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Smart meters and people using the grid: exploring the potential benefits of AMR-technology

Erica Löfström[a]*

[a]SINTEF Building and Infrastructure, Pb 4740 Sluppen, 7465 Trondheim, Norway

Abstract

The debate on the introduction of AMR (Automated Meter Reading) in Norwegian households is largely built on the assumption that users will react on price incitements in relation to electricity. However, the basic function of the AMR-system technology is to measure the use of energy and the power output (effect) and send this information to the electricity suppliers. In the list of demands on the imminent implementation of AMR-technology it is not specified *how information* on the actual use and the current price of electricity is to be communicated to end users to enable them to adjust to price signals. Simply introducing AMR in itself is not very likely to have a major influence households' use of electricity. However, it is likely that receiving this information will enable providers to better control and plan the production and to adjust the price levels of electricity. Using AMR this way only utilizes a limited part of the potential use of this technology for cutting energy demand and evening out peaks in energy use. The primary objective of the project is to explore households' incitements to be flexible users based on feedback on consumption in relation to a smart grid . In this project, participants in Demo Steinkjer living lab have participated in semi-structured focus group interviews (FGIs) in which user responses on different means of communication of AMR have been explored. The research questions are 1) what information should be communicated to households and 2) how should it be communicated? The secondary objective of the project is to use the results of the study to specify which functionalities are relevant to include in a prototype app-based *control system for household functions* based on AMR.

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Keywords: SmartGrid, users, Focus group interviews, prototype, visualization, control systems, energy efficiency; sustainability; AMS

* Corresponding author. Tel.: 47 47 66 87 66

E-mail address: Erica.Lofstrom@sintef.no

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1. Background

Automatic meter reading, or AMR, is the technology of automatically collecting consumption, diagnostic, and status data from energy metering devices and transferring that data to a central database for billing, troubleshooting, and analyzing. AMR technologies include handheld, mobile and network technologies based on telephony platforms (wired and wireless), radio frequency (RF), or power-line transmission. As part of the Norwegian energy policy, it has been decided that AMR of electricity will be installed in all households by the year of 2019 [1].

Simply introducing AMR is not very likely to have a major influence on the use of electricity in households. However, it is likely that receiving this information will enable *providers* to better control and plan the production and adjust price levels. However, using AMR this way only utilizes a limited part of the potential use of this technology for cutting energy demand and evening out peaks in energy use. The vision conveyed by policy documents and in the ongoing debate is intertwined with the discussion of it communicating with a fully functional smart grid involving systems for both supply and use of electricity [2, 3]. However, as fully developed smart grids do not exist as for today (they are still being developed and tested in pilot projects and labs) there are still many uncertainties connected to the introduction of AMR and a lack of holistic approach and evaluation may result in costly mistakes. Therefore, inter-disciplinary projects (incl. pilot studies) testing the premises of this new technology and its potential impact on energy use are necessary at this stage. The majority of studies in relation to AMR and the smart grid agenda are technically oriented. However, the ongoing research project *BEVISST* includes researchers both from technical and social sciences and is a follow up of the research project BESLUTT [2, 3].

1.1. Purpose and Research Question

The primary objective of the project is to investigate the user responses on different means of communication of AMR (Automated Meter Reading), and to find out more about: 1) what information (what data) should be communicated to households to have an impact on their use of electricity?, and 2) how (and in which context/timing) this information should be communicated (visualized) to the households? The secondary objective of the project is to use the results of the study to (further) develope the technology and to sketch out communication (feedback) concepts that will work in combination with AMR-technology and a fully functioning smart grid.

