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A synthetic view of acceptance and engagement with smart meters in the United States

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ABSTRACT

Smart meters are a crucial infrastructural feature of a modernizing grid. Smart meters enable dynamic rate structures, a wide range of smart home technologies, energy use feedback, and greater use of distributed renewable energy. Yet, ratepayers are often unfamiliar with smart meters and their benefits, have ambivalent or negative attitudes toward them, and may outright oppose their use. Past research has identified numerous factors that influence acceptance and engagement. However, these factors are tested in isolation and only partially representative of the broader literature on energy technologies. In this study, we compare the relative effect of an expanded range of factors on smart meter acceptance and engagement. We use a survey (N = 609) of homeowners in Ithaca, New York who are part of an upcoming smart meter rollout. We find that, ceteris paribus, familiarity and climate change risk perceptions have the greatest effect on smart meter acceptance, while smart meter acceptance, age, and income have the strongest effect on engagement. Our findings have two primary implications: (1) outreach and communication should focus on increasing familiarity and demonstrating the climate benefits of smart meter enabled products and services; and (2) that outreach and communication is insufficient to increase uptake by all segments of the population.

1. Introduction

To reduce greenhouse gas (GHG) emissions and avoid the direst impacts of climate change, industrialized countries must achieve two goals: 1) transition to renewable generation technologies such as wind, solar, tidal, and geothermal energy; and 2) reduce total energy demand [1]. Each of these goals will require changes to the electrical grid [2]. The combination of new technologies needed are often referred to holistically as the “smart grid”. One critical piece of any transition to a smart grid is to implement advanced metering infrastructure (AMI), such as so called ‘smart meters’, to manage electricity generation and distribution. Electric smart meters can be deployed for a wide range of functions that can lead to a reduction in GHG emissions. By sending detailed information about commercial and residential electricity use back to the utility, electricity production can be more efficiently managed, thus reducing total production [3]. Providing detailed information to property owners, often in conjunction with other smart home technologies, helps them to more efficiently use electricity [4–6]. Smart meters facilitate real-time pricing, which can reduce overall energy consumption [7]. Smart meters also facilitate distributed generation [8], thus creating further incentives for property owners to install renewable energy technology on site.

Given smart meters’ potential role in reducing greenhouse gas emissions, an increasing amount of scholarly attention has been paid to them in recent years. Here we focus on the social science-based research on smart meter *acceptance* and *engagement*. By smart meter acceptance we refer to the degree that property owners are willing to have smart meters installed on their property and what they think and feel about it. By engagement we refer to the use of the products and services enabled by smart meters. We consider both, as merely accepting the installation of smart meters is not sufficient to see significant benefits. Ratepayers must be willing and able to engage in the kinds of behaviors that smart meters enable for significant benefits to accrue. Smart meters themselves do little to curb energy consumption; rather, they are merely vectors for behavioral change [9].

Social scientists have identified a number of barriers to smart meter acceptance and, to a lesser extent, engagement. These include trust in industry, familiarity, a sense of procedural fairness, and concerns related to privacy and cost. However, these studies tend to evaluate these factors in isolation, and as such, no synthesis has been done to evaluate which factors have the *greatest relative impact on acceptance and engagement*. Consequently, we compare the relative effect of factors predicted to impact smart meter acceptance and engagement. What’s more, we expand on research on smart meters specifically by incorporating

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research from a wider range of energy technology studies that have heretofore been unincorporated into studies of smart meter acceptance and engagement. Simply, we do not know which factors have the *strongest and weakest* effect on acceptance and engagement, only that there are many factors that exhibit some effect. The summative contribution of this study, therefore, is to test an integrated and expanded model of smart meter acceptance and engagement that may assist policymakers and scholars in better designing smart meter programs to increase the GHG reducing effects of the technology.

2. Literature review

2.1. Social acceptance and engagement with energy technology

In order for the benefits of smart meters to be realized, customers must be willing to accept this technology. Opposition to implementation, as is found in other forms of energy development [10], can slow or halt development altogether. In the case of smart meters, it may also lead to less engagement with the technology. While utilities and government have often assumed that high general support for certain energy technologies will lead to seamless implementation, this has not been the case [11]. Support for energy technologies within a community or by impacted consumers is typically referred to as "community acceptance" [11], which is defined as "the specific acceptance of siting decisions and renewable energy projects by local stakeholders, particularly residents and local authorities." (pg. 2685). Wolsink [12] points out that acceptance tends to follow a U-shaped curve, with acceptance high in the early phases of the project, declining during the siting process, and then increasing after implementation.

