Exploring Emerging Customer Needs for Smart Grid Applications

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Abstract-- Customer needs considering new smart grid technologies do not pre-exist but emerge in the markets. This paper identifies and engages lead users in service development based on possibilities created by smart grids. We explore how small-scale customers can become active players in electricity markets and create benefit through smart grid applications. Our paper presents an empirical model for identifying lead users in markets and create added value through smart grid applications. We present first results from lead user focus groups and our preliminary conclusions highlight opportunities for developing successful service offerings based on smart grid applications.

Index Terms--- smart grids, applications, smart metering, services, lead users, customers, electricity

I. INTRODUCTION

HERE is extensive research and development on the technical potential of smart grid applications. In contrast, there is limited research on how such applications could create customer value and form the basis for useful and desirable services [1]. Most of the service concepts are still in a testing or pilot phase, and most relate only to smart meters or dynamic pricing.

However, the visions based on smart grid applications extend much further than current applications. Smart grids are expected to accelerate the development of services for small-scale feed-in of distributed electricity production, enhance customer self-sufficiency in electricity, increase use of home automation and smart home applications, increase storage of electricity e.g. in the batteries of electric cars and improve load management through dynamic pricing. Following increasing regulatory requirements for energy providers to reduce their customers’ energy consumption [2], there is also a pronounced interest in the industry to develop new services for energy conservation, load shifting and effective monitoring of electricity consumption.

The paper offers insights from the context of a country that has made rapid progress in smart grid deployment. By 2013, 80% of Finnish households will have automatic meter reading installed, and the industry is eager to develop new services based on the capabilities of the smart grid. This paper is based on a research project called Customer value from smart grids. It is coordinated by the Finnish Energy Industries and funded by the Pool for Electricity Research and Tekes – the Finnish Funding Agency for Technology and Innovation.

The aim of the project is to explore whether and how some small-scale customers can become active players in electricity markets and create added value through smart grid applications. The project aims to develop guidelines for electricity companies to communicate with customers, explore customer needs and co-create new services that provide added value for several parties in the value chain.

Customer value from smart grids is a highly prospective project. Customer needs do not pre-exist – rather, they emerge in the interaction between new technologies and social and market environments [3], [4]. Anticipating and proactively shaping such needs requires that customers would be engaged in a co-creation process. This is problematic because electricity is something of a “non-product” for most customers – it is invisible, not actively consumed and there is limited product differentiation [5]. Our project aims to overcome these problems by identifying and engaging lead users – i.e., customers with needs and capacities that are ahead of the market trend. We also examine customer-provider interaction in early stages of smart grid service development by evaluating existing pilots from the customer experience perspective.

Our paper presents first steps in exploring how small-scale customers can become active players in electricity markets and create added value through smart grid applications. We do so by involving lead users in service development. In particular, we present the theoretical basis for anticipating and co-creating value-added services for emerging technologies in the second chapter of this paper. In the third section, we provide a detailed account and justification for the data and methods used for exploring emerging customer needs.

In the fourth section, we present the results of our empirical research identifying lead users based on a survey. We present the characteristic subpopulations where lead users could be found for the development and first application of smart grid services. Moreover, we present our first results from lead-user focus groups. In the final section, our preliminary conclusions highlight opportunities and barriers for developing successful service offerings based on smart grid applications.

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II. THEORETICAL FRAMEWORK

Customer value from smart grids is executed within a framework of lead user theory, developed by Eric von Hippel [6]. Lead user theory focuses on a process of innovation made by users instead of manufacturers. It explains how user-centric innovations provide complements to industrial innovations.

Per definition lead users are “users who are ahead of the majority of users in their populations with respect to an important market trend, and they expect to gain relatively high benefits from a solution to the needs they have encountered” [6]. This approach was chosen because studies show that many innovations developed by lead users are ahead of the markets and in the case of smart grid services, there are hardly any markets yet.

