User Sentiments Towards Smart Grid Flexibility

A survey of early adopters' attitude towards allowing third parties to control electricity use in households

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***Abstract*—In this paper, we present the findings from a pilot survey on attitudes towards incentives for allowing third parties to control electricity use in households as part of the change to smart, green, and sustainable power grids. The survey was aimed at early adopters of smart home technology and shows that for this group, there is significant resistance towards allowing a third party to control household electricity use, at least unless the monetary incentive is high. However, early adopters are positive towards using smart home technology to lower their electricity bill if they stay in control.**

Keywords-smart grid; user sentiment; adoption; smart home; incentives; Smart-MLA.

I. INTRODUCTION

The energy market in Europe is in a state of change. The transition from fossil fuels to renewable energy, new industries such as hydrogen, electric vehicle batteries, data centers, and green shift in existing industries require electricity. The change demands an increased focus on effectiveness and smart utilization of energy resources and the power grid. In 2019 alone, Europe installed 30 GW of renewable energy production, cutting emissions by 12% compared to the year before [1]. Fighting climate change means the matter is becoming more urgent, and the European Union has set a target of 55% emissions cuts by 2030 [2], which means European energy markets need to speed up their work on smart grids, as the transition to renewables means less oil and gas and more electricity [1].

Smart grids, allowing bidirectional power flow, two-way communication, and control functions, are essential to this transition to handle the increased need [3]. Smart grids provide consumers with the information and tools needed to adjust their energy usage and may contribute to savings for the consumers and reduced needs for electricity in households [4]. However, changing consumers' behavior requires action, and there are several possible strategies, such as policy change, working to change consumer perceptions and attitudes, and material incentives [5].

The transition to renewable smart grids might increase the need for flexibility from consumers, as renewables such as wind and solar do not produce the same amount of electricity throughout the day. The transition makes grid balancing more of a challenge. The solution is either to have backup power (battery storage, coal, gas, hydropower) to meet excess demand or control demand at peak hours [6]. While Norway already produces most of its electricity using renewable hydropower, it is still affected through participation in the European markets. It can play a role in balancing the grid as hydropower can be switched on and off using water as a "battery" [1].

Vrain and Wilson [7] show significant potential for energy saving and CO_2 cuts through smart home technology. Still, Hargreaves and co-authors point out some challenges for adoption: Smart home technology is seen as complicated, time-consuming, and disruptive [8]. Sanguinetti, Karlin, and Ford point out that cost and savings are essential for adopting smart home technology [9]. Hence, there is a need for research on incentives for the adoption and efficient use of smart home technology.

The main scope of the ERA-NET project Smart-MLA (Multi-Layer Aggregator) [10] is to develop cloud-based multi-layer aggregator ICT solutions to facilitate optimum Demand Response (DR) and grid flexibility to energy systems to utilize up to 100% renewable energy. The project includes research on smart grid flexibility and possible barriers to adoption.

Thus, the objective of this paper is to examine incentives for smart home technology, as seen by early adopters. We focus on early adopters because this is the consumer group currently purchasing smart home technology [11], and we want to hear the opinions of actual users. Further, we are focusing on incentives that allow third parties to control

 ISBN: 978-1-61208-896-9

household consumption, as this might be necessary at certain times to balance a renewable-driven power grid [6] properly.

The rest of the paper is organized as follows: The following section contains a literature review. Section III discusses the research approach, followed by Section IV presenting the findings. The last section contains the conclusion and ideas for further research.

II. LITERATURE REVIEW

This section provides a literature review, first on smart grids and smart homes, then on adoption, use, and diffusion.

A. Smart grids and smart homes

As defined in the introduction, smart grids are about control, balance, and increased efficiency through communication, allowing users to save energy [4]. Smart grids need to respond to varying supply and demand [12] and rely on smart meters providing real-time consumption data and the possibility to regulate power consumption. Smart grids also include communication technologies such as 4G/5G and smart home protocols (Zigbee, Z-wave, Bluetooth, etc.) for data exchange.

Smart home technology mixes artificial intelligence, communication, monitoring, and control of household appliances [13]. A smart home consists of the external network linking home and grid, a household hub for connecting components, and the individual smart/controllable devices in the house (sensors, thermostats, heating, ventilation, air conditioning, lighting, etc.) [14]. The combination of smart homes and grids allows for dynamic pricing and load-shifting programs for managing demand and supply of electricity [15]. The International Panel on Climate Change (IPCC) estimates a 70% decrease in energy demand from lighting alone if people optimize lighting at home [16].

