1.1 Project conclusions about behaviour and everyday life

The anthropologists participating in the 'eFlex project' concluded that the users could be divided into the five following groups in relation to their interaction with the technology: The technician, the economist, the curious, the sympathetic, and the comfortable. Because of the differences between the users, the needs and wishes (in relation to the concept, design and communication) varied. The anthropologists concluded that demand response is related to lives that are being lived within private homes. Demand response thus is about getting people to change their habits and routines. They also concluded that electricity is used to create life in the homes. Electricity is used on necessities (cooking, heating etc.) and luxurious lifestyle (hobbies, social life) practises. The participants were mostly willing to change the consumption practises related to necessities opposed to the consumption related to social events or hobbies. The project found that the new technology changed the roles within the families, and concluded that if the willingness towards such technology is to be advanced, then the diversity of the users should be included in the technological set-up.

The project 'Charge Stands' concluded that electric cars are not easily integrated into the social practises of the user's everyday lives. Some core values within the families were not fulfilled by the new technology. Especially there were the notions of flexibility, freedom, spontaneity, and confidence within the users' values that were not fulfilled. Tests from the project 'Prøv1elbil' showed that electric cars can replace a traditional car in average Danish families' everyday life; and with the exciting charging infrastructure electric cars can be included in most two-car families as car number two. This conclusion supports the conclusion from 'Charge Stands' of not fulfilling all the functions and values that the families wish for in a car. The project 'Test-en-elbil' showed that drivers of electric vehicles believe that an increase number of charging stations will affect the distances that they drive and that this distance will mostly occur in holidays. The project stated that the electric cars can easily cover the needs of the families and that the desire for more charging stations is an expression of a desire that is not founded in real needs. Furthermore the project concluded that a great deal of the participants is more focused on their energy consumption after participating in the project. Furthermore a majority became more environmental friendly by participating in the project.

The project 'Energy Forecast' concluded that the SEE1 (small box indicating electricity price level) combined with a spot contract resulted in an increased interest in energy consumption. The SEE1 had a strong impact on the awareness of the electricity prices in the households and resulted in a reduction of their energy consumption by moving electric loads to hours less expensive. The project caused a considerably increased knowledge about the electricity system among the participants. Although the knowledge level was increased, only the group receiving a spot-contract had an increased interest in demand response.

3.2 Economic incentives

Out of the total eleven projects seven projects include different types of economic initiatives to change the users' consumption of energy. The economic incentives were specifically found in the realisation of demand response through dynamic pricing. The concept of dynamic pricing can be linked to the perception of the user as being 'price oriented' since it implies that the users need 'economic compensation' for adjusting his/her consumption.

Of the projects viewing the user as 'price oriented' most of them applied dynamic pricing to all the included households, suggesting an assumption of dynamic pricing to be a generally acknowledged concept in connection to smart grid. Only one project, 'Energy Forecast', tested if the concept of dynamic pricing was beneficial at all. Here 100 (out of 558) participants were given a spot contract. All the projects that included dynamic pricing (except 'Charge stands' and 'Prøv1elbil') also included an increased visualisation of the electricity consumption within the home. The user should consider electricity as something with a variable price and be aware of the consumption level of the household.

The 'ECOGRID-EU project' was focusing on real time pricing. The users within the 'ECOGRID-EU project' will get a signal with the price of electricity 5 minutes before it occurs. Within the real time pricing projects, the users will not know in advanced what the price of electricity will be. In the projects that base the price partly on the NordPools spot market the user has the possibility to know the price the day ahead of occurrence.

3.2.1 Project conclusions about Economic incentives

The 'eFlex project' concluded that the users' participation and motivation for demand response was not connected merely to economic incentives. The participant's economical rationales were complex and diverse. The users had a wish to avoid waste of energy but also had a wish to behave as social norms detect (wanted to do what is perceived as normal, reasonable actions). The project 'Charge Stands concluded that encouraging the participants to charge in off-peak periods (when the price also is cheapest) was not enough. The greatest savings were achieved in the cases where the charging was done intelligently.

3.3 Automation

Within the projects that include dynamic pricing there is a focus on including automation equipment. The automation equipment has in several projects been set up reacting on price signals and turning electric devises on/off according to the signal. Within the projects reviewed in this report seven of the total eleven projects included automation equipment. Of the seven projects including automation four projects automated on the basis of price signals. The remaining projects did not include price signals and focused on the state of power system. The participants in these projects were expected to let the automation equipment control their appliances in order to achieve a better functioning power system.

The project 'Automation systems for Demand Response' included an automation box that reacted according to the electricity price. Similarly the 'eFlex project' contained a control unit that would prevent the heat pumps in the households from operating during peak periods. The 'ECOGRID-EU project' declares that automation together with customer choice is a key feature in the concept. The project is comparing 4 groups of users with different types of load control technologies available. 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. Among other things the difference between the two last groups lies in the presence of an aggregator controlling the units remotely in one group; in the other group there is no aggregator.