This research is based on an assumption that in the absence of existing services in the market lead users may already have needs and ideas of services enabled by the new smart grid technologies that are not yet known to the average users in the market and who might act as early adopters of services. In addition, whenever the situation in the market of some product or service changes or evolves, there will always be lead users [7]. Further, the innovations from lead users are often commercially attractive and manufactures have commercialized them because they result from a real-world experience, which is the reason for their success. Lead users have more accurate and more detailed information of their specific needs than manufacturers [8], [6] and they develop innovations that are functionally new and are based mainly on use-context and user-need information [9], [6]. There are several studies where the lead user theory was successfully employed, for example in the development of pipe hangers [8] and electronic home banking services [10]. According to empirical studies, 10 to 40 percent of users engage in developing or modifying products according to their specific needs [5]. Thus, there is a great potential in these innovators for the development of future products and services in the smart grids.

In this project and in theory, the lead user innovation process should be organized in following steps: Step 1: Identification of important trends in the market; Step 2: Identification of lead users and Step 3: Lead user product-concept development [8], [11]. Step 4: Testing whether lead user concepts appeal to average users will be organized by the industry and is not a part of the present study.

III. DATA AND METHODS

There are two basic approaches for involving customers in early stages of product and service development. One involves immersing designers in the users’ world – i.e., designers visit the users at home or at work and employ ethnographic methods, empathic design or contextual design to learn about the users’ context and requirements [12]-[14]. The other entails bringing the users into the world of designers by involving them in co-design or participatory design [15]-[17]. The present study uses both approaches, since smart grid applications are a particularly challenging topic for user involvement.

Smart grid applications are challenging for a number of reasons:

- They are very technology-centred for an average customer and the main link between the various services is the two-way digital communication offered by the smart electrical grid enabled by hourly meters. From the customers’ perspective, the link between, for example, electrical car batteries, PV panels and smart meters is not obvious – nor is the fact that e.g. improved insulation is not a smart grid application.
- Electricity itself is an invisible and ‘infrastructural’ service that does not offer direct benefits to customers; benefits arise from using electricity in various appliances. Moreover, customers’ own capabilities and experience with electricity are limited by the fact that customers cannot configure their electricity systems at home due to safety regulations.
- The expected user context is partly different from currently existing user contexts. Many applications assume other products and technologies that are not yet readily available or at least not widely used (electric cars, smart homes, PV panels). Hence, users need to cast themselves into an imaginary future world in order to even envisage what their requirements for the related services could be.

Our study attempts to surmount these problems by (1) building on existing experiences from ongoing pilots and by (2) identifying and engaging lead users. Our data consist of interviews with managers and customers in pilot projects testing early smart grid applications, a survey to identify various types of lead users as well as focus groups (with some lead-user workshop elements) with identified lead users.

Workshops with experts and service providers in the field (step 1): These are used to establish the main trends in smart grid development and the development of related services. Based on the first workshop and expert interviews, we have identified 7 service concepts/use scenarios for further testing and development together with customers.

Interviews with project managers and customers of pilot projects (step 1): Early user experiences in smart grid applications such as smart meters, online billing feedback reports and dynamic pricing are collected via interviews with managers of such projects and, where possible, customers. Particular aspects of interest are: which types of marketing and offerings are perceived of as acceptable by customers, how interaction between service providers and customers is experienced, and how satisfied customers are with the service at various key ‘touch points’ of the service experience. Our interviews with pilot project managers and participants are ongoing at present, and hence the results are not reported here.

Surveys to identify lead users (step 2): The identification of lead users is one of the main questions of a lead user study. Innovation by users tends to be widely distributed rather than concentrated among just very few very innovative users [6]. In
the case of smart grid applications, lead users do not constitute a consistent group of people, but might be found in various sub-populations such as early home automation adopters, technology enthusiasts, home electricity generators, heavy electricity users, environmentalists or people who keep a keen eye on their expenses.

According to the literature, there are many ways to identify lead users. As one means to access lead users, we used a survey. We did so even though the literature [10] suggests that other methods are more cost effective. This is because we had access to a sub-population (a consumer panel maintained by our organization), which is easy to approach via a survey and with which it is fairly easy to schedule focus groups/workshops via online forms. The other reason was that we were not interested in the most leading edge lead users (in the sense of product modifiers), but rather lead users that have characteristics of early adopters. While new innovations were one focus of our study, we also needed to establish the acceptability of commercial product concepts. Hence, industry interest and capability to produce related services was one preset criterion in our search for innovations.

