EXAMINATION OF THE DETERMINANTS OF SMART METER ADOPTION: AN USER PERSPECTIVE

Completed Research Paper

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Abstract

Given rising electricity consumption, coupled with finite resources, ICT-enabled electrical networks such as smart grids are increasingly being deployed by energy companies. One part of smart grids is smart meter technology (SMT), which are digital electrical meters, having the potential to increase energy efficiency in both residential and industrial sectors. However, a challenge to SMT-implementation in residential settings is its adoption (and continued usage) by consumers. Despite these challenges, little academic research has been conducted on this topic. This study attempts to fill that void and is, to the knowledge of the authors, the first study to empirically investigate this topic from a user perspective. Specifically, we developed a model surrounding consumers' intention to continue using SMT, by drawing on theories of adoption and motivational psychology, and testing it using a sample (n = 933) of SMT-users of a large super-regional energy supplier. Results provide support for our hypotheses.

Keywords: Green IS, Smart Metering Technology, Technology Adoption, Usage Behavior, Endogenous Motivations

Introduction

Electricity consumption continues to grow worldwide (Ellis et al. 2009). In addition to this, finite resources, a rising environmental consciousness, and rapid technological advancements in power engineering concepts for a sustainable energy supply and electricity grid have attracted the attention of public policy, firms, and media. There are several initiatives aimed to enhance energy efficiency, secure supply and mitigate climate change (e.g., Energy Independence and Security Act of 2007, 2006/32/EG, 2009/72/EG). Business leaders are embracing environmental sustainability in their corporate vision and "Green IT" has become a buzzword for strategic technology. Consequently, within academia as well, Watson et al. (2010) highlight the need to introduce a new subfield to IS research called energy informatics, "that recognizes the role that IS can play in reducing energy consumption, and thus CO_2 emissions" (Watson et al. 2010). It has been argued that this new subfield should focus on how information systems can contribute to the reduction of energy consumption by addressing research questions relevant to a diverse set of stakeholders including suppliers, the government, and consumers.

One aspect of energy informatics is smart electricity (Watson et al. 2010). Since the structure of the electrical transmission and distribution grids dates back to the beginning of the 20th century, one of the main research fields in the domain of smart electricity is the enhancement of electricity grids with modern information and communication technology (ICT). A smart and ICT-enhanced energy network would work more efficiently, reliably and sustainably than today's system, and is typically referred to as a smart grid. To attain a smart grid, new electricity meters, called smart meters, are needed. The term smart meter refers to a digital electricity meter. These meters differ from simple digital electricity meters, by allowing bidirectional communication between the meter and an energy supplier, and consequently enabling the energy supplier to offer new services to the consumers. Specifically, by providing information about current prices, energy consumption and energy production in the grid, smart metering technology (SMT) is the first step toward better integration of small and decentralized energy distribution sources as well as load control approaches and intelligent distribution of large-scale power plants like offshore wind-farms. Further, it enables services such as demand response and load shifting and customer-oriented applications. Therefore, SMT has the potential to not only increase the energy efficiency of the residential and industrial sector but beyond that to radically alter the way energy is produced and consumed (e.g., Potter et al. 2009). Although, SMT obviously largely impacts people's habits, home lives, and consumption behavior, it is noticeable that energy suppliers seldom engage in programs informing their customers about the specifics of SMT (Fox-Penner 2010). This has led to significant challenges related to its adoption by consumers. Despite these challenges associated with smart meter usage and adoption, it has found little attention amongst academic researchers. Our review of the literature within the IS discipline failed to provide a list of any meaningful studies examining this issue. A search of the broader literature base (outside of the IS discipline) has revealed few studies on smart meters. These studies have either examined broad topics such as demand response (e.g., Abrahamse et al. 2005, 2007), or more technical issues surrounding SMT (e.g., McDaniel and McLaughlin 2009), ignoring adoption and usage related issues. Given the massive investments needed to establish a smart metering infrastructure, and the already existent protests against its first campaigns, it is absolutely necessary to further investigate the adoption and acceptance of SMT. Further, given the fact that the installation of SMT is (or will) become mandatory in most Western countries, it is even more important to understand the determinants of consumers' continuing intention to use SMT. This study attempts to contribute toward that endeavor and is, to the knowledge of the authors, the first study to investigate this topic from an user perspective.
Thus, the specific research question that we examine is: What are the determinants of consumers' intention to continue using SMT?

In examining our research question, we draw on existing theories of technology adoption, motivation psychology in developing a research model, and then testing that model using a sample of German consumers of SMT.

The remainder of the paper is organized as follows: In the next section, we provide a review of the existing literature on adoption and usage behavior in the residential sectors, including an overview of the relevant theories from motivation psychology, environmental psychology, among others, which form our theoretical basis. This is followed by a discussion of our model, and the development of the relevant hypotheses. Next, we discuss our research methodology, and the empirical test of our model. We conclude

with a discussion of the results, our theoretical and practical contributions, and some directions for future research.