2. Theory and Method

The project is based on a form of action research, where relevant actors are working together to achieve knowledge and to implement this knowledge in solving actual problems. Action research is a good strategy to improve the connection between theoretical models and reality [4]. It seeks to generate solutions to actual problems in different contexts [5], and to explain phenomena in inter-human interactions [6]. The method may contribute both to science and actual change [4]. Especially in the field of product design recent studies show that consumer behavior insights offer rich resources to assist in sustainable design innovation [7]. Therefore, product-based design suggestions based on the tested equipment (AMR, AMR+user display, or AMR+app) are presented for the users participating in the study in semi-structured Focus Group Interviews (FGIs) enabling the user to take active part in the product development/design phase; usually referred to as participatory design or co-design [7]. The project involves both energy suppliers (NTE) and their customers (referred to as households). The households are all part of Demo Steinkjer Living Lab and have had AMR-meters installed in their household. A total of 30 private households are participating in this study. In addition, the households are monitored in quantitative studies analyzing measured data on the actual use of electricity in the households in the study before, during and after the implementation of the new AMR-technology [7]. Quantitative methods, such as questionnaires, provide numbers and offer the means to understand describe and explain them. Quantitative research relies on an objective standpoint; this means that different points of view may be compared; it also makes it possible to verify the research at a later date [7]. However, the research project is exploratory in nature – i.e. the intention is not to test a hypothesis but to explore *how* data collected by means of AMR-technology may be used and communicated to households to have an impact on their use of and willingness to save energy (including peak shaving, general savings etc.) – aims to ensure that end users may become active parts of a fully functional smart grid involving systems for both supply and use. In order to understand how this can be done. The opinions, experience and preferences of the households are in focus. As it is difficult to measure subjective data quantitatively [8], a qualitative approach was chosen to provide an understanding of the potential benefits and means to facilitate for users to become active and smart (aware and informed) parts of a fully functioning smart grid. The 30 households are divided into three different test groups. Each test group met on two

separate occasions in semi-structured focus group interviews (FGIs). Each test group consisted of representatives from 10 households (usually one representative/household – but on two occasions married couples were represented – providing a group large enough to generate rich discussion but still controllable so that the risk of participants being left out in the discussions is minimized [9]. Each FGIs lasted approximately 1.5 up to two hours and the discussions were documented by means of audio equipment. This enables the researcher analyzing the material to use correct quotes from participants in the study and enables the interviewer to concentrate on leading the discussions without the risk of missing out on crucial information. Themes and meanings were written down, grouped, analysed and discussed. Relevant parts have been transcribed and used as quotes.

In the initial FGIs (session 1) the end-user experiences of the tested technologies in Demo Steinkjer were explored and different aspects of how the AMR-technology (measured data on use of electricity) is communicated (or not communicated) to the end users was discussed. In the second FGI, the households participated in (further) developing the tested feedback and/or communications concepts with the aim to jointly develop a strategy that will work for communicating with users in combination with AMR-technology and a fully functioning Grid. As an example product-based design suggestions are presented for the users participating in the study who are hereby taken into the process, i.e. actively influencing the design; usually referred to as participatory- or co-design [7].

Two test groups with general participants in Demo Steinkjer (users over time who have tested communications concepts, including the app-based solution for communication, visualization and controlling household functions) and one group of households and shop owners in a separate building that recently had AMR-technology installed as part of the research project, *Håkkagata*. This particular group was chosen to represent how the introduction of AMR may be used in relation to decision making processes on ambitious energy efficient upgrading and after.

3. Results and discussion

3.1. Consequences of the introduction of AMR in households

With AMR, billing can be based on near real-time consumption rather than on estimates. This timely information coupled with analysis potentially can help providers and customers to better control the use and production of electric energy. However, while the debate is largely built on the assumption that *users* will react on the current price of electricity and adjust their use in accordance to it, the basic function of AMR is to measure the use of energy and the power output (effect) and send this information to the suppliers. Implementation of AMR-technology – i.e. having more correct billing and being measured more accurately – does not in itself permanently change the use of electricity or raise awareness. Without sufficient knowledge on how the results are best communicated to end users, risk is that costly technology is installed fulfilling only parts of its potential benefits. In effect, opportunities may be lost or delayed. To prevent this, it is necessary to do user studies in living lab conditions. This risk is flagrantly described by one of the informants when he points out the fact that the main change he has experienced in shifting to AMR meters is that he actually experiences a *loss* of control over his electricity use, even though he is aware of the fact that he has the opportunity to log in to the electricity company website and check it out:

