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Original research article

Between the technology acceptance model and sustainable energy technology acceptance model: Investigating smart meter acceptance in the 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

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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

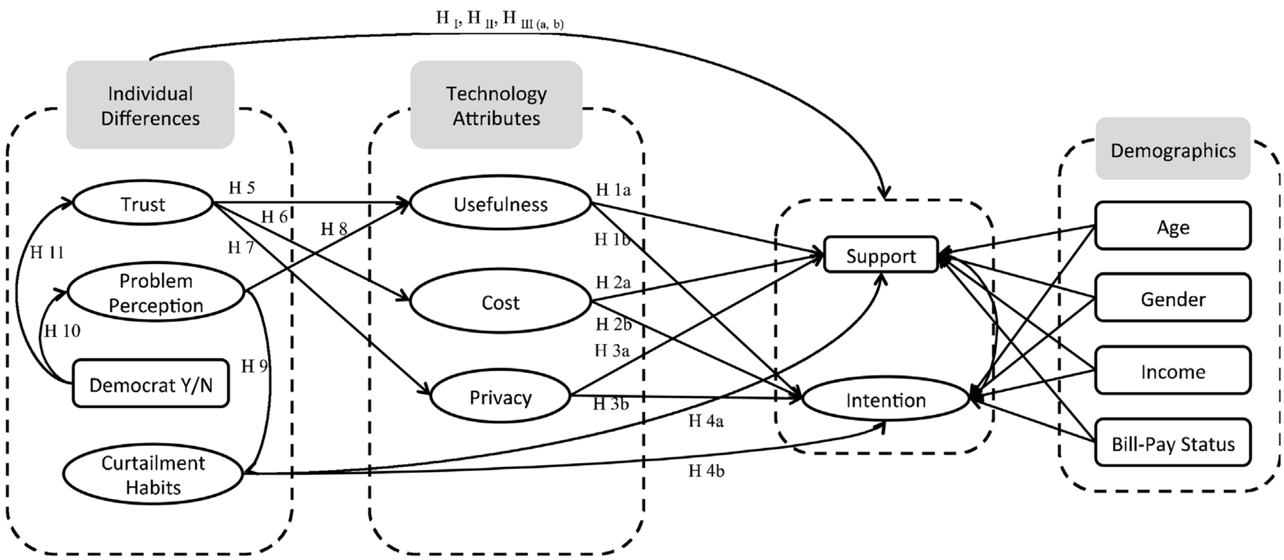

Fig. 1. The Proposed Research Model.

habits. Importantly, individual differences in trust in the utilities and problem perception are predicted to have an indirect influence on SM support and behavioral intention via their influence on the three perceived SM attributes and via prior electricity curtailment habits (see Fig. 1). We attempted to illuminate both direct and indirect effects through the approach of Structural Equation Modeling (SEM).

3. Perceived technology attributes of SMs

3.1. Perceived usefulness

Although perceived usefulness of new technology was originally defined with respect to one's job performance within an organization, the concept now often refers to an individual's subjective assessment of new technology in a specific task-related context [26,33]. The concept has been applied to the study of technologies outside of the organizational context. For example, perceived usefulness has been found to be positively associated with e-commerce behaviors (e.g., [33]) and use of mobile services (e.g., [34]). With respect to SMs, perceived usefulness has been conceptualized as perceptions of the system's ability to enhance energy management tasks, enhance efficiency, produce cost savings, and/or provide real-time information about energy consumption [18,35] and has been found to be a strong, positive predictor of attitudes towards SM technology, which, in turn, effectively predict adoption intention [18]. In the SETA model, perceived usefulness is conceptualized as a benefit of the new technology, which is predicted to be positively associated with acceptance. In line with previous findings and current theoretical propositions, we hypothesize that *perceived usefulness will be positively related to support for SMs (H_{1a}) and intention to use them (H_{1b}).*

3.2. Perceived cost

One of the most common assumptions in predictions of individuals' willingness to adopt a new technology or pay for a service is value maximization, based on the classical economics approach [36]. Extended versions of the TAM include perceived cost (or price value, the perception that benefits exceed monetary costs of the technology) as a predictor of acceptance [26]. SETA also acknowledges the influence of costs, both monetary and non-monetary, on technology acceptance. Perceived cost in this study refers to monetary cost required to adopt technology or to use a service [37]. Studies in consumer behaviors find that perceived monetary cost has a negative relationship with user perceptions and evaluations (e.g., [38]) and is negatively related to intention to adopt new technologies [39,40]. Given the findings of previous research, we hypothesize that *perceived cost is negatively related to support for SMs (H_{2a}) and intention to use them (H_{2b}).*

3.3. Perceived risk to privacy

The SETA model includes perceived risks as a predictor of acceptance. For SMs, a major perceived risk identified in the U.S. is that of privacy [5,39,40], and consumer concerns about risk have been reported by various utility companies [15,42,43]. From the consumer's perspective, privacy concerns revolve around private household activities, lifestyles, and electricity consumption patterns that can be inferred from SM data [40,41,44]. Specific examples include burglars finding out when homes are unoccupied [43], advertisements targeted at specific households or individuals [45], detection of illegal activities or verification of defendants' claims [45], and parents checking on their children's activities [28]. A recent study [46] suggests perceived privacy risk can be particularly detrimental because it increases expectations of a social norm of opposition to the SM technology. Accordingly, this study hypothesized that perceived *privacy risk is negatively related to support for SMs (H_{3a}) and intention to use them (H_{3b}).*

4. Individual differences

Several individual differences can impact household energy behaviors; however, we propose three differences that could indirectly influence support for and intention to use SMs in the U.S., via perceptions of SM attributes: trust in utility companies, problem perception, and political orientation. We also consider the direct effect of prior electricity curtailment behaviors on support and intention.

