Unfulfilled promise: social acceptance of the smart grid

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Keywords: smart grid, social acceptance, smart meters

Abstract

Smart grids use digital information technology to simultaneously increase energy efficiency while integrating renewables into the electric grid, making it a critical component of achieving a low-carbon energy system. Prior research on the social acceptance of smart grids has relied on either single time point assessment (i.e. prior to a smart grid rollout) or experimental and lab settings. These approaches miss key aspects of social acceptance because they fail to capture change over time through the interaction between stakeholders, technology, and utilities. In contrast, we compare two waves of survey data on the social acceptance of smart grid technologies, the first (n = 609) prior to a local rollout of a smart grid program in upstate New York and the second (n = 533) two years after the same rollout. Our results demonstrate that in contrast to the hopes of smart energy advocates, the social acceptance of four dimensions of smart grids either remain steady or decline over time. Further analyses reveal that the factors that shape acceptance also change over time. This study demonstrates that the social acceptance of smart grids may actually decrease over time even with the robust engagement of consumers, not only challenging optimistic views of smart grid technology but also challenging broader theoretical arguments in the literature on the social acceptance of energy technologies.

1. Introduction

Achieving net-zero greenhouse gas emissions while addressing grid reliability and energy conservation requires numerous innovations across the energy sector (Clack et al 2017, Davis et al 2018, Jenkins et al 2018). Along with a host of technological innovations in energy production, substantial innovations in demand-side management—how energy is used, monitored, and interacted with—are also needed (Delucchi and Jacobson 2011, Millward-Hopkins et al 2020). One critical innovation in demand-side management is the deployment of a smart grid. A smart grid generally includes the implementation of (near) real-time pricing, smart appliances that respond to time-variant pricing, and energy use feedback, all of which rely on the integration of digital information technologies through advanced metering infrastructure (i.e. smart meters) (Gungor et al 2011). These innovations help utilities and consumers collectively solve several production and consumption problems, including integrating variable renewable energy into the grid, improving energy conservation, and strengthening grid reliability.

Social scientists have long argued that energy innovations, including smart grids, must be socially accepted to succeed (Goulden et al 2014). That is, stakeholders (e.g. the public, or consumers) must be willing to use these technologies or accept their use by others. While social acceptance research has addressed smart grid technologies in a limited fashion, two problems are apparent in the existing literature: (a) most studies tend to occur prior to implementation or in an experimental or lab setting, and (b) studies tend to examine the social acceptance of smart grids—or any other energy technology—at only one time point, thus failing to capture how acceptance shifts over time (see Gimpel et al 2020 for further discussion of these limitations). Taken together, these limitations constrain our ability to understand (a) whether the public will accept smart grids in practice and (b) the temporal pattern of social acceptance of energy technologies generally.
To overcome these methodological constraints, we use a two-wave survey to examine support for four aspects of a smart grid initiative led by New York State Electric and Gas (NYSEG). The first wave of the study was performed several months before the initiative began in 2016, while the second wave took place in 2019, over a year after the program was implemented. Using a longitudinal analysis, we show that the social acceptance of four dimensions of smart grids remained constant (two dimensions) or decreased (two dimensions) over time, while the factors associated with acceptance change considerably over time as well. Our results have two major implications: declines in social acceptance (a) challenge optimistic views on a user-centered smart grid and (b) demonstrate how examining social acceptance of energy technologies over time can produce additional insights not captured by single cross-sectional analyses.

1.1. Social acceptance and the smart grid
Energy utilities have begun to use digital information technology to implement a smart grid. While a smart grid involves many components, it fundamentally relies on the use of digital information technology to facilitate two-way communication between energy consumers, utilities, and energy producers (Fang et al 2012). The core infrastructural component of a smart grid is the smart meter, which enables the flow of information upon which other services and innovations are built (e.g. access real-time energy use information and real-time pricing). For the public, a smart grid creates several possible energy practices that previously did not exist. While time-varying energy rates have existed for some time, a smart grid allows for rates to vary by market conditions, with this information being passed to the ratepayer in real time. This has substantial benefits for the grid itself but can also allow ratepayers to save money by managing when they use energy (Faerber et al 2018). One way that ratepayers can save money is by purchasing smart home energy technologies such as smart grid enabled thermostats that can manage home heating and cooling automatically based on market energy rates (Wilson et al 2017). Ratepayers can also access detailed energy use information enabled by fine-grained data collection that can help them better manage their energy use (Dam et al 2010). Smart grids are also critical for integrating renewable energy and enabling distributed generation microgrids (Wolsink 2012).