Theoretical Background

Existing Literature on Technology Adoption

Studies of technology adoption and use have a long history in IS research. In the last three decades, several models and theories have been applied to explain which factors influence the adoption and usage of information technologies. The majority of these models are based upon theories originating in behavioral science or social psychology such as Theory of Reasoned Action (Fishbein and Ajzen 1975), Theory of Planned Behavior (Ajzen 1991), and Technology Acceptance Model (TAM) (Davis 1989; Davis et al. 1989)). One of the most influential models – TAM – contends that the salient beliefs of perceived usefulness and perceived ease of use determine an individual's attitude toward use which, in turn, determines behavioral intention. It was originally developed for studying technology adoption at the workplace. It took until the early 1990's for the first set of studies to investigate technology adoption in private and residential settings (e.g., Brown and Venkatesh 2005; Brown 2008; Venkatesh 1996). Early studies on adoption (e.g., Venkatesh and Vitalari 1992) were heavily influenced by the utility-performance contingency of organizational IT use, while later studies began to address the differences between organizational and residential settings more thoroughly. Besides the various technology-related aspects, these models typically incorporated determinants originating in the fields of marketing and social psychology such as trust and risk issues (e.g., Pavlou 2003), pressure from one's social environment (e.g., Venkatesh and Brown 2001) and the role of values (e.g., Bagozzi 1982; Lee and Kozar 2008). In addition to the extension of the technology adoption literature to the residential sector, another research stream examining usage behavior and continuing intention to use also emerged. Some of the most prominent models on this topic are based on expectation confirmation (e.g., Bhattacherjee 2001; Brown et al. 2011) while others are based on TAM or the theory of planned behavior (e.g., Straub et al. 1995; Kim and Malhotra 2005; Hsieh et al. 2008). In our study, we draw on the latter. In addition, our literature review identified two SMT-specific factors, namely perceived privacy risk and perceived behavioral control that also directly impact consumers' SMT intention to continue using SMT.

In our literature review, we identified two SMT-specific factors, namely perceived privacy risk and perceived behavioral control, which we assume to directly impact consumers' SMT continuance intention.

Perceived risk can be defined as "a combination of uncertainty plus seriousness of outcome involved" (Bauer 1967). Perceived risk is relevant in information system usage decisions when feelings of uncertainty, discomfort and/or anxiety (Dowling and Staelin 1994) or conflict are aroused in the consumer (Bettman 1973). Specifically, when personal information is transferred via vulnerable communication infrastructures (e.g., the internet) privacy concerns arise. In the internet these concerns are found to be significant usage barriers (Hoffman et al. 1999). Since the data gathered by SMT allows service providers to identify users' lifestyle, privacy issues are the subject of public debates. Several governments and companies (e.g., in the Netherlands, Pacific Gas & Electric Co.) already had to stop SMT-rollouts because of consumer fears of privacy violations.

On the other hand, perceived behavioral control reflects the extent to which a person believes the extent to which he/she can control internal and external factors that either enable or confine performing a behavior in question (Ajzen 1991). In contrast to organizational settings where support or training is typically provided, the facilitation in consumer environments can vary significantly. Thus, Venkatesh et al. (2012) recommend incorporating facilitating conditions when studying technology adoption in the consumer context. Furthermore, behavioral control has also been identified as a key determinant of the adoption and usage behavior in the environmental sector (e.g., Bamberg and Schmidt 2003; Hsieh et al. 2008).

Next, we discuss theories from motivational psychology that also informed our model development.

Organismic Integration Theory

As outlined in the introduction, the design objective of SMT is to provide households with opportunities and incentives to lower or modify their energy consumption. Using SMT can not only result in direct (e.g., lower expenditures, increased control) but also in indirect (e.g., lower GHG emissions) benefits for users.

Thus, the endogenous motivations of consumers play a key role here (Dholakia 2006). There are several motivation-related theories that may be drawn upon to examine usage in this context. The self-determination theory (SDT) focuses on the reasons individuals have for engaging in different tasks. The organismic integration theory (OIT) a subtheory of the SDT splits the motivation for an externally induced behavior in a range from amotivation, to passive compliance, to active personal commitment. It explains these different motivations with the level of internalization and integration of the values and regulation of the induced behavior. Further, SDT considers extrinsic motivation to vary greatly in its relative autonomy (Ryan and Connell 1989; Vallerand 1997).

Instead of limiting our study by following the simplified dichotomy of extrinsic versus intrinsic motivation, we consider the whole spectrum of motivational aspects influencing consumers ranging from external to internal behavioral triggers. Research in motivation psychology emphasizes the need for scrutinizing the origins of behavior more precisely, instead of focusing solely on external influences such as incentives or external pressures (Ryan and Deci 2000). For understanding how social values are internalized to self-regulate behavior, the organismic integration theory (OIT), a sub-theory of the well-known self-determination theory (SDT) (see Deci and Ryan 2002; Ryan and Deci 2000), has proved to be valuable in different scientific areas (Deci and Ryan 2002) and specifically in environmental activism (e.g., Green-Demers et al. 1997). In contrast to mechanistic motivation theories, the organismic perspective of motivation regards individuals as being volitionally initiating all behaviors (Ryan and Deci 2000; Skinner 1953). Most technology adoption and usage studies followed a mechanistic view, treating extrinsic motivation in instrumental terms, i.e., perceived usefulness, and intrinsic motivation as enjoyment (Davis et al. 1992; Venkatesh et al. 2003). However, this approach limits our understanding of user motivations as it does not account for users' endogenous psychological states (Malhotra et al. 2008). The same external influences and stimuli may have different effects on different users which explains why some technologies are more readily used by some consumers than by others (Malhotra and Galletta 2004, 2003). The OIT considers individual behavior as not being motivated directly by external stimuli, but rather by the subjective psychological meaning of these stimuli. This means that behavior is not a result of expected rewards, but rather one of individual volition, which may even be undermined by extrinsic rewards (e.g., Curry et al. 1991; Pritchard et al. 1977). The OIT perceives extrinsic motivation as independent from external rewards stressing the endogenous notion of volitional extrinsic motivation.