4.1. Electricity curtailment habits

Individual habits generally predict current and future behaviors [47]. Triandis [48] defined habits as "situation-behavior sequences that are or have become automatic, so that they occur without self-instruction" (p. 204) [48]. Prior habits or experiences with a form of technology can influence users' attitudes toward that technology and future adoption behaviors [26,49]. Additionally, the inclusion of prior energy habits can improve the power of a model to predict future energy usage [28,50,51].

The current study focused on a specific segment of energy conservation behaviors, electricity curtailment behaviors [52]. Curtailment behaviors involve reduction of repeated actions typically associated with the use of household appliances and existing heating, cooling, and lighting equipment [51,89]. Scholars have suggested that engaging in daily curtailment or conservation behaviors without purchasing new or energy efficient appliances can effectively reduce energy consumption [52]. Prior curtailment habits likely reflect an individual's sensitivity to the larger problem (e.g., energy use and its impacts) that can potentially be solved by the technology. Therefore, we hypothesize that *prior electricity curtailment habits are positively related to support for SMs (H_{4a}) and intention to use them (H_{4b}).*

4.2. Trust in utility companies

When consumers are learning about new technologies, including those related to energy, initial acceptance could depend upon trust in those creating or providing the technology [16,17,53,54]. Accordingly, trust in utility companies and other involved parties should influence public attitudes toward SMs [55,56]. In addition, trust has been considered an important factor impacting consumers' affective response towards SM technology [55], which is predicted to be associated with adoption intentions [16]. The role of trust is of particular importance when knowledge of the situation or technology is lacking [57], and this is certainly the case with SMs in the U.S. [12]. In the absence of sufficient knowledge to evaluate technological risks and benefits associated with SM use, trust in one's utility company should have an indirect effect on SM acceptance via its influence on perceived attributes of this technology, such as perceived costs, risks, and benefits [16].

Several researchers have postulated the influence of trust in relevant individuals and institutions on acceptance of SMs [10,55]; however, to our knowledge, this particular type of trust involving the relationship between customers and utility companies has not been explicitly examined as an individual difference predicting SM adoption. In line with previous literature [16], we hypothesize that greater *trust in utility companies will be associated with perceptions of SMs as more useful (H_5), less costly (H_6), and as posing less privacy risk (H_7)*. In addition, we test two mediation effects: *trust will have an indirect effect on support* (H_{I-a}) and *an indirect effect on adoption intention* (H_{I-b}) through perceived usefulness.

4.3. Problem perception

A primary antecedent of pro-environmental behaviors, including energy conservation, is awareness of a problem (e.g., an energy shortage) or need (e.g., need for cleaner energy technology to reduce environmental degradation) that will be exacerbated by inaction [28,58–60]. Such an awareness of consequences or problems leads to pro-environmental or energy behaviors indirectly via feelings of responsibility for the problem and a subsequent personal moral motivation to mitigate the problem [28,59]. In the case of sustainable energy technology adoption, problem awareness (or problem perception as it is termed in SETA – we adopt this term for the current study) can be defined as "awareness of problems related to the current energy system when no new energy technology is implemented and used" ([16], p. 527). Given that energy use has known environmental impacts, problem perception in this context can also include concerns about such impacts [61]. Such concerns have a strong effect on intention to adopt energy-efficient technology, such as solar water heaters and alternative fuel vehicles [62]. Chen and Knight [58] found that, additionally, energy concern (conceptually related to problem awareness) directly influenced attitudes, perceived behavioral control, and injunctive norms in the context of energy conservation, making it an important variable to study further. Additionally, because SMs can possibly reduce energy use (thus mitigating some problems associated with energy consumption), it is also likely that problem perception influences perceptions of the attributes of SMs – specifically, their usefulness (or benefits, in the SETA model). Accordingly, we hypothesize that *problem perception has a positive relationship with perceptions of SMs as useful (H_8) and a positive relationship with prior curtailment habits (H_9).* In addition, we test two mediation effects: *problem perception will have an indirect effect on support for SMs (H_{II-a}) and an indirect effect on intention to use SMs (H_{II-b}) through perceived usefulness and prior curtailment habits.*

4.4. Political orientation

Neither TAM nor SETA in their original formulations explicitly included individual values as a variable that predicts technology acceptance, although Huijts et. al [16] acknowledged that individual traits such as values or worldviews likely affect acceptance. Indeed, values such as altruism and worldviews such as egalitarianism are correlated with environmental concern as well as with perceptions of environmental risks and new technology adoption [28,63–65]. However, data on citizens' values (e.g., biospheric altruism, self-enhancement) or worldviews cannot be easily or quickly procured by utility managers, public interest group leaders, or other decision makers for the purposes of predicting local support for or opposition to SMs. Conversely, data indicating political party affiliation at the state and local levels in the U.S. can be easily and quickly procured by anyone via a variety of publicly available, regularly updated data sets. We suggest that, especially in the U.S., political affiliation can serve as a reasonable proxy for values and worldviews that predict pro-environmental behaviors and environmental concern, given the consistent correlation of political affiliation and/or political orientation with relevant values such as egalitarianism, tradition, security/status quo as well as with environmental concern [30,66–71]. Additional data indicate that political affiliation (likely via the correlation with values and worldviews) can predict problem perception/awareness related to energy and environmental issues in the U.S. Consistent evidence indicates that those with a more liberal political orientation have greater environmental concern (which predicts problem awareness) [65,72–74] and are more likely to believe in anthropogenic climate change than those with a more conservative orientation [66,75]. Political ideology has also been found to be associated with perceptions of the existence and severity of an energy crisis, with liberals perceiving more risks than conservatives [31]. Finally, evidence shows conservative political orientation is negatively correlated with support for investment in energy-efficient technology [32]. Accordingly, we use political affiliation as a proxy for pro-environmental values and concern and hypothesize that *individuals with democratic political affiliation will have a higher level of problem perception (H_{10}).*