There are also different approaches to control. Some vendors leave it up to the user to set up automation, turn appliances on and off, etc. In contrast, others apply advanced algorithms attempting to optimize power consumption within the boundaries set by the user – such as needing a full charge on your electric vehicle by 8 am or not allowing the temperature to sink below a certain threshold [15]. A third option is to allow a third party to control some electricity use, or a combination of the above such as outlined by the Smart-MLA project (see Section I).

B. Adoption, ease of use, and diffusion

One challenge with home automation and grid optimization lies in this tension between control, what we are willing to sacrifice, and use complexity. There is some emerging research into this area of home automation usability, such as the paper by Stojkoska and Trivodaliec, which proposes a framework for smart home management [17].

Other studies point to specific challenges in various user contexts. Coughlin and co-authors, for example, have examined the older population's user experience with health-related smart home technology and found that older people tend to see the benefits of technology but still find it challenging to use. There is no comprehensive or integrated market for these things, meaning users have to work with many different user interfaces [18]. Yang, Lee, and Zo also find challenges for user acceptance related to mobility, security, privacy, and trust, suggesting unmet design needs in these systems [19].

Nikou [20] has researched the adoption of smart home technology and found support for an extended technology acceptance model: Perceived usefulness and ease of use were important determinants for adoption, as were compatibility with existing hardware. The cost of systems had a significant negative effect, and men and women have different attitudes towards smart home technology. Shin, Park, and Lee [10] found that the younger age group was more likely to be concerned with usability, while those over 40 were slightly more concerned with usefulness. Those with higher education were, in general, more positive towards smart home technology.

Sanguinetti, Karlin, and Ford applied diffusion of innovation theory to examine smart home energy management adoption and found four clusters of consumer segments: Those unfamiliar with the technology, those who were unpersuaded or persuaded, and finally, owners. Those who owned or planned to purchase smart home technology were, in general, more positive towards and informed about technology. They also had higher incomes and were more likely to own their own home. Those who were less positive pointed to barriers such as the difficulty of setup/use and concerns with the cost of purchase [9].

III. RESEARCH APPROACH

The study was conducted as a pilot survey study [21]. The study was conducted in Norway, so respondents replied with the Norwegian context in mind, which means high consumption due to long and cold winters; users being used to low-moderate prices; and seeing electricity as a shared social good rather than a market commodity, even though the energy sector has been deregulated since the Energy Act of June 1990.

In "The Lean Startup," Ries advocates testing ideas with early adopters [22]. The sample is not representative of the population but is focused on early adopters only since they will provide more valuable responses in the context of this paper.

As we were interested in the attitudes of early adopters, we reached out to two online discussion forums (for smart home automation and electric vehicle enthusiasts) and four Facebook groups (for electric vehicle enthusiasts, two different smart home groups, and a group for electricity pricing). As participation was by self-selection within these groups, we do not claim the findings are representative. However, they still present the sentiment potential early adopters show towards giving up flexibility to gain advantages (rewards or lower bills). The survey was left open

 ISBN: 978-1-61208-896-9

for five days, and in this period, we received 209 answers and several comments to the post where we invited people to participate.

In the survey, we asked about the demographic background, existing smart home technology in use, and acceptable incentives for allowing outside control of appliances, using a four-point Likert scale. In addition, we had an open-ended question where respondents could elaborate on their answers, which 52 of the respondents chose to do.

As this is an exploratory pilot survey, we chose not to apply a specific model such as the Technology Acceptance Model (TAM). However, we did include some questions from TAM and related models. At this stage, we are more interested in descriptive statistics of the incentives required for consumers to allow outside control of their electricity use. A more structured model-based survey approach, based on this pilot's answers, is the next step in our research.

IV. FINDINGS

This section discusses findings related to demographic characteristics of respondents and their attitude towards technology, and what they think of incentives and motivation to provide flexibility.

A. Demographic characteristics of early adopters

A vast majority of our respondents were male – 95 %. This is perhaps somewhat skewed due to the self-selection of respondents, but other studies of adoption show similar results. Men are more likely to adopt smart home technology, meaning current marketing only reaches half the population. Age-wise, our respondents are mainly in the 30-60 age group, with equal distribution for each decade. This is not surprising as most of them own houses (75%, vs. 12% for apartments and 13% for other housing types). Most Norwegians own their home and typically buy their first home when they get their first job and settle down with a partner in their middle- to late twenties or early thirties.