Users' endogenous motivation can be captured through their perceived locus of causality (PLOC) (Dholakia 2006). PLOC refers to the degree to which a behavior is initiated and endorsed by the self, and therefore describes the relative autonomy of an activity (Ryan and Connell 1989). The perceived locus of causality can range from *external PLOC* characterized by feelings of compulsion to *internal PLOC* associated with feelings of volition. The different types of PLOC exert cumulative effects on intentions which can be assigned to different types of endogenous motivations (Deci and Ryan 1985).

Model Development

Based on the reviewed literature, we propose to apply a modified version of the adoption model (see Figure 1) introduced by Malhotra et al. (2008), since it offers the combination of the technology adoption, and motivation literature aspects and was tested in the context of continuing usage. To ensure managerial and scientific relevance and to reflect the research context's specificities (Benbasat and Zmud 2003; Melville 2010; Taylor and Todd 1995), we extend the model to take into account both the specificities of the examined system and its usage context. Such characteristics are specifically more salient in the context of SMT, where variable tariffs and the opportunity to reduce and/or shift energy consumption offered by SMT could directly and indirectly shape system usage by the possible financial and ecological benefits/incentives for the consumers. As discussed earlier, we identified two SMT-specific factors, namely perceived privacy risk and perceived behavioral control, which we assume to directly impact consumers' intention to use SMT.

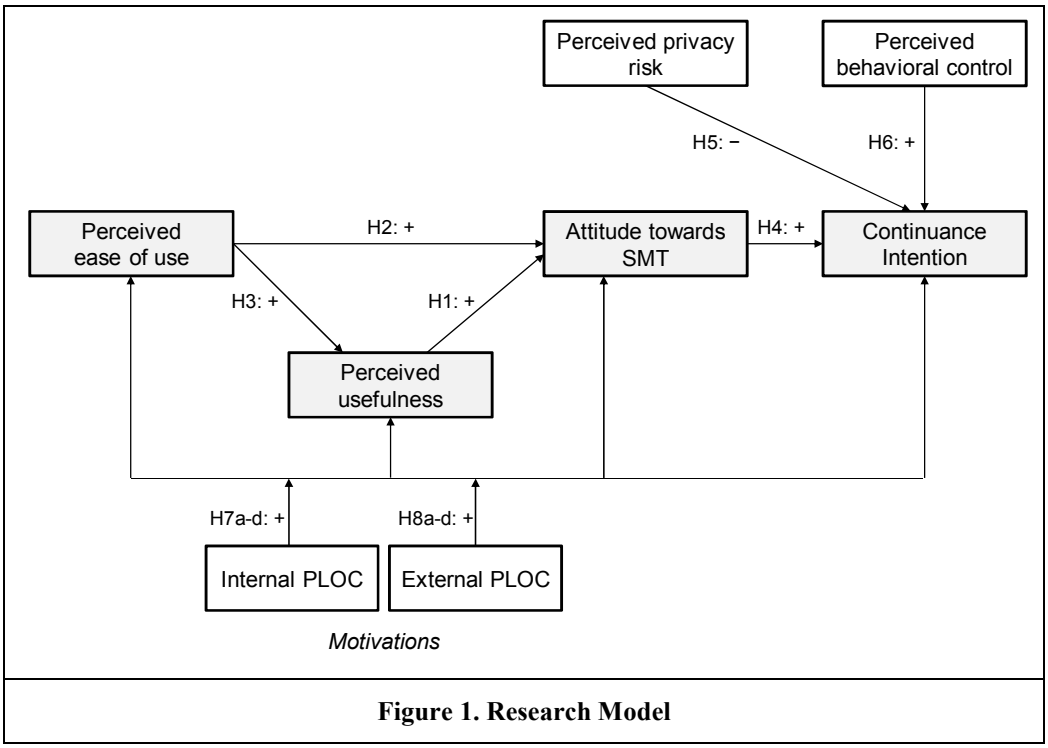

Figure 1. Research Model

In the context of this study, our dependent variable is the users' intention to continue using SMT. Perceived usefulness is defined as the degree to which a consumer believes that using SMT enhances the effectiveness of energy management-related tasks, primarily related to the provision of information, cost control and savings. The perceived ease of use reflects the degree to which consumers perceive using SMT to be free of effort. Concerning the usage of SMT, attitude reflects the consumer's evaluative judgment about using the technology as either being harmful or beneficial. In line with previous studies which found that attitude is a strong predictor of intention (Lee and Kozar 2008), we hypothesize that a favorable attitude towards using SMT is positively related to actual use. According to these statements and the relationships proposed by the TAM we contend:

Hypothesis 1: *Perceived usefulness positively influences attitude towards SMT.*

Hypothesis 2: *Perceived ease of use positively influences attitude towards SMT.*

Hypothesis 3: *Perceived ease of use positively influences perceived usefulness of SMT.*

Hypothesis 4: *Attitude towards SMT positively influences the intention to continue using SMT.*

To facilitate communication between consumers and service providers, SMT uses the internet which represents a potential target for illegal actions (Zetter 2010). Therefore, concerns about privacy risk may evoke consumers' skepticism about using SMT which may negatively impact the usage. Hence,

Hypothesis 5: *Perceived privacy risk negatively influences the intention to continue using SMT.*

In our context, perceived behavioral control is related to the consumers' subjective degree of control over using SMT. In line with prior research, we suggest that the higher perceived behavioral control, the higher the usage of SMT (e.g., Lee and Kozar 2008; Liao et al. 2007). Hence,

Hypothesis 6: *Perceived behavioral control positively influences the intention to continue using SMT.*

The level of autonomy, external pressure or the combination of both can be determined by examining users' psychological states in terms of the perceived locus of causality (PLOC) (Dholakia 2006). PLOC refers to the degree to which a behavior is initiated and endorsed by the self, and therefore describes the relative autonomy of an activity (Ryan and Connell 1989).