As Goulden et al (2014) note, a smart grid requires the integration of users in the management and control of the system. Unlike the existing system of energy production and consumption, a smart grid obscures boundaries between producers and consumers by making consumers active managers of the energy system. This occurs through the provision of real-time, accurate energy production, cost, and use information in a centralized system, but also in the management of distributed generation microgrids. In distributed generation microgrids, user acceptance is fundamental to a system’s success, as users are expected to routinely interact with the energy system to produce and manage energy consumption and production, transforming them from consumers to prosumers (Wolsink 2012).

That users are central to the success of smart grids echoes research on other energy technologies that broadly argue that stakeholders (e.g. consumers) must accept a technology for it to be widely effective. Social acceptance has numerous dimensions but broadly refers to ‘a favourable or positive response…to a proposed or in situ technology or socio-technical system, by members of a given social unit (country or region, community or town and household, organization)’ (Upham et al 2015, p 103). Social acceptance research examines how social groups impacted by the implementation of energy technology think, feel, or behave toward that technology (Wüstenhagen et al 2007). If a technology is not socially acceptable, the public or specific stakeholder groups may oppose it, strongly curtailing or altogether stalling the implementation of the technology. Research in this area tends to focus on how nearby communities respond to new energy production, i.e. the physical siting of wind, nuclear, solar, or other energy sources (Gaede and Rowlands 2018, Boudet 2019).

Scholars have explicitly argued that social acceptance is crucial to the success of smart grids (Gaede and Rowlands 2018). Similar examinations have covered specific aspects of smart grids, including smart meters (Bugden and Stedman 2019), demand-response pricing programs (Stelmach et al 2020), and smart home appliances, among other consumer-facing technologies (Ji and Chan 2020). Challenges to smart grid initiatives driven by low social acceptance have been observed in rollouts in Europe (Sovacool et al 2017), where low levels of acceptance have driven substantial pushback from customers. Low levels of social acceptance can also lead to disengagement with the consumer-facing aspects of the technology, reducing the effectiveness of the system as users tune out—or even resist—and the co-management of production and consumption fails. Evidence from previous smart grid initiatives suggests that they are unlikely to succeed unless they adequately engage consumers (Kaufmann et al 2013).

Evaluating the social acceptance of smart grids requires evaluating the underlying dimensions of acceptance. A smart grid involves smart infrastructure (e.g. smart meters), time-variant pricing (e.g. real-time electricity pricing) in-home technologies that interact with the grid in real-time (e.g. displays and appliances), and the ability to monitor and respond to energy use information through digital portals. Research shows that the social acceptance of
smart grid technologies is based on a range of underlying concerns. Bugden and Stedman (2019) synthesize the existing literature on these technologies and examine how they influence social acceptance, forming the basis for the ensuing analysis. They show that factors such as procedural fairness, climate change risk perceptions, price consciousness, and support for renewable energy are associated with the acceptance of smart grid technologies. While an inability to directly test causality precludes us from definitively stating that these factors cause the social acceptance of smart grids, we do assume that these factors precede social acceptance in theory and thus would shape social acceptance rather than the opposite.