Within above listed projects the users have the possibility to enter specific settings in to the installed automation equipment. In the following period the automation equipment would turn on/off and optimize the energy consumption according to the settings. In this case the users would passively get an economic benefit. The user would have an incentive to not be in charge of their energy consumption but to leave out the daily practices of turning the heat on/off. If the user was not satisfied with the indoor temperature for example, the settings could be changed. However this did not seem to be a daily practice.

3.3.1 Project conclusions about Automation

The project 'Automation systems for Demand Response' which, mainly focused on the technological ability to move the consumption, concluded that information on energy prices alone did not have any effect on moving consumption. The users that had installed automation equipment had clearly moved consumption.

Furthermore the project concluded that there is potential for activating the electricity users in order to move their consumption by means of variable prices. The ‘eFlex project’ reached a quite similar conclusion in relation to the users’ willingness to let others control their heat pumps. The project concluded that given the right incentives the users were willing to let their heat pumps be controlled externally. The project showed that flexibility could be achieved without giving up comfort levels.

3.4 Feedback and visualization

4 projects include types of consumption feedback or visualisation of peak periods. The users in the ‘eFlex project’ had a home automation portal installed on their premises. The home automation system allowed the participants to change the settings related to their heat pumps and electric vehicles. Furthermore the system allowed closely monitoring of the electric devices that were attached with smart plugs. The participants were on the one hand eliminated in relation to the direct (everyday) control of certain energy consuming devices (heat pumps and charging of electric vehicles) and on the other hand made aware of their consumption of other appliances.

All of the 4 projects included visualization of price. The projects however contained different types of price feedback. In the project ‘Automation systems for Demand Response’ a comparison between automatic control and price feedback was conducted. One group got feedback/messages that indicated the variation of the electricity price (spot price). The feedback was delivered by e-mail or text message. This group was compared to another group where the electrical heating was automatically controlled. This project tested if the user would react upon dynamic pricing. The project ‘Energy Forecast’ that visualized the coming 36 hours of energy spot market prices to the participants. The energy forecast was visualised on a website, on TV and in a 100 households a box was implemented. The box indicates the relative electricity price using tree different colours.

Other projects included visualization of electricity price as part of a larger project set up. For example within the ‘eFlex project’ PODIO (social platform) was used to inform of electricity prices along with other functions. This is also the case for the ‘ECOGRID-EU project’ that includes price visualization at different levels.

The ‘ECOGRID-EU project’ includes 4 different types of visualisation (different in each group). In the first group the households receive only a smart meter (no consumption visualisation or electricity prices). In the three remaining groups the households receive equipment that visualises the electricity consumption and price. One group will receive simple marked price information, while the two remaining groups will receive advanced home automation and visualisation equipment. The home automation system contains a central unit with display where settings may be adjusted. These (two) groups will also receive thermostats visualising different settings in the house that can be changed according to the participant's wishes. The users are thus capable of interfering with the remote control of their heating devises if they are not comfortable.

3.4.1 Project conclusions about feedback and visualization

From the projects that included both 'automated control of appliances' and 'consumption visualisation', the results were that the visualisation equipment had an effect on the awareness of energy consumption. The households thus in general were more aware of how much energy they used when they were presented to their consumption on different visualisation equipment.

The 'eFlex project' concluded that the home automation equipment in the project functioned as a 'mediator' between the abstract 'electrical world' and the real world. Through the equipment the users could learn and understand their consumption. The home automation equipment advanced the willingness towards demand response among the users.

4. Concluding remarks

The investigation of learning processes in the projects showed that five out of eleven projects included investigation of the user's behaviour and everyday life in relation to the new technology. Thus around half of the projects investigated the alignment between the social and technical aspects. Three out of four projects investigating electric vehicles and intelligent charging included research on the behavioural patterns and everyday lives of the participants. Thus they seemed more aware of the inclusion of social aspects than the other projects.

Moreover, we explored the elements of economic incentives, automation, and feedback addressed in the projects. The results showed that around half of the projects included economic incentives in form of dynamic pricing in the project set-up (often in combination with automation aspects). Around half of the projects included automation equipment. There is a tendency to consider the user as economic oriented among the projects. However also other aspects as the interaction with the technical equipment, environmental concerns and energy saving behaviour are addressed in some projects.

In the visualisation section we found that four projects included visualisation of consumption and electricity price. Although automation of devices or remote control appeared in seven projects none of the projects included investigation of visualisation of the subject or an investigation of how the users are to 'allow' flexibility. This entails speculations of the future of the user in relation to remote control of electrical products. One possible option is that users may become increasing passive and let the aggregators or energy companies control their loads. Another possibility is that remote control will be warned or visualized in the households.

The projects seem to conclude on if the projects succeed in changing the consumption of the consumers so that they save money. Energy conservation does not seem to be a goal in the projects although some investigate if the experience in using the new technology enhances the users to be more environmental conscious.

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