We have also applied other methods to identify lead users, such as broadcasting in the media and snowballing, where experts identify especially innovative other individuals. These individuals are asked to identify fellow innovators or experts as they are often networked in one way or another [10]. However, on the basis of our experiences, we expect that surveys can in fact be cost-effective for companies that have an existing customer register and that are not looking for the most innovative lead users, but for a (fairly broad) group of customers that represent an emerging market trend. This solution is further supported by the fact that the integration of lead users especially in the beginning of the product or service development positively influences the acceptance and diffusion of new concepts in the market [18], [10].

We have identified, or are in the process of identifying, lead users in various populations:

- A consumer panel maintained by the National Consumer Research Centre (N=625)
- Customers of a local electricity utility in Western Finland (N=120 000)
- Various handpicked sub-populations such as consumers having installed advanced home automation, solar and wind energy enthusiasts, members of environmental associations and electric vehicle experts. Here, snowballing was used to find participants.

Focus groups/workshops with lead users (step 3): In the literature, there is evidence that lead users gladly share their information and experience with others, which has surprised innovation researchers [6]. There are several reasons why lead users would like to share their knowledge and take part in a product or service development workshop. There are possible private benefits that the sharing of information can offer: improvements to products, which lead to mutual benefit, or the innovator may benefit from enhanced reputation or from positive networking effects [6].

We used the service concepts/use scenarios developed in the expert workshop as a starting point for testing and further development in focus groups with customers. Due to the complexity of the topic of smart grid applications, and to the low engagement of even quite leading customers, we deemed a full lead user workshop unfeasible. Instead, we combined methods from concept testing in focus groups with elements from lead user workshop methodology. Through this combination, we studied customers’ needs, concerns and suggestions concerning key features of smart grid –based services.

Nine focus groups/lead user workshops were organized in spring, summer and autumn 2011. Our analysis is still ongoing, but we report here our first results.

IV. EMPIRICAL MODEL

Our lead user survey aimed to determine the characteristics of lead users and factors explaining lead user innovativeness. We designed the questionnaire to measure three factors leading to lead user innovations, which can be found in the lead user literature [6]-[8], [19]: expected benefits, expertise and opinion leadership. With these factors, lead users can be identified from a larger population.

In our empirical research (n=367), we first tested a hypothesis according to which:

Hypothesis 1: Lead users qualities can be found within a large group of people based on survey responses.

According to H₀, the hypothesis cannot be rejected if the internal reliability of the model is high enough. H₁ states that we must reject the hypothesis 1, if the questions in the survey are not reliable enough in filtering relevant factors from the group of questions.

We calculated sum variables from questions representing the three factors. In the factor expected benefits, the items measured e.g. how people monitor their electricity consumption and expenditures, how they try to save electricity and how interested they are in electricity issues like producing electricity themselves or buying an electric vehicle. Expertise was measured with such items as do the respondents generally know what is wrong if an electric appliance does not work, do they make small home repairs themselves, are they interested in new technology and do they follow technology developments in the media. Questions determining opinion leadership concerned e.g. the respondents’ active participation in their own condominium administration, membership in an environmental association, interest in various Internet forums discussing energy and membership in neighborhood associations.

The validity of the model elements was tested statistically with Cronbach’s alpha. It measures the reliability and is used as a measure of the internal consistency of a test score. It is widely used e.g. in social sciences to test how well the items in a survey measure the same construct.

The reliability of our survey is satisfactory in measuring
expertise ($\alpha=0.77$), and expected benefits ($\alpha=0.65$). The value of for opinion leadership is not good, $\alpha=0.44$. In fact, the questions may measure another dimension, which is participation and activity, and thus the items within this sum variable might be better as background variables that help to identify subgroups in which lead users could be found in real-life populations. In this early model we, however, consider it as a potentially promising factor of the lead user construct, but this requires further research.