"We are actually losing our overview of our household consumption, unless we go into the suppliers' web site to find our consumption in relation to the electric bill. Because now we do not scan the meter any longer." (Arne)

This is also commented on by other informants, for example:

"My experience with the new meter is that now I no longer need to bother to scan it." (Morgan)

"Now I have much less control than ever before. Before, at least we got a monthly check up." (Simon)

But, the perceived loss of information is not a direct consequence of the implementation of AMR-technology in itself, but has to do with *how* the information is communicated to the end users; as expressed by one informant:

"Consequently, what's in the Internet-part, what we now have to log in to find out, I would have wanted that information on one of those boxes instead." (Reidun)

This may indicate that to log on to a website may be too much effort for at least some end users, or that some households may prefer to have their information accessed via other channels. Evidently, this does not mean that websites is not one alternative for making the information available, but it does imply that access to a website is not enough for

communicating the results of AMR-technology to end-users. Even though installation of AMR-technology in households does not in itself change the use of electricity or raise awareness, having a new technology installed in the household has an initial visualizing effect in the *appropriation phase* [10]). The informants described how the mere introduction of AMR-technology in their building has stirred up a discussion, and the residents are clearly interested in exploring different energy saving measures for the building as a whole. At Håkkagata, installation of AMR has, so far, contributed to giving residents and shop owners a common platform for discussions, and consensus that something (energy efficiency measures) needs to be done. The installation also brought up a discussion of important aspects to consider regarding the future choice of a common energy system. Aspects such as safety, comfort, aesthetics and health were brought up. The new technology has also given rise to more awareness on energy use in the building as a whole, in addition to the energy use in the separate apartments:

"It has made me more aware. Now I switch off the radiator in the staircase when I pass it." (Sofia)

The AMR-technology has resulted in a change in the electricity billing for separate households in the building. While some had a notable increase, others had a decrease. This is taken as a confirmation of the new metering system being more "correct". Based on the FGIs with the more experienced participants of Demo Steinkjer, who have had AMR-technology installed between 2 and 4 years so far, the initial visualizing effect of the technology has disappeared. This is in line with previous studies of the implementation of energy-measuring technology in households [10]. Alas, even though the initial visualizing effect of having AMR-technology installed could well be used as part of a strategy to start decision making processes for energy efficiency measures and changes in households' energy use, it is not in itself enough for it to enable end users to become active parts of a smart grid.

3.2. What information should be communicated?

One advantage of AMR is that billing can be based on near real-time consumption rather than estimates. Using previous studies on household "rationalities" in relation to energy indicating that households may belong to one or any mix of the three categories; technology oriented, economically oriented and environmentally oriented as a starting point [10], the FGI participants were presented with an app solution for smartphones/iPhone that visualizes the household electricity use in three adjacent categories (see fig 1 and fig 2).

The possibility of having the information presented in different categories was perceived as positive. Representatives of all three rationality types were found in the different FGIs. However, in relation to the informants' willingness to change their everyday activities (routines) the category in which their use was presented was not the main aspect. Instead, it was important to have something relevant to compare ones' own energy use with. Precisely w*hat* is interesting to compare with varied, but the wish was stressed, as expressed by one informant:

"Having some kind of base line would be important here; either it is your own use over time or comparable houses in the neighborhood or something." (Morgan)

In relation to the wish of many informants to have access to historical data of ones' own household electricity use, the fact that having new smarter meters installed actually meant losing access to ones' historical (pre AMR-meters) data was discussed:

"When I received the AMR I was disappointed for a long, long time, and I am still a bit disappointed, because then the statistics over the last three years disappeared. Because they (NTE, the electricity company) never quite managed to get old data transferred to a new system." (Thord)

In effect, ensuring user access to historical data for comparison should be included in the imminent implementation of AMR-technology (and the shifting of metering devices in general). In relation to the possibility to compare ones' own electricity use with that of others, the possibility of competitions for saving energy was discussed. Here, the informants were divided. While some were motivated by the possibility to compete, others stressed the importance of having a "private life" and highlighted the fact that they were not interested in what their

neighbors might be doing. However, due to the growing tendency of people sharing more or less personal data on social media in general (for instance on facebook), investigating the possibility of sharing the monitored data on household electricity use via an app based solution such as the one tested in this project will be explored in a forthcoming project.