Further, we see that smart home early adopters are relatively affluent, but not extensively so. According to Statistics Norway, the median income for all households in Norway is € 68,600, for households with no children € 86,000, and € 117,000 for couples with children aged 0-17. In our survey, only 6% have a household income below € 60,000, and 77% earn more than € 100,000. This would put most respondents in a comfortable financial position, with two adults in the household having well-paid jobs, indicating that investment in smart home technology is a surplus phenomenon.

B. Attitudes towards technology, existing smart technology

Here, we asked respondents about their attitudes towards technology and technology adoption to examine if they had early adopters' characteristics. Table 1 shows that a vast majority of respondents are positive towards technology and that friends and family will consult them in technical matters. This indicates that we were indeed able to capture the sentiment of early adopters.

TABLE I. ADOPTION OF TECHNOLOGY. RESPONSES IN PERCENT

"I adopt new technology…"	Fully agree	Somewhat agree	Somewhat disagree	Disagree
quickly	58.4	38.8	2.4	0.5
if it is easy to use	59.1	33.2	6.7	1.0
if it is useful to me	79.9	20.1	0.0	0.0
if the price is right	71.8	25.4	2.9	0.0
Friends and family ask my advice about technology	57.2	36.1	5.3	1.4

We also asked the respondents about their preferred smart home setup (Fig. 1). As early adopters, more than 70% prefer to tinker with advanced settings or custom build their own system.

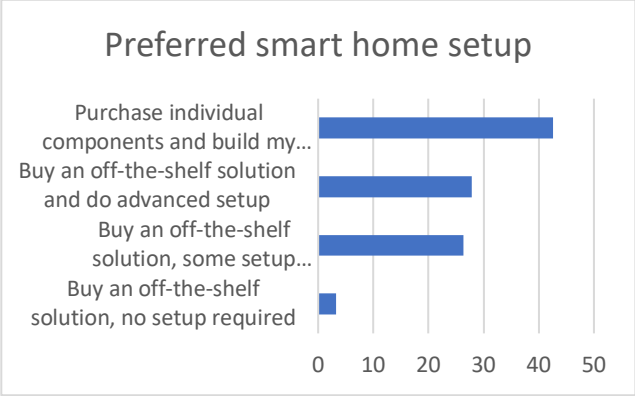

Figure 1. Preferred smart home setup

In Fig. 2, we show the smart home products owned by respondents. We see that the most common are off-the-shelf technology such as electric vehicle charging, smart plugs, and thermostats. 15.5% have installed solar panels, which is quite a bit higher than the national average. 14% report other technology such as Heating, Ventilation, Air-Condition (HVAC), heat pump, sunscreens, alarm systems, and door locks. Two of the respondents have installed battery packs for energy storage.

Only 2.4% report having solar capture technology (storing solar energy as warm water), even though solar capture makes sense in the cold Norwegian climate.

C. Incentives and motivation

Here, we asked specifically about incentives for allowing the Distribution System Operator (DSO) or other external parties to regulate different areas of people's homes. The responses are listed in Table 2. In short, we see that significant incentives are needed, and the respondents are

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generally negative towards allowing others to control their homes' electricity use.

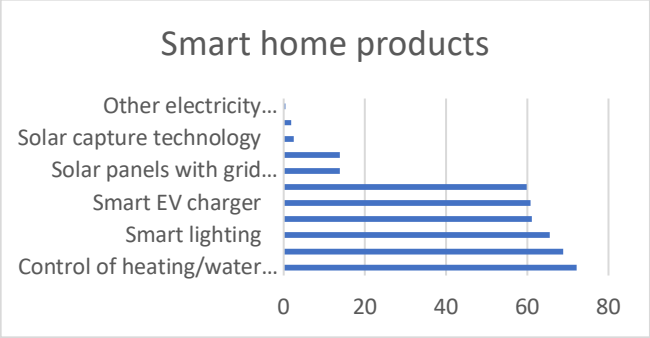

Figure 2. Smart home products owned

They far prefer being in control themselves and setting up automation within the boundaries they find acceptable, such as the electric vehicle having a full charge by a specific time, lowering temperatures when rooms are not in use, etc. There is some interest in allowing outside parties to control electric vehicle charging or the house's water heater, but only if the savings exceed €150 a/year in each case.

TABLE II. INCENTIVES FOR ALLOWING CONTROL TO THIRD-PARTIES

I am willing to let outsiders	Annual savings					
	Less than €30	€30-79	€80-119	€120-149	€150 or more	Not at all
Use my EV's battery to balance the grid	2.9	4.3	10.1	5.3	**39.9**	37.5
Control charging of my EV	10.6	9.7	14.0	6.3	**31.4**	28.0
Control heating in rarely used rooms	11.1	7.7	13.0	5.3	16.8	**46.2**
Control heating in frequently used rooms	4.8	4.8	7.7	3.8	19.2	**59.6**
Control my water heater	12	4.3	16.7	5.3	26.3	**35.4**

Further, 97% report that good statistics and visualizations of energy use and savings are important or somewhat important for their motivation to use smart home technology (Fig. 3).