Our empirical model suggests that people’s answers to certain questions can reveal the lead user quality of a respondent. In addition, it suggests that a survey can be practical tool for finding early adopters for a firm’s products or services. As a conclusion, for expertise and expected benefits, the H0 cannot be rejected and therefore hypothesis 1 is proven true.

The second hypothesis that we tested, concerns the innovativeness of the lead users found through the first part of the research:

_Hypothesis 2: Lead users make innovations also in a difficult service field such as electricity services._

According to $H_0$, the hypothesis cannot be rejected if the correlations are statistically significant. According to $H_1$, we must reject the Hypothesis 2 if the correlations for innovations with the lead user characteristics are not significant.

We chose as proxies for innovativeness the following three dimensions: own inventions, suggestions and participation and contribution to innovation. The respondents’ own inventions were measured with the item: “I have made small technical inventions at home or at work” We found a significant and positive correlation between participants’ own inventions and all the lead user factors described above. Expertise even correlates quite strongly, with a correlation coefficient of more than 0.5.

In the survey, the respondents were given the option to give their own ideas or suggestions. All lead user factors correlate positively with whether the respondents spontaneously made suggestions on how to improve services. The survey also measured respondents’ willingness to participate in the lead user focus groups, which is our third measure for innovativeness. The factors expertise and opinion leadership correlate significantly with the willingness to participate. The correlation for expected benefits is not significant, which is surprising, but possibly the respondents did not believe that the focus groups would bring them any benefit. Figure 1 shows the correlation coefficients for lead user qualities and the proxies for innovativeness.

Thus, our results reveal that $H_0$ is true. Therefore, the second hypothesis is also true and cannot be rejected. The correlations of the lead user characteristics are statistically significant and positive for measuring innovativeness. Thus, lead users can be innovative also in difficult service fields, where they cannot principally make product or service modifications themselves.

Finally, we focused on finding out in which kinds of environment or situations lead users could be found. Correlating with expected benefits, expertise or opinion leadership we found the following background variables. Lead users concerning smart grid applications can be found among people who:

- are living in a detached house (correlates with expected benefits and expertise)
- have a large electricity bill (correlates with expected benefits and expertise)
- are concerned about the environment (correlates with all lead user factors)
- have replaced their heating system (correlates with all lead user factors)
- have adopted advanced home automation (correlates with all lead user factors).

The results are in line with intuitive reasoning. Living in a detached house or having a high electricity bill do not imply opinion leadership. Environmental concern, heating system replacements and home automation adoption correlated significantly with all three lead user factors, so they are the groups where the most likely users for smart grid applications could be found in the initial phase of the technology diffusion, at least in Finland. Thus, it might be a good idea to tailor the early services offered in the market to ensure their positive influence on the environment or to bring extra benefit to home automation customers or heating system replacers.

V. Focus Groups with Lead Users

Based on the expert workshop, we designed seven service scenarios that we tested and used as a sounding board for further ideas in the lead user focus groups/workshops. Nine focus groups/workshops were organized with a total of 61 participants. The scenarios discussed in the groups were:

1) Mobile energy saving tips with user-, context- and appliance specific information
2) Security and distant monitoring and control service for users
3) Storing service for electricity in the battery of an electric vehicle – inexpensive leasing of vehicle offered in return for storage
4) Feed-in service for distributed/own electricity production
5) Load control by grid operator with boundaries set in agreement with the user
6) Dynamic pricing based on real-time electricity consumption
7) Home maintenance service - monitoring of appliances and automatic maintenance alerts by the service company or maintenance staff.

Our focus group participants were particularly interested in obtaining personalized information on energy use concerning specific appliances and gaining alerts and advice in case of unusual changes in electricity consumption (scenario 1).

1 This variable was measured with the question “I have personally taken action to combat climate change”, with the scale 1-5, where 1 is disagree and 5 is agree.
Figure 1 Factors contributing to lead user innovations in smart grid application

Distant monitoring and control of appliances (scenarios 2 and 7) raised interest, as well. These were also the services for which at least some of the participants were willing to pay a reasonable charge. Here, many suggestions were made for how to tailor services to specific types of users while maintaining ease-of-use. Pre-programmable profiles for e.g. different situations or appliance stocks were the most frequently voiced suggestion.