Political orientation likely also predicts trust in given actors associated with SM technology because of its association with variables such as environmental concern [76]. For example, political liberalism and associated values tend to correlate positively with trust of others in general and in government entities and to correlate negatively with trust of industry; political conservatism has been found to be positively associated with trust in industry or related institutions that serve to preserve the status quo and embrace hierarchy and social power [67,77–79]. Accordingly, liberals might be more trusting of SM providers if the utility is a government/municipal entity, while conservatives might be more

Table 1
Correlation Matrix among Major Variables.

	1	2	3	4	5	6	7	8	9
1. Support	–	0.75**	0.28**	0.30**	0.64**	−0.25**	−0.40**	.11**	0.11**
2. Intention to adopt	–	–	0.25**	0.34**	0.74**	−0.20**	−0.41**	0.10**	0.10**
3. Trust in utility companies	–	–	–	0.15**	0.34**	−0.24**	−0.31**	0.06	0.09*
4. Problem perception	–	–	–	–	0.30**	−0.09*	−0.15**	0.26**	0.16**
5. Perceived usefulness	–	–	–	–	–	−0.23**	−0.43**	0.07	0.09*
6. Perceived cost	–	–	–	–	–	–	0.27**	−0.02	−0.06
7. Perceived risk to privacy	–	–	–	–	–	–	–	−0.03	−0.15**
8. Prior curtailment habits	–	–	–	–	–	–	–	–	0.04
9. Democratic orientation	–	–	–	–	–	–	–	–	–
M	5.12	5.06	4.59	5.13	5.59	4.36	3.28	5.02	–
SD	1.33	1.33	1.31	1.43	1.08	1.11	1.49	1.25	–
Cronbach's α	–	0.94	0.94	0.93	0.95	0.88	0.93	0.64	–

* $p < 0.05$.
** $p < 0.01$.

trusting if the provider is a corporation. Further, if a utility company is perceived as supportive of environmental policy, then liberals should be more likely than conservatives to trust their utility companies, as liberals tend to be more supportive of pro-environmental policy in general [76]. For the sake of parsimony, we did not investigate such intermediary perceptions of consumers (e.g., whether they believe their utility supports pro-environmental policy), but rather engaged in a more exploratory examination of consumers' overall trust in their utility companies. Accordingly, we hypothesize *political affiliation will be associated with trust in the utility companies (H_{11})* but do not specify the direction of the relationship. In addition, we hypothesize that *political affiliation has an indirect effect on support for SMs (H_{III-a}) and intention to use SMs (H_{III-b}) through trust and problem perception of energy consumption and its environmental impacts.*

4.5. Demographic variables

Previous literature suggest that demographic variables can predict energy behaviors such as household size, gender, age, income, and rent/own status [80,81]. Regarding technology adoption, age, gender, and experiences are important factors related to learning and accepting new technology [26,82]; for example, older consumers have been found to be more likely to have difficulty in learning to use new technologies than their younger counterparts [83]. Accordingly, this study examined the influence of the following demographics on our two dependent variables: age, gender, income, and whether the respondent is responsible for household electricity payment.

5. Method

5.1. Participants and procedure

An internet-based survey was conducted through Amazon Mechanical Turk (MTurk), a crowdsourcing Internet marketplace that enables researchers to collect data on human intelligence tasks rapidly and inexpensively and that is often used by social scientists to collect data [84]. A panel of 711 U.S. residents who reported not having SMs installed in their households was recruited across the states.[1] Among the 711 participants, 59.5% were males, and 39.9% were females. Age ranged from 18 to 76 (*Mean* = 30.6). The majority of participants were White (74.3%), followed by Asian (11.4%), Black (6.1%), and other ethnicities.. Compared with U.S. census data [84], our sample, as most online samples, contained more young and white people. The income distribution was similar except that people with high (>$100,000) incomes (10.6%) were somewhat underrepresented. More participants identified themselves as Democrats (39.9%) than Republicans (15.5%); 30.7% identified themselves as "independent" and 9.6% identified themselves as "apolitical". This discrepancy was somewhat larger than that reported in the U.S. national census data (22.0% Democrats vs. 31.0% Republicans) [85]..

5.2. Measures

All measures except for demographic variables were estimated by participants' responses to the items with a 7-point Likert-type scale.

5.2.1. Dependent variables

5.2.1.1. Support for SMs. Based on previous conceptualizations of support for pro-environmental policies and energy-related technologies [16,25,30], one item was used to measure support: "To what extent do you support or oppose the installation of a SM in every household?"

5.2.1.2. Intentions to adopt SMs. Four items, adapted from a previous measure [86], asked participants to rate how much they agreed or disagreed that "I am likely to use SMs in the near future," "Given the opportunity, I will use SMs in the near future," "I am willing to use SMs in the near future," and "I intend to use SMs when the opportunity arises." The internal consistency across items was high, Cronbach's α = 0.94.