While past research has examined factors that may influence the social acceptance of smart grids, what is most important for our purposes are methodological concerns. Following a review of the literature, it does not appear that any social acceptance research on smart grids or their component technologies has ever been examined over time. Several studies have used lab and experimental settings, which partially capture learning and interaction, but they fail to capture the real-world experience of living within and interacting with a smart grid (e.g. Chen et al 2017). Other studies rely on representative surveys based on hypothetical experiences with smart grid technologies and are taken at a single point in time (e.g. Wilson et al 2017). The failure to examine social acceptance over time is theoretically problematic. Social acceptance is fundamentally a temporal process rather than a fixed event, with acceptance being determined over time through interactions between stakeholders and technology (Wolsink 2018). For instance, Wolsink argues that the social acceptance of energy technology tends to follow a U-shaped pattern, declining initially and then increasing following implementation (Wolsink 2007). As such, single time point examinations cannot, by design, demonstrate social acceptance. Examining social acceptance at a single time point does not show whether acceptance increases or decreases as stakeholders learn, adapt, and interact with each other, with the technology itself, and with the institutions that govern it. Taken together, limitations in the existing literature suggest that methodological choices have limited our understanding of social acceptance of smart grids in important ways.

This study addresses two core research questions and expands on earlier results presented in Bugden and Stedman (2019). By examining how social acceptance of smart grids changes over time—and how the factors associated with it change as well—we can obtain a clearer picture of how users engage with future smart grid initiatives. As such, our research questions are stated as:

(a) How does acceptance of the smart grid change over time?
(b) How do the factors associated with acceptance of the smart grid change over time?

2. Methods

2.1. Study context

This study takes place in Ithaca, New York, and the surrounding area from 2017 to 2019. During this time, homeowners were part of the regional utility company’s ‘Energy Smart Community’ (ESCC) and its ‘Grid Upgrade Area,’ meaning that in mid-2017, residents living in this testbed (approximately 12,000 households overall) had smart meters installed on their homes. In addition, the regional utility, NYSEG, began to advocate for time-of-use pricing, implemented a home energy manager that provided consumers detailed energy use data on their home, and began offering a range of incentives for smart home energy technologies and even created an online market through which consumers could purchase many of these products. The ESC is a pilot program for NYSEG and its parent company, Avangrid, to model an integrated energy system that can serve future needs. NYSEG partnered with both Cornell University researchers, Cornell University Cooperative Extension, and several local organizations to promote and develop the project. NYSEG sponsored a large informational campaign that not only informed direct mail efforts but also peer-to-peer communication and engagement through their Energy Navigator program. The program places residents through a 10 week training program to turn local residents into resources for helping to transform their communities’ use of energy.

2.2. Survey data

Prior to the program rollout in 2018, we implemented a four-wave mail survey with a random sample of 2000 homeowners in the rollout footprint. The sample was provided by the regional utility. The four-wave approach involved first sending a copy of the survey with a cover letter, followed by a reminder one week later, a reminder and an additional copy of the survey a week after that, and then a final reminder 1 week after that. A total of 609 homeowners completed the survey for a response rate of 30.5%. This response rate suggested the need to test for nonrespondent bias by conducting a telephone survey of nonrespondents using a subset of critical variables (Stedman et al. 2019). Analysis of the nonrespondent data indicated no meaningful differences between the respondents and nonrespondents, suggesting that our respondents are representative of the original sampling frame. The full mail survey took approximately 10 min to complete, and no incentives were offered for completion.

Two years later, we administered a second survey using the same sampling frame. In addition, we
also resurveyed the respondents from the first survey. Following the same procedure, 533 surveys were returned out of 1500 for a response rate of 35.6%, with 219 of the original survey respondents completing the second survey. Demographically, the sample for the second survey does not differ on education, political partisanship, income, gender, or race from the sample in the first wave. As with the first survey, we tested for nonrespondent bias by conducting a telephone survey of nonrespondents using the same variables. As before, analysis of the nonrespondent data indicated no meaningful differences between respondents and nonrespondents.

The outcome of interest in this study is the social acceptance of smart grids. To measure this, we focus on four common technologies and tools enabled by the digitization of energy use: smart meters, time-of-use pricing, energy analysis tools, and smart home technologies. Several covariates, which were found to predict acceptance of these same outcomes in a prior study (Bugden and Stedman 2019) were also included in the survey and are used in the ensuing analysis. These include measures of procedural justice, climate change risk perceptions, price consciousness, and support for solar energy development. A copy of the entire questionnaire instrument can be found in the supplementary material (available online at stacks.iop.org/ERL/16/034019/mmedia).