In general, having the possibility for end users to choose what information (in which unit) he/she will have communicated is important. Also, the possibility of alternating the information communicated for variation would be a good idea as people may well change priorities depending on context and life situation and for it not becoming too familiar, hence invisible [10]. However, the most interesting – and somewhat surprising – results of the performed study emanated from the discussions followed after presenting the possibility of having personal messages sent to end users' phones (see fig 2). After an initial discussion on the likeliness or unlikeliness of this kind of messages to be sent and how one would react if receiving them – a discussion that included lots of laughs – a serious discussion on what they all perceived as a general under-estimation of the competenc of end users followed. This discussion was insightful and revealed an extensive knowledge on how the electricity net in Norway works and its challenges in a national as well as international context. The following quote is used to illustrate this discussion:

"I would suggest we create a society where we actually are playing together, on the same team. This would require the power supplier to provide sufficient information on the heart of the matter; how is the situation, the storage capacity, the electricity production, the peak load… To make it public! And then the supplier could say that "we are very interested in you keeping yourselves posted and taking active part of this" and communicates the necessary data, preferably using an app solution like this one, saying that "now weather is cold, and up in some place somewhere, the net capacity is low and we are approaching the limit of being able to supply enough electricity." If only people were better informed, I am convinced they'd be willing to contribute. Therefore, I think it would be a good idea to have a more open approach in relation to information."(Arne)

Alas, it would appear that information on the smart grid, including political aspects of use and supply, could well be communicated and understood by end users. Drawing on this, it does not seem unlikely that a more open approach may result in an increase in general participation and motivation amongst end users to take active part in the politics on energy in general and its production and consumption in particular. Or, as put by one informant:

"People may not know a lot about this, but we are able to draw our own conclusions on this matter. It seems they do not trust us to be smart enough". (Simon)

Also, the willingness to adjust ones' own electricity use to contribute to net security and avoiding that some may be without electricity (systems break downs) was relatively high. In general, the results indicate that communication of information in relation to net security and safety issues in general and in relation to electricity should be pursued in further research on motivating factors for end users to save energy and change their daily routines to minimize the strain on the electricity net (load shifting et cetera). Although the willingness to adjust and the motivations for doing so (economy, ecology or technology) varied between different informants, the discussions on the tested app based messages (fig 2) revealed that having their electricity rationed or temporarily cut due to an actual crisis or the risk of break downs of the net would be accepted. Also, some households would be willing to have an agreement with the supplier to have their power cut when approaching peak load, as exemplified by one informant:

"I like the idea of having an agreement to let my heater be turned off if there is a crisis. (Morgan)

