Original research article

Between the technology acceptance model and sustainable energy technology acceptance model: Investigating smart meter acceptance in the United States[☆]

Chien-fei Chen [a,*], Xiaojing Xu [a], Laura Arpan [b]

[a] NSF Center for Ultra-Wide-Area Resilient Electrical Energy Transmission Networks (CURENT), Department of Electrical Engineering and Computer Science, The University of Tennessee, Knoxville, United States
[b] School of Communication, Florida State University, Tallahassee, FL, United States

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ABSTRACT

This study investigated a set of social-psychological predictors affecting smart meter support and adoption intention based on the Technology Acceptance and Sustainable Energy Technology Acceptance Models among 711 U.S. residents. Despite low levels of adoption in the U.S., this study suggested that the majority of our participants supported smart meter technology and were willing to adopt this technology. Two perceived technology attributes – usefulness and risk to privacy – had direct effects on support for smart meter installation and adoption intention, while the other technology attribute, perceived cost, had no impact. Individual differences in trust in one's utility company and problem perception related to energy issues affected support and adoption intention through the mediators of perceived usefulness and privacy risk. Problem perception also had direct effects on support and adoption intention. Democrats reported higher levels of trust in utility companies and problem perception than non-Democrats. This study provides useful insights for utility managers, researchers and policy makers.

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1. Introduction

Recently, the application and acceptance of smart meter (SM) technology has been widely discussed among researchers, community members, industry, and policy makers. A smart or advanced meter is an electronic device that can record detailed electricity usage for time intervals of one hour or less and can send the information back to the utility via the feature of two-way communication, allowing utilities to respond to the data [1]. In 2014, electric utilities in the United States (U.S.) had installed 51,710,725 SMs in the residential sector; however, the majority of households still do not own them [2,3].

The U.S. government promotes installation of SMs as a way to help consumers monitor their energy use and spending. Researchers projected an energy consumption saving of 5–15% with

different types of feedback programs through SMs [4,5]. In general, environmentally conscious residents can reduce their carbon footprint more efficiently with SMs. Furthermore, SMs can help utility companies offer and manage Demand Response (DR) programs, which encourage customers to reduce energy consumption when the demand and the market price is high and power system reliability is jeopardized [6]. A successful DR program with SMs can help decrease the overall need for building new power generation and transmission infrastructure, which, in turn, reduces energy waste and carbon emissions [7]. Specifically, energy savings at the system level, as a result of reducing incremental capacity, transmission, and distribution investments, will benefit the environment in the long run [8].

Previous studies of SMs have focused on engineering aspects, such as data security, potential energy load reductions, or the effect of different energy tariffs on the extent to which consumers value SMs [9]. A growing number of studies, however, have recently focused on public acceptance of SMs in the U.S. [10–13]. Despite the usefulness of SMs to balance electricity load and reduce costs, strong negative reactions toward SMs among some American citizens and interest groups have limited or slowed SM installations in some areas [12,14]. Concerns about threats to personal privacy, negative health effects from radiation [10], and possibly increased

electricity bills [15] have been identified as some of the major causes of objections to SMs in the U.S. In short, there seems to be significant variation in public perceptions of the specific attributes (e.g., perceived risks and benefits) of SMs that are influencing adoption rates. Therefore, increased understanding of factors predicting perceptions of SM attributes can potentially facilitate the widespread implementation of SMs as well as effective energy-saving and DR programs.

When attempting to predict the acceptance of SMs in the U.S, we suggest it is important to consider how individual differences, such as political orientation and trust in utilities, influence perceptions of technology attributes (e.g., risks, benefits, costs), which, in turn, predict adoption intention and behavior. For example, several scholars have suggested that the concept of trust plays an important role in the acceptance of new/sustainable energy resource technologies, such as nuclear and wind power [16] (also see [17]). Individual differences in trust in utilities also seem to be of particular relevance to how SMs are perceived, given documented consumer concerns about privacy. Additionally, many energy and environmental issues have become highly politicized in the U.S., and SM adoption seems to be susceptible to such politicization. Evidence indicates a link between political affiliation and problem perception regarding energy, climate change, and other environmental issues in the U.S. Finally, demographic variables can have a significant influence on energy-related behaviors as well as adoption of new technologies. Accordingly, we consider these factors in our model predicting SM support and adoption intentions.