The first part of the study compares the mean values of the four outcomes previously described between surveys one and two. We then use a series of regression analyses to examine the relationship between the four aforementioned covariates and acceptance over time, comparing results between time one (T1) and time two (T2). For the first outcome—acceptance of smart meters—Ordinary least squares (OLS) regression is used. For the acceptance of smart meters, a composite index of several questionnaire items (alpha T1 = 0.928; alpha T2 = 0.923) is used (e.g. level of agreement with the statement, ‘smart meters would benefit my community’), with values ranging from 1 to 5. For this dimension, acceptance is any value over 3, which is the midpoint in the index. The remaining three outcome measures are recoded from their original four responses (will not use; unlikely to use; likely to use; and have already used) to two categories that combine (a) will not and unlikely to use and (b) likely to use and have already used. Logistic regression is used in the analyses of these outcomes. All models use robust standard errors (RSE).

3. Results

We begin by addressing research question 1: How does acceptance of the smart grid change over time?

Figure 1 compares the mean levels of acceptance over two time periods for each of the four dimensions of smart grids examined here. 95% confidence intervals are included. Social acceptance of smart meters is stable over time, with the average level of support (on a scale of 1–5) in the first survey 3.37 and 3.31 in the second survey. This is arguably unsurprising—smart meters are the least user-facing aspects of smart grids and are more important for enabling services and technologies that users interact with. In the second survey, only 10.2% of respondents had a value below 3, indicating a lack of acceptance. The vast majority of variance, then, was between levels of acceptance.

While most respondents accepted smart meters, acceptance of the other three dimensions was much lower. In the first survey (T1)—prior to the rollout of smart grid initiatives—59% of respondents indicated that they were likely to use or to have already used smart home energy technologies. In the second survey (T2)—following the rollout of the initiative—this number declined to 41%. For time-of-use pricing, the likeliness of using dropped from 75% to 61%. For energy analysis tools, the decrease was from 85% to 68%. However, for only smart home technologies and energy analysis tools, an independent sample t-test indicates a statistically significant decrease between T1 and T2.

Additionally, we take advantage of the partial panel design enabled by the second survey to directly compare acceptance for the 219 respondents who answered surveys in both T1 and T2. This comparison measures within-subject change, providing a more accurate assessment of change over time than the previously described cross-sectional comparison. Results essentially mirror the cross-sectional comparisons (figure 2). The mean level of acceptance for smart meters was 3.36 in survey one and 3.33 in survey two. For smart home technology, acceptance declined from 57% to 37.5%. For time-variant pricing, acceptance dropped from 74.3% to 63.6%. For energy analysis tools, acceptance decreased from 84% to 65%. As with the prior analysis, the decreases for smart home technologies and energy analysis tools are the only statistically significant differences in a paired sample t-test.

To address research question #1, we find that acceptance either remains stable (for smart meters and time-variant pricing) or decreases over time (energy analysis tools and smart home technology). This is true for both the between-subjects and within-subjects comparisons.

We now turn to research question 2: How do the factors associated with acceptance of the smart grid change over time?

To evaluate how social acceptance is influenced over time, we examine four factors that a previous study using the pre-rollout data found to be associated with social acceptance (Bugden and Stedman 2019). To address this question, we compare the same regression models with respondents from
T1 and T2 (Table 1). This allows us to compare the magnitude, direction, and statistical significance of different factors over time. The results are clear: in each time period, for each dimension, the factors associated with acceptance are substantially and entirely different. For smart meters, concurrent with our previous analysis (Bugden and Stedman 2019), all four of the primary explanatory variables are associated with social acceptance. As respondents are more likely to believe that their
Table 1. Regression results for social acceptance for the T1 and T2 surveys.