We also asked about other incentives for energy saving in general. It seems that while early adopters are reluctant to release control to others, they are concerned with societal issues. Keeping costs down for everyone via energy-saving and better utilization of the national grid and contributing to phasing out fossil fuel energy in Europe is seen as important or somewhat important for 70 – 90% of the respondents.

D. Qualitative concerns

Summing up the findings, we see that while users are happy to contribute to a more sustainable future and invest in smart home technology to cut costs, monetary incentives need to be significant for users to allow outside control of their home's energy use. The free text answers supplement the survey questions, with 52 of 207 respondents choosing to comment. The following categories emerge from the free text-answers and are candidates for future research:

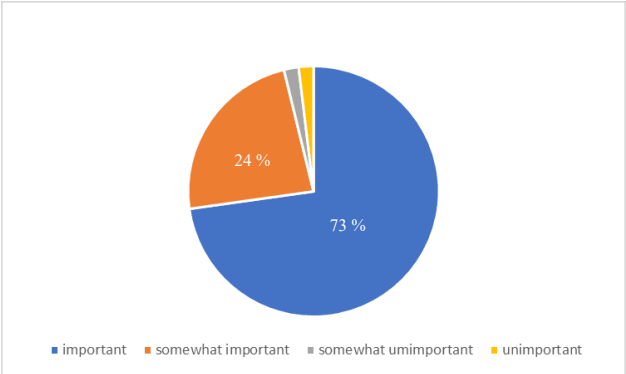

Figure 3. The importance of statistics and visualization

1) The cost of grid access and use is a barrier

In Norway, electricity customers pay a fixed rate plus a certain amount per kWh to access and use the power grid. The sums are set via a complex set of regulations and meant for grid maintenance and updates. This means that the total electricity bill comprises the cost of electricity and the grid access tariffs (plus taxes). There are currently proposals to change this tariff to save on investments in the grid. Several respondents claim that the way this cost is structured, as well as suggestions for tariff changes such as paying for delivering excess solar power to the grid or raising the tariff based on maximum electricity use, take away the monetary incentives for investing in smart home equipment:

"The grid tariff in its current and planned form is the major obstacle to a more aggressive approach to cutting electricity consumption."

"I can easily upgrade my home, so I can charge my two electric vehicles with a total of 14 kW during the two hours at night when the grid is least used, but I have no incentives for that [with a tariff based on maximum kWh used]."

"Now we are threatened we might have to pay the DSO for the electricity we supply to the grid from our solar panels."

2) Money first, ideology second

We also see several comments showing that monetary incentives and the total cost of electricity weighs heavier than

social or ideological reasons for power saving and investment, and there are some calls for increased support for the installation and upgrade of solar panels, heat pumps to replace regular heaters, etc. Several mention home installation of solar as an option, but one that is currently too expensive. This is in line with findings from other surveys, such as the Norwegian electric vehicle user survey [23], showing that clean air and fighting climate change are important reasons for adoption, but the monetary savings from electric vehicles are still the most important reason why people buy electric cars.

"The choices in the survey are way too low. I'd need to save a lot more than 150 Euros if I were to release control to the DSO."

"I'd need to save a lot more than what the questions in this survey suggest for the investment in smart home equipment to pay off."

"There should be better incentives for a gradual replacement of old technology…such as better grid tariffs."

Storage capacity is also mentioned as important:

"Cheaper solar and maybe battery storage would make this a priority, but without the possibility to store generated electricity for later use yourself, it is too costly… Or maybe the DSO "borrowing" your solar energy [when generated in the summer] and delivering it back to you for free later [in winter, when needs and prices are higher] could work"

Others point out that that smart home technology is too expensive for some (as reflected in the income question in the survey):

"Those with a lot of money can afford to do all kinds of things and are rewarded with money for doing it, but others can't afford to invest in power-saving technology. So this pricing of maximum effect used will hit the poor hardest."