Our lead users were also interested in distributed, renewable energy in general (scenario 4), and basically attracted to the idea of generating electricity themselves, e.g. via PV panels. However, many considered this a somewhat futuristic concept in Finland, especially in apartment buildings. Concerns were raised about technical, contractual and legal complexities of self-generation and feed-in to the grid. Packaged services for different types of buildings were suggested as a way to facilitate the uptake of distributed generation.

Electric cars (scenario 3) raised some interest, but the idea of storing electricity in car batteries seemed quite distant to our focus group participants, as there are few plug-in electric vehicles in use today. Concerns were voiced about practicalities, such as maintaining sufficient charge for driving off to work in the morning. Participants understood the need for increased electricity storage in the future, but many were doubtful about the potential of electric vehicle batteries as a solution.

Load management by grid operators (scenario 5) and dynamic pricing (scenario 6) are two scenarios that aim to control peak loads via demand response. They offer more benefits for grid operators and electricity suppliers than for customers. They are also the most potentially controversial scenarios, as they challenge the status quo of convenient and carefree electricity use. Many of our lead user participants, however, were quite concerned about peak loads, and were willing to make efforts to reduce electricity use at such times. Nonetheless, few were willing to take the risk of paying real-time prices for electricity, either. Many were also of the opinion that they have little excess loads to reduce.

Some feasible applications for load management and dynamic pricing were suggested, however. More variable time-of-use pricing – without the full risk of peak prices – was deemed an acceptable compromise by at least some participants. Some participants were also willing to try to cut their consumption at peak load periods voluntarily, if information on peak load periods were readily available. External load control by grid operators was also seen as a relatively inexpensive alternative to expensive timer-controlled thermostats for electric space and water heating. Yet good contracts were deemed necessary, as were options for manual override and assurance that devices are not damaged by such interventions. There were thus at least some users who understood external load control as an option for the user to select certain loads for time-based control.

While our participants were more enthusiastic about new service scenarios than the population at large, they called for clear justifications and detailed calculations of the benefits offered by the new services and for their relative advantage vis-à-vis alternative routes to the same solution (e.g. appliance-specific controls). Realistic cost-benefit calculations and proof of the environmental benefits offered were deemed necessary. They also stressed that smart grid services – including the entire service chain – should be thoroughly tested and designed for ease of use and reliability. Data security and privacy issues were also raised. Even fairly leading users are thus unlikely to be willing to serve as a test-bed for unfinished services.

Another related concern voiced in all focus group
discussions was the participants’ inability to understand why electric utilities would want to reduce their customers’ electricity bills. In a competitive and liberalized market, even leading-edge users were not fully convinced that energy providers would want to seriously cut energy demand. Hence, sound arguments for why demand-side and demand-response services are offered are necessary to convince customers that their service providers have a sensible motive and a serious intention to actually achieve reductions in their customers’ energy use.

The ideas for new services from our lead users focused on service design and packaging from the point of view of user needs. One frequently voiced suggestion was for service packages that do not focus merely on electricity, but include also other services (fire safety, HVAC, facility management, home maintenance, insurance), which from the customers’ point of view are closely related to electricity. Ideas were also voiced for using the smart grid to supply smart home services for older buildings with less inbuilt automation. Here, load management was envisaged by some participants as a feasible motive for electric utilities to provide customers with automated control services or devices.

The focus groups/workshops indicated that there is a great demand for good advice on how to save electricity, in particular among users with electric heating. However, participants indicated their dissatisfaction with the available energy-saving advice, which they often found elementary, self-evident and uninformative.

In particular, participants reported their need for advice concerning the specific electricity consumption of different appliances – in particular, newer appliance types such as ventilation systems and home office equipment. Smart grid applications that offer tailored advice for specific users, appliances, and user contexts raised significant interest. Demand was also voiced for good visualizations of energy use, which enable discussions among the family and offer a way to educate youngsters on electricity use and costs.