The **internal PLOC** is depicted by the intrinsic and the identified PLOC. Both states are characterized by feelings of volition meaning that actors perceive themselves as origins of the behavior. The intrinsic PLOC refers to behavior that is spontaneous and performed for inherent fun, whereas the identified PLOC refers to behavior based on personal values and goals and outcomes (Ryan and Connell 1989). Although the associated behavior is performed freely, it results from internalization and integration of external regulations and is, in contrast to the internal PLOC, a type of extrinsic motivation. As it is volitional, it is not dependent upon external rewards or referent others but focused on regulations, values and outcomes, and helps explain why some social values and norms are accepted by individuals while others are not (Vansteenkiste et al. 2004). The effect of volitional extrinsic behavior is similar to behavior associated with intrinsic motivation (Deci and Ryan 1985). Identified PLOC is thus an important state with regard to the adoption of SMT. SMT is linked with consumer and societal welfare improvements, such as preserving the environment and environmental awareness is rising all over the world (Poortinga et al. 2004). If a consumer internalizes external regulations (e.g., by federal institutions, NGOs, or influential others) regarding SMT's positive impact on environmental sustainability in a way that the behavior is perceived as a self-endorsed choice, she/he will be more likely to use SMT. Thus,

Hypothesis 7a: *Internal PLOC positively influences the intention to continue using SMT.*

Attitude is referred to users' positive or negative feelings about a particular behavior (Fishbein and Ajzen 1975). In case a behavior is motivated by internal motivations, it tends to be associated with positive feelings of volition, freedom, and autonomy (see also Melancon et al. 2011). If users regard the usage of SMT as autonomously driven and meaningful to themselves and society and additionally feel good while using SMT, they should thus have a positive attitude. Hence,

Hypothesis 7b: *Internal PLOC positively influences the attitude towards SMT.*

Intrinsically motivated behavior also leads to perceptions of lower cognitive burden since one is experiencing pleasure while performing the activity and is furthermore willing to invest more effort (Agarwal and Karahanna 2000; Deci 1975). In contrast, behaviors that are associated with feelings of coercion appear as burdensome or enervating, whereas behaviors linked with perceptions of volition and autonomy seem to be free of effort and easy (Csikszentmihalyi 1990). Using a complex device or programming your washing machine doesn't seem to be that bothersome, if you do it because you are following your own goals. As a result, the perceived ease of using SMT should increase. Thus,

Hypothesis 7c: *Internal PLOC positively influences perceived ease of use.*

Prior technology adoption research was dominated by a normative view of productivity and performance with regard to behaviors performed to satisfy external instrumental contingencies (Malhotra et al. 2008). In a SMT context, one may seek to lower energy expenditures or to get approval by friends, neighbors, or family members. However, this perspective only partially reflects why users might actually use SMT. Individuals may also use associated services as these features and opportunities facilitated by SMT are personally and societal meaningful and contribute to their personal development. Hence, we state:

Hypothesis 7d: *Internal PLOC positively influences perceived usefulness.*

External PLOC is associated with perceived reasons for one's behavior that is attributed to external authority or compliance (Ryan and Connell 1989). It represents the least autonomous form of extrinsic motivation and it is assumed that there is no conflict between the perceived external influences and personal values of the user. This leads to behavior that is typically performed to satisfy external demands. In the case of SMT, such external demands could be in the form of recommendations by public institutions, financial incentives. Although less sustainable and dependent on the rewards, user intentions are contingent upon external factors, presumably to a lower extent than upon internal PLOC. Thus, external PLOC should also have a positive impact on intention. Therefore,

Hypothesis 8a: *External PLOC positively influences intention to continue to using of SMT.*

Otherwise non-spontaneous behavior can be promoted by external incentives (Deci and Ryan 1985). If users are offered financial incentives or can follow official recommendations their attitude towards SMT will be positively influenced. Depending on these rewards, the evaluation of performing this specific behavior can change. Thus, consumers should perceive the usage of SMT as less self-determined. However, external rewards should still have a positive influence on attitude towards SMT. Hence,

Hypothesis 8b: *External PLOC positively influences the attitude towards SMT.*

If an activity is not fully self-endorsed, the execution of a behavior may feel coerced or pressured when motivated by external rewards (Deci and Ryan 2002). However, users may still perceive it as meaningful because of external incentives such as financial benefits. Given that personally important incentives are present, individuals may still perceive performing SMT-related tasks as less annoying and difficult to use. Therefore,

Hypothesis 8c: *External PLOC positively influences perceived ease of use.*

Little evidence exists regarding the question what actually makes a technology perceived as useful (Benbasat and Barki 2007). While some may perceive usefulness by its instrumental value, others may perceive it in the development of the self (Schwarz and Chin 2007). Individuals often perceive external incentives as useful when they are not deemed as coercive (Deci and Ryan 1985). This means that if SMT provides personally meaningful external incentives which are not perceived as coercive, users will value this technology as more useful. Thus,