5.2.2. Independent variables

5.2.2.1. Perceived usefulness. Seven items adapted from those used in the TAM [87] assessed the level of perceived usefulness of SMs: "Overall, I find SMs useful in my home," "Using a SM can give me greater control over my energy saving," "SMs can help me avoid wasting electricity," and "Using a SM can improve my electricity saving," "SMs can help me check the accuracy of electricity bills," "Using SMs enables me to monitor energy use more quickly by providing real-time information," and "SMs can encourage others in my home to think about how they save electricity," Cronbach's α = 0.95.

5.2.2.2. Perceived cost. Four items were adapted from those in previous studies investigating the extent to which perceived fees were associated with new technology adoption intention [42]: "The fee for paying for SMs is too high," "The fee for installing SMs is too high," "The fee for paying for SMs is reasonable," and "I would be

[1] Workers on MTurk decided whether to take this survey on their opinions about SMs for a one-dollar payment. A brief description of SMs with neutral language was provided before the survey started. Once workers completed the survey, they received the payment via Amazon.

Table 2
Factor Loadings and Composite Reliability.

Construct	Mean	S.D.	Factor loading	Composite Reliability	Average Variance Extracted
Intention to adopt smart meters				0.94	0.80
I am likely to use a smart meter in the near future.	4.74	1.49	0.84		
Given the opportunity, I will use a smart meter in the near future.	5.08	1.42	0.93		
I am willing to use a smart meter in the near future.	5.39	1.40	0.91		
I intend to use a smart meter when the opportunity arises.	5.01	1.48	0.89		
	Trust in utility companies	0.94	0.80		
I trust my utility company overall.	4.57	1.48	0.96		
I trust my utility company provides good service.	4.91	1.35	0.84		
I trust my utility company cares about their customers.	4.32	1.56	0.83		
I believe my utility company is honest.	4.60	1.44	0.93		
Problem perception				0.93	0.82
I am concerned about the environmental impact due to energy use.	5.12	1.51	0.92		
I am concerned about energy resources.	5.28	1.46	0.97		
I am concerned about energy shortage.	4.99	1.59	0.83		
Perceived usefulness				0.95	0.72
Overall, I would find a smart meter useful in my home.	5.20	1.37	0.82		
Using a smart meter can give me greater control over my energy saving.	5.57	1.26	0.89		
Smart meters can help me avoid wasting electricity.	5.63	1.24	0.89		
Smart meters can help me check the accuracy of electricity bills.	5.64	1.27	0.82		
Using smart meters can improve my electricity saving.	5.63	1.22	0.91		
Using smart meters enables me to monitor energy use more quickly by providing real-time information.	5.78	1.16	0.85		
Smart meters can encourage others in my home to think about how to save electricity.	5.46	1.30	0.73		
Perceived cost				0.87	0.78
The fee for paying for smart meters is too high.	4.30	1.23	0.93		
The fee for installing smart meters is too high.	4.34	1.24	0.84		
Perceived risk to privacy				0.91	0.83
The risk of an unauthorized party misusing smart meter data is low.	3.28	1.56	0.90		
The risk of an unauthorized party misusing personal inform from smart meters is low.	3.25	1.54	0.92		
Electricity curtailment habits				0.66	0.33
Turning off lights when not in use.	6.16	1.08	0.55		
Setting computers to sleep mode when not in use.	5.04	2.06	0.58		
Unplugging electronic devices when not in use.	3.55	2.03	0.61		
Turning off household appliances when not in use.	5.35	1.86	0.55		

pleased with the fee that I have to pay for SMs." The latter two items were reverse-coded. Because both exploratory and confirmatory factor analyses supported a two-factor rather than a one-factor structure, we suspected that the reverse wording of the last two items might have produced this result [88]. Therefore, this study only used the first two items (Spearman-Brown coefficient = 0.88), which resulted in higher commonality, in further analyses.

5.2.2.3. *Perceived risk to privacy.* Two items adapted from Schierz, et al. [86] measured the extent to which participants perceived privacy risks associated with SM data: "The risk of an unauthorized third party misusing SM data is low," and "The risk of an unauthorized party misusing personal information from SM data is low." The ratings were reverse-coded so that higher scores indicated a greater perceived privacy risk. Spearman-Brown coefficient = 0.91.

5.2.2.4. *Electricity curtailment habits.* Items similar to those in previous studies of curtailment [87] asked participants to indicate the frequency of performing each of four behaviors in the past six months, including "turning off lights when not in use," "setting computers to sleep mode when not in use," "unplugging electronic devices when not in use," and "turning off household appliances when not in use" Cronbach's $\alpha = 0.64$.

5.2.2.5. *Trust in utility companies.* Based on Metlay's [90] work, four items assessed the affective and competence components of trust: "I believe my utility company is honest," "I trust my utility company overall," "I trust my utility company provides good service," and "I trust my utility company cares about their customers." Cronbach's $\alpha = 0.94$.

5.2.2.6. *Problem perception.* Three items assessed the extent to which participants were concerned about energy-related problems and environmental impacts of energy use, similar to previous items employed by Steg, Dreijerink, and Abrahamse [91]: "I am concerned about the environmental impact of energy use," "I am concerned about energy resources," and "I am concerned about an energy shortage." Cronbach's $\alpha = 0.93$.