|                      | Smart meters T1 | Smart meters T2 | Home tech T1 | Home tech T2 | Pricing T1 | Pricing T2 | Energy analysis T1 | Energy analysis T2 |
|----------------------|-----------------|-----------------|--------------|--------------|-----------|-----------|-------------------|-------------------|
|                      | B (RSE)         | B (RSE)         | B (RSE)      | B (RSE)      | B (RSE)   | B (RSE)   | B (RSE)           | B (RSE)           |
| Procedural fairness  | 0.056**         | 0.076**         | 0.150        | −0.032       | −0.036    | 0.054     | 0.074             | −0.200            |
|                      | (0.022)         | (0.026)         | (0.132)      | (0.140)      | (0.170)   | (0.147)   | (0.211)           | (0.166)           |
| Price consciousness  | 0.064**         | 0.063           | 0.091        | 0.394        | 0.153     | 0.518*    | 0.108             | 0.382*            |
|                      | (0.023)         | (0.036)         | (0.135)      | (0.216)      | (0.158)   | (0.214)   | (0.234)           | (0.198)           |
| Climate risk         | 0.039**         | −0.028          | −0.003       | −0.169       | −0.126    | −0.078    | −0.078            | −0.130            |
| perceptions          | (0.015)         | (0.018)         | (0.088)      | (0.094)      | (0.100)   | (0.099)   | (0.131)           | (0.110)           |
| Solar support        | 0.181***        | −0.058          | 0.434*       | 0.042        | 0.115     | −0.022    | 0.729**           | −0.366            |
|                      | (0.050)         | (0.031)         | (0.203)      | (0.183)      | (0.208)   | (0.181)   | (0.264)           | (0.192)           |
| Constant             | 2.130***        | 3.240***        | −1.575       | −0.615       | −2.166    | −1.128    | 0.487             | 0.274             |
|                      | (0.276)         | (0.307)         | (1.507)      | (1.692)      | (1.744)   | (1.554)   | (2.369)           | (1.851)           |
| N                    | 404             | 311             | 420          | 334          | 419       | 334       | 420               | 333               |
| R²                   | 0.196           | 0.085           | 0.196        | 0.085        | 0.196     | 0.085     | 0.196             | 0.085             |

*p < 0.05.
**p < 0.01.
***p < 0.001.
utility operates fairly and transparently (i.e. procedural fairness), acceptance increases. As respondent’s climate change risk perceptions increase, so does acceptance. As respondents become more willing to adjust their behavior to save money on energy (i.e. price consciousness), so does acceptance. Finally, as support for solar energy increases, so does acceptance. However, 2 years later, only procedural fairness is associated with the acceptance of smart meters.

For smart home technologies, in T1, higher levels of support for solar energy are positively associated with higher levels of acceptance. In contrast, in T2, none of the factors are associated with acceptance. For time-variant pricing, higher levels of climate change risk perceptions are positively associated with acceptance in T1, while in T2, price consciousness is associated with acceptance. Finally, for energy analysis tools, higher levels of support for solar energy are associated with higher levels of acceptance in T1, but only price consciousness is associated with acceptance in T2.

The shifts toward price consciousness in T2 for both the acceptance of time-variant pricing and energy analysis tools suggests that some consumers began to realize the cost-saving opportunities associated with smart grids, even though this was not apparent or prioritized in the pre-rollout phase. The sustained effect of procedural fairness on acceptance of smart meters suggests that procedural concerns are vital as smart grid initiatives are rolled out and that other factors are likely to disappear. While our adjusted r-squared values are relatively low, this is common in social science for theoretically underspecified models and suggests future work should better articulate the precise mechanisms through which social acceptance is produced. Taken together, these results suggest that cost savings and procedural fairness are critical to the success of smart grid initiatives in securing social acceptance from consumers—a result that would not have been observed in a single time-point evaluation.