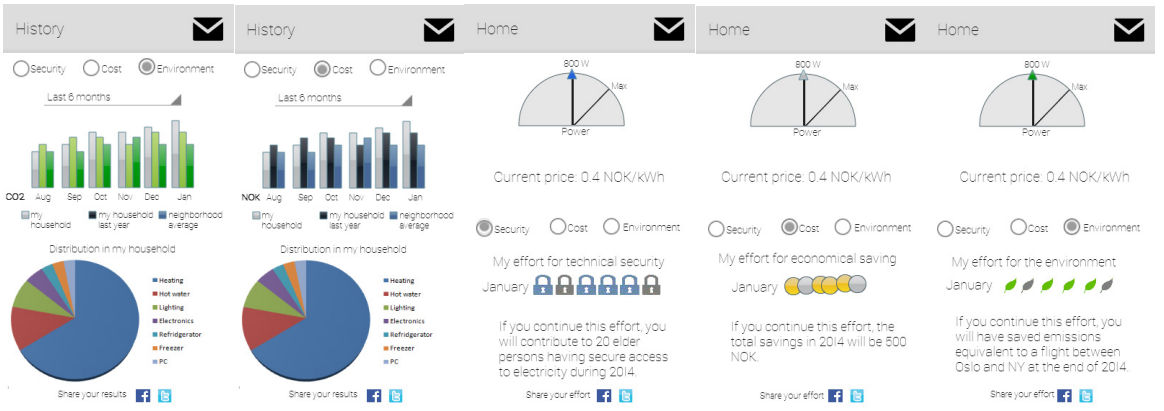

Fig. 1. Example from the tested app solution for communication/information and control of hosehold energy use visualizing the results of AMR-technology in the Demo Steinkjer test households using Security; Environment or Cost as 'motivators'.

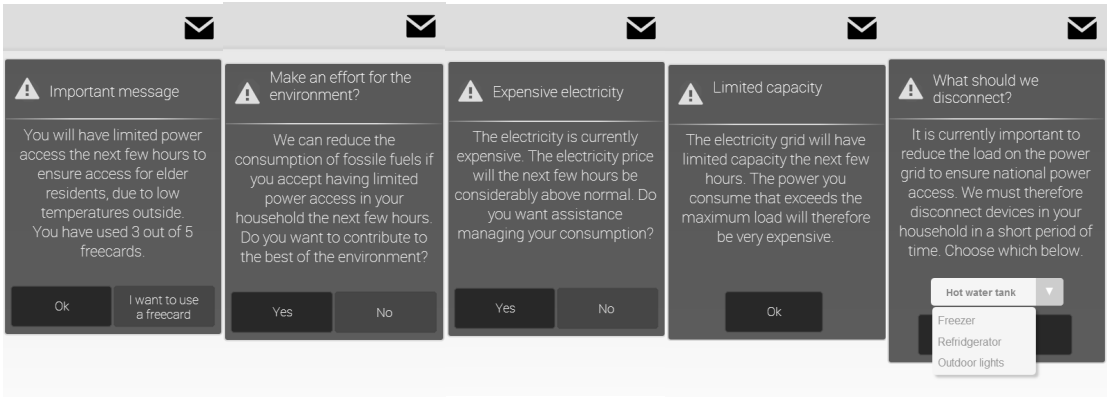

Fig. 2. Example from the tested app solution for communication on and control of household energy use (a) Limited access, possibility to use free card; (b) Environmental concerns; (c) Offered help for saving money when high prices; (d) Limited net capacity message with price motivation; (e) Message on disconnecting equipment due to net security with the possibility to choose what to switch off. (app solutions by K Tønnesen in cooperation with the researcher).

3.3. How should the information be communicated?

Comparison – in context: The results suggest that information on electricity use should preferably be communicated so that end users are able to compare their own measured electricity use with something that makes sense for them. As previously stated, access to ones' own historical data for comparison makes sense for some end users. Another interesting option was access to reference buildings or households to compare with. Interestingly, it seems non-essential what information is communicated (unit used) but rather the possibility to make comparisons:

"For comparison, it would have been interesting to have, for instance, the average use in the neighborhood on that cake (circle diagram, fig 1) there, and then you may see if you are using very much more than the neighbors. Then, you might think that, here I could make an effort. This is the field in which I have greatest potential for improvement." (Carl)

Timing: Another aspect that was brought up was that timing is relevant. To maximize the effect of feedback on measured electricity it needs to be given when and where the actual use of it takes place:

"Directly yes! Simply seeing what equipment I'm using in real time and my total consumption at all times." (Kristian).