Hypothesis 8d: *External PLOC positively influences perceived usefulness.*

Research Methodology

A survey-based study was adopted to test the predicted relationships within the model. The survey was administered online in Germany. For our study, we relied on a panel of SMT users of a super-regional Southern German energy supplier. Using an online survey had multiple advantages: 1) although our participants were familiar with SMT, we could add an introduction to smart metering, including pictures for virtualization to make sure to establish a common meaning amongst them, 2) we could control if respondents actually read through the introduction or just skipped ahead, and 3) we could reach a large number of citizens to test our model. The survey was administered by a professional polling firm. Below, we discuss the sample, procedures, and measures used in the study.

Sample

Our sample consisted of German citizens. We believe that a German sample is appropriate for many reasons. SMT is taking on a significant importance in Germany. Amongst others, one important reason for this is the focus of the European Union (EU) on renewable energy (Council of the European Union and European Parliament 2009). In this, it is formulated that by 2020 renewable energy sources will have a 20% share in the energy mix throughout EU. National studies expect an over achievement of these targets and assume a 35% share of renewable energies by 2020 in Germany (Energieagentur 2010). Due to the regional structure of Germany and its very energy intense industries, and large private consumption peaks in the south of the country, major congestion of the network is expected (Veit et al. 2009). At the same time, very stable and non-volatile energy sources like nuclear power being phased out in Germany. Steering the demand accordingly can be an approach to improve this situation. Smart meters offer this opportunity. Given these changes in Germany, it presents researchers with an interesting platform on which to empirically investigate the usage of smart meters in private households.

Consequently, our sample consist of survey respondents in Southern Germany that are (co-)responsible for energy decisions in their household. Overall, 10000 SMT customers of a large super-regional energy supplier in Southern Germany were invited via email to participate in the survey with a response rate of 11.67%. Uncompleted questionnaires and questionnaires with implausibly short handling time were removed from the sample. 933 completed questionnaires were used for the further analysis. The participants' age was ranging from 25 to 89 years (mean: 54.91 years), with 86.7% being males and 13.3% being female respondents. The high proportion of male participants can be explained due to the fact that we asked that the survey be completed by those responsible for making energy decisions in households.

Measures and Instrument Validation

The TAM constructs (Attitude, Perceived Usefulness and Perceived Ease of Use) were measured using an adapted scale by Davis et al.(1989), and the adapted scale of Bhattarcherjee (2001) was used to measure intentions to continue using SMT. For the PLOC scales, we used the measurement instruments suggested

by Ryan and Connell (1989). These abstract measures were combined with self-developed items to create a better fit to the smart metering context. To measure perceived behavioral control, we used the scale by Venkatesh et al. (2003). Perceived privacy risk was measured with adapted instruments provided by Featherman and Pavlou (2003). The definitions of the constructs are given in Table 1. The items used in our survey are shown in the Appendix I.

Table 1. Constructs and their definitions

Construct	Definition
Attitude	The affective or evaluative judgment of the consumer towards SMT (Fishbein and Ajzen 1975).
External PLOC	The external PLOC is associated with perceived reasons for one's behavior that is attributed to external authority or compliance. This assumes that there is no conflict between perceived external influences and personal values of the user (Malhotra et al. 2008).
Internal PLOC	The internal PLOC refers to feelings of volition where consumers perceive themselves as the "origin" of their behavior (Malhotra et al. 2008).
Continuance Intention	Users' intention to continue using SMT (Bhattacherjee 2001).
P. Behavioral Control	Perceived behavioral control reflects perceptions of internal and external constraints on behavior and encompasses self-efficacy, resource-facilitating conditions and technology facilitating conditions (Ajzen 1991).
Perceived Ease of Use	Perceived ease of use refers to the degree to which a person believes that using SMT is free of effort (Davis et al. 1989).
Perceived Usefulness	Perceived usefulness refers to the degree to which a person believes that using SMT is enhancing his or her energy efficiency (Davis et al. 1989)
P. Privacy Risk	Perceived Privacy Risk describes the potential loss of control over personal information, such as when information about a consumer is used without their knowledge or permission. The extreme case is where a consumer is "spoofed" meaning a criminal uses their identity to perform fraudulent transactions (Featherman and Pavlou 2003).

The items were first evaluated by peers and experts in the area of technology adoption and psychology. Based on the reviews, many of the items were reworded or rephrased. This helped achieve face and content validity of the scales (Brown and Venkatesh 2005; Straub 1989). Further, qualitative and quantitative pilot studies were conducted to validate the instruments and clarify the experimental procedure (Moore and Benbasat 1991). In our final pilot study, we tested the refined questionnaire with a larger sample (n=110) to further improve it. While the sample for the pilot study was small, the computed reliabilities of the scales indicated that they were appropriate for use in a larger study (Brown and Venkatesh 2005). Further, some of the hypothesized relationships were tested and were found to be in the predicted direction.

Analysis

SmartPLS Version 2.0 M3 (Ringle et al. 2005) was used for analyzing the data. PLS models are typically analyzed in two stages: The first stage involves "the assessment of the reliability and the validity of the measurement model," and the second stage involves "the assessment of the structural model" (Hulland 1999).