Evidence from previous rollouts suggests that the widespread implementation of smart meters is unlikely to be successful unless it adequately addresses the perspectives of consumers [13,14]. In Europe, notable controversies have occurred over mandatory rollouts of smart grid technology [15]. Though a more limited amount of research has been conducted on acceptance in the United States, in 2009, as part of the American Recovery and Reinvestment Act (ARRA), federal funds were poured into implementation of the smart grid [16], with 4.5 billion dollars coming directly from the ARRA, making issues of implementation directly relevant to the U.S. context. In a meta-analysis of 100 smart meter pilot programs containing almost 450,000 European consumers, a 2011 report by Empower Demand [17] concludes:

> "During piloting, there can be a technological focus or a preconceived opinion that the technology is what decides program success. Our findings challenge this focus. The main difference we found between pilot success and failure is the ability of the program designers to meet consumer needs through the demand side program. Meeting a need is the foundation of consumer engagement and thereby of a program's success. The technology is the enabler within this value chain." (pg. 62)

Opposition as a form of obstruction is not the only negative outcome of a smart meter rollout. The strongest climate change mitigation effects of smart meters require that homeowners engage with the technology and use the products and services it enables to reduce their energy consumption, including the use of smart home technologies, adapting to dynamic pricing, or using energy analysis tools that allow ratepayers to voluntarily adjust their own behavior. Compared to *acceptance*, far less research has considered the social psychological factors—that is, the non-economic factors—that shape *engagement* with the technologies and services that meters enable. This not only has implications for accessing the benefits of smart meters but may also play into the response to rollouts of the technology. As Goulden et al. [18] argue, "…smart grid designs must look beyond simply the technology and recognize that a smart user who is actively engaged with energy is critical to much of what is proposed by demand side management." (p.21) Simply, understanding the factors that influence whether and how ratepayers engage with smart meters after their installation is equally as critical as understanding the factors that shape their general acceptance of the technology's presence in their homes.

In the review that follows, we turn our attention to the factors that may influence customer technology acceptance and engagement. We review research that directly examines smart meter acceptance and engagement while also considering alternative factors that have yet to be applied to the topic. In doing so, we present eight hypotheses describing the relationship between social psychological factors and acceptance and engagement with smart meters.

2.1.1. Privacy

Some customers believe that smart meters lead to a loss of privacy by providing detailed information about household behaviors. As such, beliefs about how smart meters may expose consumers to violations of privacy are a critical factor in acceptance [19–21]. Quinn [22] identifies four types of privacy concerns related to smart meters: individual patterns, real-time surveillance, information detritus, and physical invasion. Individual pattern concerns refer to the ability of any person with the data to determine a person or household's general behavior based on, for instance, the use of appliances such as a hot water heater. Real-time surveillance concerns refer to the ability of a person or group to monitor behavior as it happens, either a utility or a person who has hacked into the network. Information detritus concerns refer to the sale of information to a third party. For instance, the utility could sell this information to other corporations or to law enforcement. This is not uncommon, as companies frequently sell business records, which in most cases in the United States are not covered under the fourth amendment of the constitution [16]. In the E.U., smart meter data is classified as personal data and therefore protected from resale [23]. Physical invasion concerns refer to the ability of anyone in control of real-time data to determine if a property is occupied for the purpose of illegal activity such as burglary or arson. Scholars have suggested that privacy concerns can be reduced by implementing "privacy friendly" alternatives, for instance by decreasing the granularity of the data collected by the smart meter [23].

Privacy concerns are directly linked to the issue of trust. Customers who do not believe that utilities can be trusted to secure their personal information are less likely to support smart meter implementation [15]. Therefore, we fold privacy concerns into procedural fairness concerns, as trust is a key component of procedural fairness, as we discuss below.

2.1.2. Procedural and distributive fairness

As has been demonstrated repeatedly, concerns over procedural fairness have a significant effect on the acceptance of energy infrastructure [24–26]. Procedural fairness generally refers to access or representation in decision-making processes and the power (or lack thereof) to influence them [26]. Colquitt and Rodell [27] define fairness as the "global perception of appropriateness" (p. 188), and it may include dimensions related to consistency [28,29], trust [30], respect [31,32], ability to influence the final agreement [33] and control [34].

One particular sub-characteristic of importance in perceptions of procedural fairness is trust. Trust is particularly important in situations where familiarity with a technology is low [35]. Trust in this case operates as a heuristic in the intuitive mode of information processing characteristic of dual-process theories [36]. It is also likely to influence perceptions of risks and benefits [37]. Research on social acceptance of carbon capture and storage technologies has found that local residents, lacking familiarity or interest in the project, tend to delegate responsibility to organizational actors (e.g. industry, government), particularly those who they trust [38]. Trust has been identified as a central factor in the technological transition to a smart grid technologies [19–21,39].

The perceived distribution of risks and benefits from smart meter technologies is likely to play a key role in the acceptance of this new technology, or what is often referred to as distributive fairness. Distributive fairness may be conceptualized as a balance in the risk and