5.2.2.7. *Political orientation.* Political orientation was measured as reported political party affiliation: Democrat, Republican, indepen-

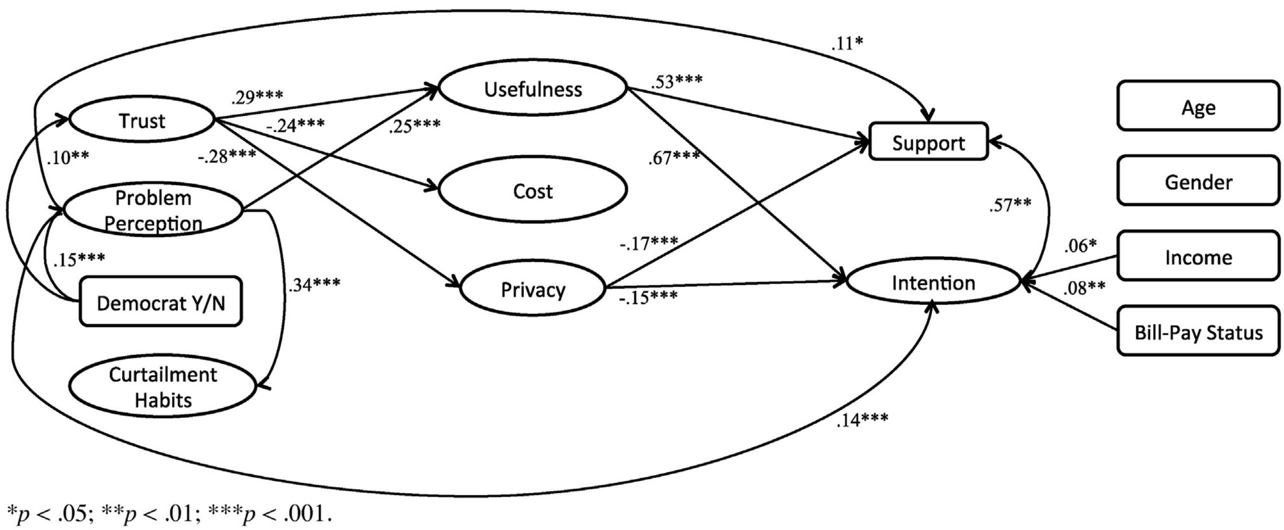

Fig. 2. Structural Model of Factors Affecting Smart Meter Support and Adoption Intention.

dent, or apolitical. For the model analysis, we coded affiliation as a dummy variable, Democrats = 1 vs. non-Democrats = 0.

5.2.2.8. Demographics. Gender, age, bill-pay status (i.e., whether pays non-flat-rate utility bills[2] or not), and income were included as control variables. Gender (male = 1) and bill-pay status (pay non-flat-rate bills = 1) were dummy-coded, and income was treated as an ordinal variable.

6. Results

6.1. Analytic strategy

All descriptive statistics were calculated with IBM SPSS 21, and the SEM depicted in Fig. 1 was tested with M*plus* 6.0 [92] based on the two-stage approach demonstrated by Anderson and Gerbing [93]. In the first stage, all measures were examined for uni-dimensionality, convergent and discriminant validity. In the second stage, path coefficients and the level of significance were calculated to determine the best-fitting model. All models were fit with the maximum likelihood (ML) method. The rationale for using SEM here is as follows [94]: 1) SEM estimates the relationships among variables by adjusting for measurement errors, unlike ordinary least squares (OLS) approaches, which assume that variables have been measured without errors; 2) SEM models include the measurement (e.g., exploratory and confirmatory factor analyses) and structural models (specifies how latent factors are related to one another), which leads to a more rigorous analytic procedure; 3) SEM is a theory-based approach, which is appropriate to measure latent variables as well as direct and indirect relationships; and 4) the hypothesized model can be tested simultaneously with multiple mediators for the entire system of variables [95].

6.2. Descriptive statistics

Results indicated that 82% of participants felt somewhat supportive to strongly supportive of installing SMs in every household, and that 70.46% held a moderate-to-strong intention to install a SM. In addition, 91.16% of the participants felt that SMs were at least somewhat useful, while 21.51% expressed some level of concerns about privacy issues, and 24.19% reported themselves as not trusting their utility companies. See Table 1 for means, standard deviations (*SD*), as well as correlation matrix.

6.3. Measurement model

The overall fit of the measurement model was good: χ^2 (278) = 532.67, $p < 0.001$. CFI = 0.98, TLI = 0.97, RMSEA = 0.04 (0.03–.04, with a 90% CI), and SRMR = 0.03. All items loaded significantly on their corresponding factors (see Table 2) with no meaningful cross loadings. Additionally, the composite reliability (CR) of each latent factor ranged from 0.66 to 0.95, and the average variance extracted (AVE) ranged from 0.33 to 0.83. Except for the CR and AVE of curtailment habits, which were slightly smaller than the values recommended by Hair, Black, Babin, and Anderson [96], all numbers in our model were satisfactory. The results provided evidence of uni-dimensionality of each factor except curtailment habits. However, because results of the factor analysis indicated that a one-factor solution for the curtailment habits measure still out-performed multiple-factor solutions, and because it is not advisable to select items solely based on CR [97], we decided to keep the 4-item curtailment habit measure. The maximum shared squared variance (MSV) and average shared squared variance (ASV) for each factor are smaller than the corresponding AVE, demonstrating good discriminant validity. Therefore, the measurement model was found to be sufficient for further SEM analyses [96].

6.4. Structural relations

Based on the hypotheses, we then fit the model with all proposed relationships, and the overall model fit was good: χ^2 (432) = 863.64, $p < 0.001$. CFI = 0.96, TLI = 0.96, RMSEA = 0.03, and SRMR = 0.08. Fig. 2 shows all significant paths. Results of the SEM model also indicated that support for SMs (Support) and intention to use SMs (Intention) were positively correlated at 0.57, $p < 0.001$.