In assessing the validity of our instruments using the PLS-approach, we relied on prior/recent research using PLS (e.g., Bhattacherjee and Premkumar 2004; Brown and Venkatesh 2005; Chin 1998, 2001; Gefen and Straub 2005; Hulland 1999). Prior research suggests that convergent validity of items can be established by satisfying the following three criteria: First, each item should load significantly on its respective constructs (Gefen and Straub 2005). While many researchers suggest that items should have a

loading of .70 or above, others suggest that it is "often common to find that at least several measurement items in an estimated model" have loadings below the ".70 threshold, particularly when new items or newly developed scales are employed". Researchers further suggest that items with loadings "less than .. .50 should be dropped" (Hulland 1999). Second, the composite reliabilities should be greater than .70 (Hulland 1999), and third, the average variance extracted (AVE) for each construct should be greater than .50 (Bhattacherjee and Premkumar 2004). Each of the items loaded significantly on their respective construct, and all the items (except for one) had loadings of .70 or higher, and none of the items loaded on their construct below the cutoff value of .50. Further, as Table 2 highlights, the composite reliabilities of all the constructs are over .70 and the AVEs of all the constructs are over the threshold value of .50. This established the convergent validity of our items.

Gefen and Straub (2005) suggest that discriminant validity can be established by examining the correlation between the latent variable scores with the measurement items, and ensuring that the measurement items load higher on their "assigned factor" than on other factors (Appendix II). Another way to establish discriminant validity is to ensure that the square root of the AVE of a construct exceeds all correlations between that factor and any other construct within the study (Bhattacherjee and Premkumar 2004; Fornell and Larcker 1981; Gefen and Straub 2005). Table 2 highlights that the square root of the AVEs for all the constructs are indeed larger than the correlation between that construct and other constructs (the square root of the AVEs have been reported on the main diagonal, with the off-diagonal cells reflecting the correlation between that construct and other constructs). This confirmed the relative discriminant validity of our instrument.

Table 2. Correlations and Measurement Information

	Mean (STD)	C.R.	AVE	1	2	3	4	5	6	7	8
Attitude	5.95 (1.42)	.96	.90	.95							
External PLOC	4.57 (1.49)	.80	.58	.26	.76						
Internal PLOC	5.26 (1.43)	.89	.74	.53	.38	.86					
Continuance Intention	4.97 (1.53)	.92	.79	.56	.35	.58	.89				
P. Behavioral Control	4.81 (1.47)	.90	.76	.32	.14	.41	.42	.87			
Perceived Ease of Use	4.99 (1.47)	.93	.82	.36	.18	.46	.52	.71	.91		
Perceived Usefulness	5.76 (1.28)	.93	.78	.47	.37	.59	.54	.44	.49	.88	
P. Privacy Risk	3.33 (1.45)	.86	.68	-.25	-.25	-.28	-.23	-.21	-.20	-.35	.83

Notes: STD: standard deviation; C.R.: composite reliability; AVE: average variance extracted.

In the next phase of our analysis, we examined the significance and strength of our hypothesized relationships. While the following section only briefly describes the results, they are extensively discussed in the concluding sections (that is, Discussion and Implications) of this manuscript.

Hypothesis 1 suggested that perceived usefulness would have a positive influence on the individual's attitude towards the technology. This prediction was supported ($\beta = .217$, $p < .01$). Further, hypothesis 2, which suggested that perceived ease of use would have a positive influence on the individual's intention to adopt that technology, was also supported ($\beta = .079$, $p < .05$). Hypothesis 3 suggested that the perceived ease of use of the technology would have a positive influence on the perceived usefulness of SMT. This prediction was supported ($\beta = .283$, $p < .01$). Consistent with hypothesis 4, results indicated that that consumers' attitude towards SMT would have a positive influence on the individual's usage of SMT ($\beta = .311$, $p < .01$).

Hypothesis 5 argued that perceived behavioral control would have a positive effect on the individual's usage of SMT. This prediction was supported ($\beta = .185$, $p < .01$).

Furthermore, hypothesis 6, which suggested that perceptions of risk with respect to privacy would have a significant negative effect on consumers' usage of SMT, was not supported ($\beta = -.005$, $p > .10$).

Drawing on the OIT and Malhotra et al.'s (2008) framework, hypothesis 7a predicted that the internal PLOC would have a positive influence on the individual's usage of SMT. Results supported this prediction (β= .281, p < .01). Further, hypothesis 7b predicted that the internal PLOC would have a positive influence on the individual's attitude towards SMT. This too was supported (β= .357, p < .01). Hypothesis 7c predicted a positive effect of the internal PLOC on perceived ease of use. This prediction was supported (β= .458, p < .01). Also, hypothesis 7d predicted that the internal PLOC would have a positive influence on the perceived usefulness. Results supported this prediction (β= .392, p < .01). Hypothesis 8a, which predicted that the external PLOC would have a positive influence on consumers' usage of SMT, was supported (β= .140, p < .01). Further, hypothesis 8b predicted that the external PLOC would have a positive influence on the individual's attitude towards SMT. This hypothesis was not supported (β= .025, p > .10). Hypothesis 8c predicted a positive effect of the external PLOC on perceived ease of use. This prediction was not supported (β= .009, p > .10). Further, hypothesis 8d predicted that the external PLOC would have a positive influence on the perceived usefulness. Results supported this prediction (β= .166, p < .01). Overall the variance explained by perceived ease of use, external PLOC and internal PLOC on perceived usefulness was 43.1%. The variance explained by both PLOC variables on perceived ease of use was 21.3%. And finally the variance explained by perceived usefulness, perceived ease of use and both PLOC variables on attitude was 32.6%.