3) Users are happy to invest in power saving smart homes but prefer to be in control

This is by far the topic most commented on, which is not surprising given that we asked about incentives for allowing others to control the use of electricity in people's homes. The conclusion seems quite clear, both from the free text answers and the survey: Most users are interested in lowering their electricity use and keeping costs down, but they are not comfortable allowing the DSO or other parties to control this. They list several reasons:

Lack of trust is a recurring issue. In Norway, cheap electricity used to be seen as a common good, where prices were kept low so people could stay warm in the cold winter. After deregulation in the 90's/00's and the establishment of the Nordpool electricity market, however, prices have fluctuated a lot more, and the media covers every price raise. This seems to have led to a lack of trust in the market and Transmission System Operators (TSOs) in particular:

"Energy companies will never be allowed to control anything in my house. They have shown time and time again they can't be trusted, with their hidden terms and conditions."

"The DSOs…have neglected investing in the grid for the past 25 years while paying out hundreds of millions to shareholders. It's time they step up, without shoving the [financial] burden on to consumers."

"I don't trust them. What if something goes wrong?... and if the system is able to cut costs, that won't get back to consumers."

Privacy and security issues are also mentioned as reasons for not allowing outside control.

"privacy issues…if something is to be controlled, or data stored, who has access and for what purpose? How are data kept?"

"I don't want anything in the cloud or stored on external servers. (there is no Cloud - it's just someone else's computer)."

Technology not perceived as mature. Some raise concerns that the technology just isn't ready yet, or not stable enough.

"What happens when the DSO system suddenly crashes, and you have no electricity in your car, no hot water, no heating?"

"I have tried to turn control over to a third party but found the technology was just not mature yet."

"I have the hub from [producer name], and while it is ok to use, it is a bit complicated. I think regular users with little interest in technology would struggle with setting up conditions and rules".

4) Social aspects.

Finally, we see some comments regarding social and societal aspects. One respondent says, "this is mostly for people with interest in technology. There's no way I can get my family on board with these things" – a statement supported by the fact that 95% of the survey respondents are male. Others are concerned with sustainability and are positive towards efforts that visualize their carbon footprint:

"It is just as important to inform and visualize the greater good, for example, by creating a community for those who allow the DSO to take control and show what this effort does in terms of energy-saving."

"I would like to see my carbon footprint and how [smart technology] contributes to a more green and sustainable consumption of electricity."

 ISBN: 978-1-61208-896-9

V. CONCLUSION AND FUTURE RESEARCH

In this paper, we have reported the findings of a survey on incentives for allowing the DSO or other third parties to control household electricity use through smart grid/smart home technology. The survey was aimed at early adopters of technology, as this is the group who so far seems to have invested the most in this kind of technology, and also are more reflecting on issues related to electricity use.

The responses show there is a lot of interest in this issue, with more than 200 replies in just a few days, and over 50 free text comments elaborating on the answers, as well as comments directly in the forums and Facebook posts used to recruit respondents. The main finding is that smart home users are interested in saving money by controlling household energy use, but they are unwilling to allow third parties to take control. Monetary incentives seem to be the most important, with most saying they need to save more than € 150 a/year for each of the categories listed in the survey.

For practitioners, our survey shows that to make the grid smarter and control household consumption in peak hours, the consumer needs to be rewarded enough to offset the resulting lack of flexibility. Trust seems to be a barrier, so there is a need to address this by clearly showing how and how much households benefit. Finally, we see a great deal of interest in this area. It seems many consumers (at least in the demographics who responded to the survey) are willing and eager to save on their electricity bills through smart home technology.

For researchers, the free text answers and comments reveal some emerging themes, which should be topics of future research on smart grids and user acceptance:

- The cost of grid access, use, and smart home technology is a barrier to investment
- Ideology and sustainability are important, but money comes first
- Users are happy to invest in power-saving smart homes but prefer to be in control
- The technology is not yet perceived as mature.
- Social aspects, including sustainability and gender differences, are important

The lack of trust and reluctance to surrender control and flexibility to the DSO could perhaps be offset by more localized initiatives, such as the neighborhood approach proposed by the Smart-MLA project, where an aggregator acts as a broker between consumers and DSO. Figuring out how to organize this is also a topic for future research.

Finally, the responses are skewed towards males with a relatively high income and deliberately aimed at early adopters. Future research should aim to examine the views of the wider population, including the late majority attitudes towards ease of use. While our early adopter sample prefers to build their smart home systems or tinker with complex settings and adjustments, user research has shown this is not the case for most users.

ACKNOWLEDGEMENT

This work was supported under the ERA-Net Smart Grids Plus scheme Grant number 89029 and funded through the Research Council of Norway Grant number 295750 with the project title "Multi-layer aggregator solutions to facilitate optimum demand response and grid flexibility."

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 ISBN: 978-1-61208-896-9