6.4.1. Direct effects of independent variables

Among all perceived technology attributes, which were hypothesized to contribute to Support and Intention directly, perceived usefulness of SMs (Usefulness) was the strongest predictor (Fig. 2): residents felt more supportive of SM installations and had stronger intentions to use them when they perceived SMs as more useful. Hypotheses H_{1a} and H_{1b} were supported. Perceived risk to privacy

[2] Non-flat rate energy bills fluctuate as a reflection of the actual amount of energy consumed, as opposed to flat-rate bills, for which customers pay a set amount of money regardless of how much energy they consume.

Table 3
Significant Mediation Effects

		Y: Support			Y: Intention		
X	Mediator	Indirect Effect	Direct Effect	Total Effect	Indirect Effect	Direct Effect	Total Effect
Trust	Total	0.22***	0.00	0.22***	0.24***	0.00	0.24***
	→Usefulness	0.15***			0.18***		
	→Privacy	0.05***			0.04**		
Problem perception	Total	0.15***	0.11*	0.26***	0.17***	0.14***	0.31***
	→Usefulness	0.13**			0.16**		
Political orientation	Total	0.06***	–	0.06***	0.07***	–	0.07***
	→Problem perception	0.02*			0.02*		
	→Problem perception → Usefulness	0.02**			0.03**		
	→Trust → Usefulness	0.02**			0.02*		

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

(Privacy) also predicted Support and Intention in a negative and significant fashion, thus supporting H_{3a} and H_{3b}. Perceived cost (Cost), on the other hand, failed to predict either Support or Intention. Curtailment habits also failed to predict Support or Intention.

In terms of the direct effects of individual differences on perceived technology attributes, trust in utility companies (Trust) indeed predicted Usefulness, Cost, and Privacy, supporting H_5, H_6, and H_7. Additionally, problem perception predicted Usefulness and curtailment habits, supporting H_8 and H_9. Further, having a democratic affiliation, as H_{10} proposed, led to a higher level of problem perception, and was significantly related to Trust, as H_{11} predicted. Democrats had greater trust levels in their utility companies than non-Democrats.

Additionally, the demographic variables of age, gender, income, and bill-pay status did not impact support for SMs. However, intention to use SMs was positively associated with paying non-flat-rate electricity bills and household income, although the effects were small.

6.4.2. Indirect (mediation) effects

Table 3 presents all the significant mediation effects. Because the patterns of significant and non-significant paths were the same for Support and Intention, the findings of the indirect effects on these two variables are presented together below. Trust had overall significant indirect effects on Support and Intention, via its influence on Usefulness and Privacy. The indirect effect through Cost was not significant. H_{I-a} and H_{I-b} were partially supported. To determine if Usefulness and Privacy fully mediated the influence of Trust on Support and Intention, we also examined the direct effect of Trust while controlling for the indirect effects, following a standard procedure [94]. Because the direct effects of Trust on Support and Intention, after controlling for all the mediation effects, were non-significant, the effects of Trust on the two outcome variables were fully mediated by the influence of Usefulness and Privacy.

Problem perception also had significant, indirect effects on both Support and Intention, but only the indirect effect through Usefulness was significant; the other indirect effect through curtailment habits was not significant. Therefore, H_{II-a} and H_{II-b} were partially supported. It is important to note that the direct effects of problem perception on Support and Intention, after controlling for the mediation effects, were significant. Therefore, the influence of problem perception on the outcome variables was only partially mediated by Usefulness.

Lastly, political affiliation, as hypothesized, had significant indirect effects on Support and Intention through its influence on problem perception and Trust. Thus, H_{III-a} and H_{III-b} were supported. There were three significant indirect influences of political affiliation on the outcome variables: one via a single variable – problem perception, one via problem perception and its subsequent influence on Usefulness, and the other one via Trust and its subsequent influence on Usefulness.

7. Discussion and conclusion

This study investigated the influence of social-psychological and demographic factors on perceptions of SM attributes, support, and adoption intentions in the U.S., a country in which the technology has encountered significant resistance. One of the main contributions here was the adoption of both the TAM and SETA models to empirically examine how perceived technology attributes and individual differences directly and indirectly influenced the outcome variables. This study's consideration of both direct and mediating effects of technology attributes in one model allows for an in-depth analysis. Importantly, concurrently exploring aspects of individual differences in political orientation, trust in utilities, problem perception, and curtailment habits allows researchers and utilities to further understand possible consumer segmentation and determinants of consumer decisions. Given the increased politicization of many environmental and energy-related issues in the U.S. [32,75] and the potential influence of trust on energy technology acceptance explicated by recent models such as SETA and found in studies of SM adoption, we believe the inclusion of these two individual differences is particularly important when modeling acceptance of SM technology in this context: indeed, they are significant antecedents to most of the variables in the model (we discuss the specific relationships below).

Consistent with previous studies conducted in Korea [19] and Germany [18], perceived usefulness was a positive predictor of SM adoption intention. This finding is also consistent with a research overview in the United Kingdom, Germany and Italy [98], which found that some participants (e.g., Italians) view SMs positively as a good means to frequently monitor energy consumption or to compare the efficiency of household devices, beliefs that are similar to those in our perceived usefulness variable. These findings and the magnitude of the influence of usefulness in this study suggest that successful efforts to enhance such perceptions could significantly increase SM adoption in the U.S. In addition, perceived usefulness was the strongest mediator in our study: its mediation role that has not been much explored by other studies. This finding indicates that the relationships among trust, problem perception, and SM support and adoption intention cannot be well explained without considering perceived usefulness. In addition, our model found a direct influence of problem perception on perceived usefulness of the technology; which is consistent with the previous findings in that intrinsic motivation significantly predicted intention to continue using SMs in Germany [22] and that the problem perception of energy-environmental issues influenced home energy-saving measures and support for government environmental regulations [99].