Overall the model was able to explain about 46.4% of the variance of consumers' usage of SMT.

We summarize the results in Table 2.

Table 2. Results of the Model Estimation

Hypothesis	β	p	Supported or not
H1: Perceived Usefulness -> Attitude (+)	0.217	p < 0.01	supported
H2: Perceived Ease of Use -> Attitude (+)	0.079	p < 0.05	supported
H3: Perceived Ease of Use -> Perceived Usefulness (+)	0.283	p < 0.01	supported
H4: Attitude -> Continuance Intention(+)	0.311	p < 0.01	supported
H5: Perceived Behavioral Control -> Continuance Intention (+)	0.185	p < 0.01	supported
H6: Perceived Privacy Risk -> Continuance Intention (-)	-0.005	p > 0.10	not supported
H7a: Internal PLOC -> Continuance Intention (+)	0.281	p < 0.01	supported
H7b: Internal PLOC -> Attitude (+)	0.357	p < 0.01	supported
H7c: Internal PLOC -> Perceived Ease of Use (+)	0.458	p < 0.01	supported
H7d: Internal PLOC -> Perceived Usefulness (+)	0.392	p < 0.01	supported
H8a: External PLOC -> Continuance Intention (+)	0.140	p < 0.01	supported
H8b: External PLOC -> Attitude (+)	0.025	p > 0.10	not supported
H8c: External PLOC -> Perceived Ease of Use (+)	0.009	p > 0.10	not supported
H8d: External PLOC -> Perceived Usefulness (+)	0.166	p < 0.01	supported

We applied the recommended procedural and statistical remedies by Podsakoff et al. (2003) to minimize and control common method bias. This included proximal and methodological separation of the measurement and respondents were assured of anonymity. Further, using Harman's one-factor test (Podsakoff et al. 2003), neither a single factor emerged nor was a general factor apparent in the unrotated factor solution indicating that common method variance was not a problem. The results showed a .377 variance explained and is therefore below the recommended 0.5 mark. The marker variable test (Rönkkö and Ylitalo 2011) as well showed no signs for common method bias in the model. No difference in the significance of the paths could be found applying three different value questions that were unrelated to the topic of SMT as marker variables.

Discussion and Implications

In this manuscript, we examine the factors affecting users' intention to continue using SMTs, by drawing upon a sample of German users of SMT. Our results refine the understanding of user motivations by disentangling the role of "collections of motivations" influencing users. Different endogenous motivations seem to have different effects on users' technology perceptions, attitudes, and usage behavior. Generally, internal PLOC was found to be more important than external PLOC. This underlines that while financial aspects and official recommendations are important, they are subservient to environmental considerations. This finding is in line with results from the Eurobarometer which indicated that citizens perceive climate change as one of the most important challenges in the future and that many of them are willing to pay to stop climate change (European Commission 2008) and with prior work on the effects of external rewards on the adoption of e-learning systems (Malhotra et al. 2008). Opposed to the extrinsic–intrinsic dichotomy that treated extrinsic motivation in terms of external rewards and intrinsic motivation as being self-inherent, our study shows that although not intrinsic, users internalize (identified) social values such as environmentalism which can influence behavior as powerfully as intrinsic motivation. This finding suggests that researchers and practitioners should seek to establish congruence between the values inherent to Green technologies and those of their target group. Furthermore, our results demonstrate that endogenous motivations underlying perceived ease of use and perceived usefulness are predominantly driven by internal PLOC. This underscores the notion that if individuals experience their behavior as self-determined they perceive it as easier to perform (see also McGinnis et al. 2008). The substantial effects of internal PLOC on these core determinants of adoption and use are an important finding regarding the central role of these variables in technology acceptance research. The non-significant effects of external PLOC on attitude and perceived ease of use, further strengthen the argument that internalized social values drive the usage behavior of SMT. As this study examines current users, the results suggest that once users build their attitudes towards a technology, external factors cease to influence it. Similar findings would have been expected following other motivational theories as e.g., goal theories (e.g., Elliot and Harackiewicz 1996, 1996; Elliot 1999) or attribution theories (e.g., Graham 1991; Weiner 1985). One example is Wati et al. (2011), who tested Green IS adoption employing a goal theory framework. Results show that normative and hedonic drivers (intrinsic motivation) were stronger than the goal gain frame oriented drivers (extrinsic motivation) legislative pressure and economic factors. Whereas differences between both motivational factors seem to be not as distinctive in adoption settings (see also Wunderlich et al. 2012), intrinsic/internalized factors seem to play the more important role.

Further, our findings show that perceived privacy risk has no direct influence on adoption intentions although SMT was at the center of public controversies. It appears that consumers make a trade-off between privacy concerns and benefits (Malhotra et al. 2004), or are simply confident about effective privacy protection mechanisms in place. This "privacy paradox" is well known in research and may result from users' perceptions regarding the sensitivity of information disclosed (Mothersbaugh et al. 2012). Furthermore, perceived behavioral control was found to be significant. This implies that the more respondents feel in control over using SMT the higher is their actual use.