4. Discussion

This study contributes to both our understanding of smart grid technologies as well as the study of social acceptance of energy technology more broadly. Regarding the former, we show that the social acceptance of smart grids declines and that the factors that are associated with acceptance change over time. That the public becomes less interested in smart grid technologies over time will be troubling for proponents, especially those that advocate for distributed generation microgrids as a crucial component of any future climate-friendly grid. Any smart grid initiative requires consumers to be actively engaged in the use, production, and management of energy. In its less radical form, this implies the use of a centralized energy system that sends signals (price, energy use) to consumers who can adapt accordingly or use appliances and devices to adapt automatically. In a more radical form, advocates of distributed generation microgrids call for a restructur- ing of energy production and consumption, putting users at the center of the process, turning them into ‘prosumers’ (Wolsink 2012, Kubli et al 2018). Our results, which show a decline in user acceptance over time, suggests that even robust efforts along these lines may struggle. It is worth noting, however, that other research suggests that high volumes of smart grid users are not necessary to achieve meaningful effects within the grid (Tchuisseu et al 2017, 2019). Future research on smart grid acceptance should benchmark levels of acceptance against these baseline levels of necessary user engagement.

Results from the regression analyses on the acceptance of smart grid technologies suggest a clear learning process. Prior to the rollout, when salience and knowledge of the technology and the program were lower, the public was far more likely to lean on a heuristic approach to acceptance. That is, the public relies on beliefs about climate change and solar power to shape how they view this new energy technology. The relationships here make intuitive sense—those who believe in the risks of climate change and support solar power base their support for smart grids on their beliefs about the issues smart grids are most directly aimed at addressing. However, over time, the factors that shape acceptance change. In T2, we find that acceptance is driven by an individual’s willingness to take steps to save money on their energy use along with belief in their utility’s treatment of customers (procedural fairness). But why is the emergence of price consciousness simply not additive? That is, why do beliefs about climate change and renewable energy disappear? While we cannot directly test this, it is possible that initial expectations about the climate and renewable energy benefits of smart grids simply did not materialize in this case, leading respondents to no longer believe that smart grids are a useful approach to supporting these technologies.

Beyond the study of smart grids, the aforementioned findings demonstrate how crucial it is for social acceptance research to move beyond single time point analyses and toward longitudinal field tests. While most studies in this area tend to rely on single cross-sectional survey analyses or experimental lab tests, our study captures social acceptance before and after a smart grid initiative was launched. This generated two crucial insights that could not have been observed in a single cross-sectional analysis. First, we show how acceptance changes over time as users interact with the technology and other stakeholders. Second, we show that the factors associated with acceptance are substantially different at each time point. Regarding the latter, if we had relied solely on a single time point assessment prior to the initiative,
we would have come to entirely different conclusions about the factors that shape acceptance. Likewise, the substantial decrease in r-squared values between T1 and T2 indicate meaningful underlying changes in the mechanisms explaining social acceptance over time. This method for evaluating the social acceptance of energy technologies should be used more liberally in social acceptance research to better reflect our understanding of social acceptance as a fundamentally temporal process (Wolsink 2007).

The major limitation of this study is that it is confined to a narrow geographic context. Ithaca, New York is a useful test case for understanding social acceptance of smart grids given its politics and enthusiasm for renewable energy, but a broader test of these findings would determine if they are applicable across cases. Another limitation of this study is that we do not include a measure of familiarity with the four smart grid dimensions. That is, we do not measure how much they learned about each of these dimensions over time. We suspect that familiarity is a key factor in driving both increases and decreases in social acceptance, depending on whether increasing familiarity leads to positive or negative evaluations. Regardless, the model deployed here—evaluating multiple dimensions of smart grids over time, including a pre-test—will prove useful for evaluating social acceptance for a wider range of energy technologies and innovations.

5. Conclusion

The results of this study demonstrate that social acceptance of the smart grid decreases over time, challenging optimistic views on how user engagement with energy supply and demand can transform our energy system. Regression results show that the factors shaping acceptance also change over time, suggesting that our theoretical understanding of social acceptance of energy technologies is likely biased toward analyses that focus on hypothetical rather than actual experience with said technologies. Future research should focus on using longitudinal analyses to develop theoretical explanations of social acceptance of energy technologies that capture the time dimension with a focus on learning and interaction.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

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