2. Theoretical framework

Previous studies have drawn on a variety of theories and models to examine the determinants of adoption of SMs. Some have focused more on cognitive factors, using the technology acceptance model (TAM, described below) or a combination of TAM and the Theory of Planned Behavior (TPB) [18,19]. Other studies have focused more on affective and motivational factors, such as those included in self-determination theory [20]. Others combined multiple theories to build models that uniquely suit the SM context, including combinations of TPB, the norm activation model (NAM), and organismic integration theory (a motivational theory) [21,22]. A comparatively more holistic and integrated approach has been recently suggested, based on existing theories and empirical evidence (e.g., the Sustainable Energy Technology Acceptance model, SETA, which we later discuss in detail). Among the aforementioned studies, a few were empirical, while most were speculative. A review of these previous studies of SM adoption suggests that there seems to be no consensus on the most appropriate theoretical approach to predicting or modeling SM adoption. However, we suggest that, in order to better predict SM adoption in the U.S., theories or models that include individual differences particularly relevant to the U.S. context, such as problem perception related to energy-environmental issues, trust in the technology provider, as well as political orientation (or related variables such as values or worldviews) should be employed. Further, more complete models that examine how perceptions of technology attributes might mediate the influence of these individual differences on adoption and support for SMs can potentially better predict SM adoption intentions. The current study tests such a model.

Given that SMs are a technological device that do not directly influence energy use or environmental impacts (as compared to, for example, a dishwasher or air conditioner) but rather help individuals manage energy use, expenditures, and behaviors through in-home displays, websites, or smartphones, the TAM seemed to be an appropriate model upon which to base a study of perceptions of SM attributes. Accordingly, this study relied predominantly on the TAM [23] as the general theoretical framework, supplemented by the newly proposed SETA model [16], described below, based on the latter's emphasis on environmental issues and technologies.

The TAM was originally proposed for information technology (IT) and is now considered as one of the most influential models widely applied to explain how users accept and use various technologies [24–26]. The TAM in its original form predicted that behavioral beliefs about usefulness and ease of use are the primary determinants of individuals' attitudes toward using a particular technology or system, which in turn impact their intention to use and/or engage in the actual behaviors afforded by the technology [23].

With the rapid introduction of new technologies, it has become more difficult to predict consumers' behaviors; that is, perceived usefulness and ease of use may not fully explain users' motives or attitudes [24]. Accordingly, a growing number of recent studies have proposed that additional factors such as habits, enjoyment, motivation, attitudes, computer self-efficacy, social influence, and demographics are associated with technology acceptance [24,26]. Extensions of the TAM have also included perceived cost (or price value, the perception that the benefits exceed the monetary costs of the technology) as an important predictor of acceptance [26]. With respect to SMs, perceived usefulness and cost of the technology could be more relevant predictors of adoption than perceived ease of use, because in many cases, the technology serves mainly as an indicator of electricity consumption or as a communication tool with the utilities. Specifically, consumers do not physically use SMs themselves [27]. Consumers can certainly monitor their energy use through an in-home display, which is sometimes provided with an SM but is not a part of an SM [28]. Therefore, it might be difficult for consumers to accurately estimate the ease or difficulty of "using" SMs.

Perceived costs are also included in the SETA model [16]. The SETA model includes variables adapted from TAM but adds others, such as trust in technology providers, knowledge, perceived risk, values-driven predictors (such as problem perception and a personal moral norm), and affective reactions (positive vs. negative) to the technology. Data on fairly strong public and political opposition to SM installations in the U.S. suggest that trust in SM providers and perceived risks to privacy could significantly predict acceptance [14]. Conversely, knowledge of SMs has not been found to be predictive of acceptance in the U.S., and external influences such as social norms or recommendations from institutions might have limited influence on this particular behavior, given that it is fairly private and seems to be more strongly associated with intrinsic motivations [12,22,29]. Therefore, in order to better understand public acceptance of SMs in the U.S., this study relied on extensions of the TAM and incorporated what the authors believed were the most applicable variables from the SETA model in the current context, specifically trust in the technology provider (the utility), perceived risk (to privacy), and problem perception/awareness (concerns about energy and environmental problems, in this case). Additionally, in the U.S., political affiliation or orientation is typically associated with values that motivate environmental concern [30] and with energy-related attitudes and behaviors [31,32]. Political affiliation has also been associated with opposition to SMs in North America [14]. Therefore, this study especially considered the potential role of political affiliation in predicting perceptions of SM attributes.

Both the TAM and SETA models predict that support for and intention to use a new technology are influenced by perceptions of the technology itself. Based on those models and the specific attributes of SMs, our model hypothesizes that support for and adoption intention will be directly predicted by three perceived technology attributes: perceived usefulness, perceived cost, and perceived privacy risks, as well as by prior electricity curtailment