Consistent with our predictions and previous studies in Korea [19] and in some European countries [97], perceived privacy risk of the technology was negatively associated with acceptance of SMs, indicating a need to address privacy concerns in order to increase adoption. Interestingly, our participants generally trusted their utilities, but were fairly concerned with unauthorized third parties' misuse of SM data or personal information. Accordingly, we suggest that, prior to SM implementation, utility representatives widely publicize procedures for data recording, storage and protection. Policy makers, government regulators, and utility managers should also work together to prevent unauthorized data use and to alert consumers of such efforts. For example, utilities and policy makers in the U.S. should publicize the Obama administration's recent announcement regarding a Voluntary Code of Conduct (VCC) relating to privacy of customer SM data for utilities and third parties [100], which could possibly enhance customers' confidence in SM technology. It is interesting to note; however, in contrast to our findings, perceived privacy risk had no direct impact on adoption intentions in one German study [22], and a study in Hong Kong found that local residents were not aware of the privacy issues [11]. Additionally, some evidence [101] indicates that privacy concerns associated with new technologies decrease as perceptions of personal benefits of the technology increase. Increasing efforts to promote benefits of SMs to consumers, especially among those who do not already have privacy concerns, could indirectly enhance adoption via decreased privacy concerns.

Although the effect size was somewhat small, the results of the mediation analysis highlight the important role of trust in utilities. Trust significantly influenced all three perceived SM attributes here, two of which directly influenced acceptance and adoption intentions. Previous studies have not demonstrated mediating relationships among these variables in a single model. Given that (1) previous studies indicate knowledge of SM attributes is low and (2) the gains in SM knowledge do not necessarily enhance adoption intentions and can even decrease intentions [12], enhancing trust in the technology providers might be an especially effective means of enhancing adoption. In short, efforts might be better spent on enhancing trust than on attempting to further or better explain attributes in order to increase knowledge. Overall, we suggest that building trust between consumers and utilities could enhance adoption of SMs via perceptions of SM attributes. Resolving trust issues could potentially lead to a reduction in perceived privacy risks, an increase in perceived usefulness, and therefore a more successful deployment of SMs on a large scale. Trust concerns might also arise from perceived loss of control, especially the control over SM data, so utilities enterprise managers should allow customers to retain some level of control and perhaps also attempt to combat misperceptions that SMs are designed to control residents' energy consumption at any time and monitor them like "big brother" [102].

It is perhaps not surprising that, given the location of this study, political affiliation predicted problem perception, with more politically liberal participants (Democrats) reporting a higher level of problem perception than more conservative participants (non-Democrats), and these perceptions led to stronger support and adoption intention, either directly or through perceiving SMs as being more useful. In short, these data suggest that more conservative individuals might be less likely to adopt or support SMs because they do not perceive a need for them. The influence of political affiliation on problem perception is consistent with recent research pointing to the politicization of environmental and energy-related issues within the U.S. and with observations that such politicization is driven by marked differences in values and worldviews that predict pro-environmental behaviors [68,103–111]. Accordingly, when promoting the attributes of SM technology in the U.S. or in countries where these issues are similarly politicized, it might be important to emphasize the benefits of the technology that are related to a particular group's values, rather than emphasizing the ability of SMs to help protect the biosphere [74]. For example, when addressing consumers who more strongly value self-enhancement or traditionalism, utilities could highlight the usefulness of SMs at the community level in better balancing power demand, avoiding blackouts, and reducing electricity prices, as well as emphasizing the ability of SMs to enhance energy security and supply. Additionally, using message sources that share specific consumer groups' worldviews (and are perceived as credible/trustworthy by those groups) to disseminate information about SM benefits should increase acceptance of that information and subsequent positive perceptions of the technology [112].

Political affiliation also predicted trust in the utility companies. This finding further underscores the challenges associated with making SMs appealing to all sectors of the public, but also provides utility managers and policy makers in the U.S. with (1) a fairly easy means to identify likely proponents/opponents and (2) guidance for attempts to identify technical, promotional, and incentive-based strategies that are appealing to different segments of the population and related interest groups. In short, political affiliation can serve as an indicator of consumer values that predict (positively or negatively) trust and subsequent adoption. As stated above, tailoring messages and product attributes to appeal to the values of relevant groups could enhance adoption. Although more liberal respondents in this study had more trust in their utility service providers, our design does not allow use to understand why this was the case. The findings herein suggest additional research is needed to better understand the relationship between these two variables, especially the specific beliefs about utility providers on which trust might be based. In particular, it would seem useful to examine the extent to which liberals' vs. conservatives' trust in the utility might differ based on (1) their perceptions of the utility provider's interest in expanding sustainable energy use, development, and related policies as well as (2) whether the utility is publicly owned or investor-owned. Of note, in some parts of the U.S., city governments are attempting to take control of utilities from private or investor-owned companies, based on citizens' and lawmakers' concerns about climate change and a desire to more rapidly increase the availability of renewable energy [113]. Of course, it would be useful to determine whether and why political orientation and related values (such as traditionalism or universalism [77]) might predict trust in utilities in other countries given that orientation and related values have been found to predict trust in various institutions [77,114,115].