Our discussions with lead users revealed the need for intensive tailoring, as users’ needs varied greatly depending on their building types, appliance stocks and lifestyles (e.g. timing of different activities, variable working hours). The lead users participating in our discussions expressed a certain degree of willingness to tailor packaged services to their own needs, and made a number of suggestions for how such tailoring could be facilitated via programmable and adjustable user profiles. This group of ideas suggests that mass customization is an important aspect in smart grid-based services.

There is much work ahead in specifying the implications of our findings for smart grid –based service development. However, we are satisfied with the format of these workshops, as existing service scenarios facilitate discussion and help to focus idea generation on smart grid service development. On the basis of the existing results, we can already conclude that the lead users delivered educated and considered comments on the service concepts designed by experts and had good ideas for how to improve them further.

VI. CONCLUSIONS

The present study contributes to fill an information gap, as there is little research available about the possibilities of the smart grid from the customer’s perspective. Our results can thus help to utilise the novel potential of smart grids faster and more smoothly.

Our lead user survey aimed to determine the characteristics of lead users and factors contributing to lead user innovativeness. We have explored how easy it is to identify lead users and what are likely to be the most promising groups of lead users concerning smart grid services. We found that people’s responses to a survey can reveal the lead user quality of a respondent. Expertise of a user and the expected benefits are important factors explaining the lead user qualities of a person. In addition, we found out that a survey can be a practical tool for finding early adopters for a firm’s products or services. In further work, however, we will also test other methods for identifying lead users, and expect these will help to identify users with a sharper and more specific leading edge status.

Environmentally concerned people, home automation adopters and heating system replacers are groups where the most likely users for smart grid applications could be found in the initial phase of the technology diffusion. We conclude that in initial stages of market penetration, it might be a good idea to design services that offer positive, measurable environmental benefits or serve the specific needs of people installing other new technologies in their homes.

Even though our work is still in progress, the results already obtained from the lead user focus groups/workshops demonstrate that lead users can be innovative also in difficult service fields, where they cannot principally make product or service modifications themselves. We found that lead users can nevertheless offer new ideas for service development based on smart grid applications. The value of the lead users’ participation in service development ensues from their experience and ability to express user needs and constraints in the user context in a way that is conducive to service development.

The results of our focus groups/workshops with lead users suggest that service developers should focus on service packaging. In particular, the combination of smart grid services with other services for energy, safety, maintenance and overall home management appears to be a promising line of development. Moreover, services need to be designed for mass customization with usable and well-designed user interfaces. Pre-programmed, adjustable profiles can be one way to allow user customization without too much effort by users.

We also found that lead users are demanding customers, even though they are relatively enthusiastic about the benefits of smart grid-based services. Hence, even initial services introduced in the market need to be well designed and offered together with sound arguments concerning their benefits for
the user, the environment and society at large. For example, online electricity consumption feedback services need to compete with and outperform self-made Excel spreadsheet solutions. Moreover, customers need assurance that risks, such as data security, are well under control. Lead users are just as discriminating as the average customer, or even more so.

Our paper has presented our first findings concerning customers’ concerns, ideas and service experiences regarding smart grid applications. The implications for system, service and product developers are clear. User needs and user contexts are highly variable – hence, a close understanding and cooperation with lead users is needed.

Services need to be tailored so that they are easy to use yet adjustable to individual conditions. Users need to retain control and autonomy without excessive effort or information overload. This is the case, in particular, for services that entail risks for the user or challenge their current level of convenience, such as service contracts focusing on load management. Here, partnership and close co-operation with customers is key. Simulations and trial use periods might also help to allow customers to explore the benefits of new services without the risks.

Moreover, the case for smart grid applications needs to be much more detailed, specific and grounded in real-life conditions than it is today. Service developers and marketers need to make a clear connection between the benefits offered (costs, peak load management, electricity saving, CO₂ reductions) and the particular functionalities of the applications they are offering. The relative advantage [20] of the services – vis-à-vis other existing options – needs to be clear.

VII. REFERENCES


VIII. BIOGRAPHIES

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