When given directly and in connection to the activity instigating the consumption in question, feedback may well be given in less advanced ways. The informants brought up some examples of well-functioning feedback solutions that they had previous experience with. The old excess-power- or overload meter (which is still in the kitchen, disconnected) was used as an example in this discussion between FGI participants:

- We have one of these in the kitchen today, right next to the stove. It was used actively, and if you turned on one of the plates, then you turned off the hot water for instance, to keep it… (Morten)
- To make sure it did not tip over to red, yes. (Reidun)
- I would presume that meter is the reason why I still do that even without it functioning. It has become a habit that I kept up even without it working. It reminds me. (Phillip)
-You see it so clearly there and then, and you have the opportunity to do something about it. (Reidun)

Hence, it seems a relatively simple device for giving feedback on electricity consumption was successful there and then. There are numerous examples of devices and prototypes of devices giving direct feedback on electricity use, amongst other the Power Aware Cord as developed by The Interactive Institute (www.tii.se), and it may be a good idea to – via direct visual feedback – provide information on the household electricity use in relation to data in relation to a smart grid. For instance, a warning signal of some sort (such as the needle tipping over to red) could be communicated to the end user when net capacity is low, i.e. giving a direct opportunity to make informed decisions in relation to actual smart grid emanated data. In addition to this possibility of having access to an immediate feedback that will seek out the end user in context – in a way impose on the user in relation to performing certain household activities involving the use of electricity – it would be interesting for end users to have the opportunity to seek out information on the electricity use in relation to different parts of the household:

"I want a website, where each instrument would be represented with its individual load… It would be quite easy to connect an inductive thing to all household equipment, connect it to a box with a network and a web server inside, and then you have a web page."(Carl)

One of the informants compares the household electricity use with that of a net bank, and suggests the possibility to control household equipment in a similar way as making transactions via a net bank app solution:

"If I am curious on how much money I have left on my account, I will log on to my net bank, right? The other thing that would be interesting is to get an overview of the temperature in different rooms. It would probably be possible to – in an easy way [informant picks up smartphone] – using a small device that you could put in your pocket, to control the household equipment." (Reidun)

Hence, it appears that simply having access to information is not particularly interesting for some end users. What seems more interesting is to receive an overview of the household as a system, paired with the possibility to make informed decisions based on this information. As one informant puts it:

"One should not disregard the possibility that good information on real time use may stimulate people to adjust their behavior either by saving or relocating it." (Morgan)

4. Concluding remarks

The performed study suggests that the assumption that *users* will react on the current price of electricity and adjust their use in accordance to it is not very realistic. Instead, it seems that although economy is one of *several factors* of importance for the households in relation to energy use, the possibility to see ones' own household electricity use in a systemic context – i.e. in relation to a smart grid – opens up for the possibility of users to become a much more informed and active part of the electricity system as a whole than that of simply reacting to price signals. It appears to be interesting for end users to have the opportunity to compare their household electricity use with that of others and/or of ones' own use over time. Direct intuitive feedback on a day-to-day basis paired with the possibility of having an overview of the household as a system online/via an app-solution, including the possibility to make informed decisions based on this information would be well worth pursuing. The results show that households are able to understand the complexity of a smart grid, and may be willing to act in accordance to information in relation to it. In effect, the information generated in a smart grid should not just be collected on the end user side, but information on what is happening on the grid as a whole (net capacity, risk of systems break downs etc.) could well be provided to end users and may be used as an incitement to be flexible. Based on this finding, a study on how information on the smart grid should be communicated is being planned. In addition, it would be important to have the possibility to personalize the information as different households have different rationalities in relation to electricity use, and to have the feedback made flexible to avoid it becoming too familiar, hence counteracting the visualizing effect of it [10]. As a concluding remark, it seems an imminent risk that we implement this new technology without exploring its full potential in relation to end users' potential role as flexible parts of a smart grid. To fulfil the large potential of having a fully functioning smart grid we need to make sure the smart meters do not only measure electricity use more accurately and frequently, but that the measurements are communicated in a way that will make sense for the user to take active of the smart grid system. Electricity end-users are smart, let's give them the information they need to act in accordance to their full potential.

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