Surprisingly, neither perceived cost nor curtailment habits was a significant predictor of our dependent variables. The lack of influence of perceived cost may be due in part to the fact that some utility companies provide a free SM or waive the installation fee for customers. Regarding the lack of influence of curtailment habits, there may be two explanations. First, and most likely, problem perception seems to have suppressed the direct influence of curtailment behaviors. As our data shows 1) curtailment habits were influenced by problem perception, consistent with previous studies [111]. In particular, those with a lower level of problem perception tend to engage in curtailment behaviors less often, and 2) problem perception had significant effects, including direct effects, on both outcome variables. Second, we believe the adoption of SMs might be different from adopting other energy-saving technologies, in that consumers might perceive SMs primarily as a technological device to help utilities monitor electricity demand and supply. For example, in some cases, SMs merely serve as a communication device that sends data to the utilities without having energy consumers actively monitor or respond to the data.

Therefore, consumers might not perceive SMs as a straightforward personal energy efficiency device, thus limiting the influence of prior curtailment behaviors on the acceptance of SMs. Finally, the influence of demographic factors including age, gender, bill-pay status, and income on SM support and adoption intention was less important than that of the social-psychological factors examined here. Although income and whether residents paid electricity bills appeared to relate to adoption intention (not to support), the effect sizes were small. Accordingly, utility managers should pay more attention to psychosocial factors when promoting or considering SM installations.

The intent of this study is to examine theoretically and culturally relevant predictors of SM adoption in a country in which significant opposition has occurred. Given that our sample included citizens from across the U.S., we believe the relationships among the individual differences, perceptions of technology attributes, and adoption intentions identified in our model should manifest in other, similar samples from this culture. Indeed, a bootstrapping procedure (a widely used resampling method to deal with potential bias in the original sample [116]) conducted with our data produced a model with all the significant and non-significant paths remaining the same ($\alpha = 0.05$), suggesting that our results can be generalized to the population from which our sample was drawn, i.e., the U.S. We expect the influence of perceived usefulness on support and intention identified in this study to hold across other cultural contexts because this central prediction of the TAM has been supported in studies conducted in other countries (e.g., [18,19,117]). The relationship between privacy and SM acceptance should also hold, because privacy concerns have been found to predict SM acceptance in survey research and to be voiced as a major concern in public actions opposing SMs across countries and/or cultures, with a few noted exceptions. However, the magnitude of the relationships among these variables might change in other contexts. The individual difference variables of trust, problem perception, and political affiliation are considered external variables in extended versions of the TAM [118] and TPB [119]. The relationships among these external variables and their influence on intermediary beliefs about SMs and utility providers likely vary from culture to culture (given that beliefs about objects and behaviors stem from interpersonal interactions, traditions, and messages disseminated in a given culture) [120]. So, for example, in other cultures, political affiliation might not predict trust in the utility provider, while trust might still predict privacy concern. This would likely be the case in countries such as China or in U.S. states such as California or Wyoming, where there is limited variance on political party affiliation. Indeed, a supplementary analysis of a subsample of our participants from predominantly conservative states, such as Wyoming, Idaho, and Utah,[3] found that party affiliation was not associated with trust,[4] but trust was positively associated with privacy concerns.[5] In summary, although we cannot state with certainty if all the relationships found here would be replicated in studies within other cultures, we believe that the model tested in this study offers a framework that can serve as a good starting point for future SM studies, especially those conducted within cultures in which energy issues are fairly politicized.

These findings should be considered in light of their limitations. First, participants were volunteers, which might have resulted in self-selection of those who are interested in energy use or SMs. However, the findings regarding privacy concerns and perceived usefulness are consistent with those of previous studies using other public populations [10,18]. Second, this study only used electricity curtailment habits as a predictor of the outcome variables; future research could investigate how other energy efficiency behaviors, for example, appliance purchases and home weatherization, influence outcomes. Third, we did not investigate the influence of some key variables in the TAM and SETA, including social norms perceptions and perceived ease of use. It is important to note that social norms perceptions (perceptions that others are engaging in and/or expect us to engage in a given behavior) are typically positively correlated with energy conservation behaviors both in residential and commercial settings [63,121–125], although sometimes are associated with boomerang or social loafing effects [31,126]. It is possible that social norms perceptions would have somewhat less of an impact on SM support and adoption than they do on other energy or pro-environmental behaviors, given that SM support and adoption are somewhat less public behaviors than behaviors such as hybrid car use, recycling, and solar panel adoption [29]. We suggest future studies investigate the role of norms perceptions on SM-related behaviors.

Although we did not measure perceived ease of use, based on the current features of SMs that require little from consumers in terms of physical operation, previous research has found that consumers have expectations about ease of use and that such perceptions are positively related to attitudes toward [18] and intention to use SMs [19]. Finally, given how little consumers seem to know about specific features of SMs, it might be especially helpful to examine the influence of affect associated with the devices. It is possible that existing concerns about privacy and health risks are associated with negative affects that could, over the long-term, mitigate adoption and support [16].

In conclusion, the findings described here regarding the interplay of factors that influence public support for, and willingness to adopt SMs should assist policy makers and utility managers in this domain who are considering initial or additional deployment of SMs. With the rapid development of SMs and smart home technology, industry and policy makers should continue to investigate consumers' needs, concerns, and perceptions of the technology attributes and to propose policies based on the consideration of these factors.

[3] The complete list included Wyoming, Idaho, Utah, Alaska, Montana, North Dakota, South Dakota, Nebraska, Kansas, Alabama, Tennessee, Indiana, Oklahoma, Arkansas, Mississippi, and Texas ($n = 147$).

[4] $\beta = 0.08$, $p > 0.05$; participants with a democratic affiliation did not differ from non-democrats in their trust levels.

[5] $\beta = -0.30$, $p < 0.001$.

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