Consistent with the TAM, perceived ease of use affects perceived usefulness and both were found to be significant as predictors of attitude towards SMT in this sample. However, only a minor effect of perceived ease of use on attitude towards SMT could be established. The consumer's attitude might be less affected by perceived ease of use when consumers internalize the social values associated with the type of artifact and have positive feelings while using it. This interpretation is underpinned by the strong effect of internal PLOC on perceived ease of use. Finally, attitude was found to be a significant and strong predictor of consumers' usage behavior. Therefore, our results confirm the relationships proposed by the TAM in the area of energy informatics and expand our knowledge on TAM by testing how endogenous motivations affect the model's relationships in the environmental sector as proposed by Melville (2010).

From a practitioner's point of view, energy suppliers were used to stable market conditions for a long time. Starting with the liberalization of energy markets and the transition to more renewable energy systems, however, the energy sector is going through very significant changes. Energy suppliers are forced to win over their customers. SMT allows the energy supplier to launch variable tariffs that offer customers the possibility to save money by changing their consumption behavior. Further, by establishing a bidirectional communication channel it enables a variety of services. Our study demonstrates the substantial direct and indirect positive effect of internal PLOC. Users feeling volitional about SMT are

more likely to adopt (and continue using) it. Thus, providers of SMT first have to establish an understanding about which extrinsic and intrinsic motivations are important to their target groups. As our study shows, energy suppliers have to find a way to offer both, internal and external incentives. On the one hand socialized values as the protection of the environment are playing an important role and can lead to a volitional usage of the technology. On the other hand external factors as recommendations and financial incentives are another distinct factor in users' adoption decisions. Hence, reaching the mainstream customer requires providing meaningful extrinsic motivations which have to be complementary to the provided intrinsic motivations and to the users' feelings of autonomy and volition. Further, although the study's findings suggest that perceived privacy risk only has an indirect effect on adoption intentions, we advise to take privacy issues seriously and to highlight privacy-enhancing measures in advertising campaigns to overcome a possible negative media echo.

Despite its contributions, this study also has some limitations. The latter should be addressed by future research. First, this study investigated only one country. Although Germany is a particularly interesting country when studying the energy sector, in light of its long tradition of anti-nuclear energy demonstrations, and it being the only country that enforced to phase out of nuclear energy after the melt down of the reactor in Fukushima, for generalizability of the model future studies involving other countries need to be conducted. Second, although the study is based on a large sample, user perceptions may change over time, for example, because of changing societal values or contemporary incidents. Thus, we encourage future research to employ longitudinal studies to shed light on consumers' usage behavior in this sector. Finally, our model could be extended with respect to an investigation of moderators on the effects of external and internal PLOC to answer the questions when and how the effects of these psychological states differ.

Conclusion

Given the continuous rise of energy consumption, the limited availability of fossil fuel and the uncontrollable risks inherent to nuclear power, a transition of the energy system is necessary and inevitable. Thus, governments around the world are promoting renewable energy sources to achieve a cleaner and sustainable energy production. Being able to integrate massive flows of renewable and therefore fluctuating energies needs a new way to run the electricity grids.

SMT is one part of these new smart grids, and one of the first steps in the transformation progress from today's grids to the smart grids of the future. Practitioners and researchers (e.g. Watson et al. 2010) stress the need to understand consumers' adoption and usage in the field of energy informatics, such as SMTs. To the knowledge of the authors, this is the first study to examine consumers' intention to continue using SMT by examining how motivational states and incentives, perceived behavioral control, perceived privacy risk, and technology-related considerations such as perceived usefulness and ease of use influence the usage behavior of it.

Further, a key goal of adoption research is to identify and understand how managerially controllable antecedents influence consumers' adoption intentions. This article provides important insights on the role of endogenous motivations in forming consumers' intentions about adopting sustainable technologies such as SMT. Thus, our study serves as a starting point for future research on the role of users' endogenous motivations on green technology adoption. From a practitioners' point of view the model can help to identify effective strategies to address and motivate customers to use SMT by supporting and facilitating their endogenous tendencies. Such strategies are expected to lead to a more persistent and better behavioral performance (Deci and Ryan 2002).

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Appendix

Appendix I. Measurement Items	
Construct (Source)	Items
Attitude (Davis et al. 1989)	I assume that it is a good idea to use SMT. I think, that it is reasonable to use SMT. All in all, I think it is a bad idea to use SMT.* I like the idea, to use SMT.
Continuance Intention (Bhattacherjee 2001)	I can imagine continuing using SMT regularly in my household. I am using SMT regularly. I am using SMT in everyday life.
Internal PLOC (Ryan and Connell 1989)	I use the system … …Because I want to help protecting the environment. …Because I personally like using SMT. …Because I think it is personally important to me. …Because I enjoy using SMT
External PLOC (Ryan and Connell 1989)	I use the system … …Because it is recommended by my energy supplier. …Because it is recommended by governmental institutions.* …Because using SMT offers me financial incentives. …Because the European Union recommends using SMT.* …Because I can avoid price peaks in peak load times.
Perceived privacy risk (Featherman and Pavlou 2003)	Using SMT could lead to a loss of control over the privacy of my personal data.* My personal data would not be used for other purposes. My personal data that is gathered due to the usage of SMT would not be sold to third party providers. I am anxious about the data security of SMT.* The databases that are used to save my consumption data are protected against unauthorized access.
Perceived ease of use (Davis et al. 1989)	Learning to operate SMT was easy for me. I find it easy to use SMT to do what I want to do. It took me some time to become skillful at using SMT.* I find it easy to use SMT.
Perceived Behavioral Control (Venkatesh et al. 2003)	Using SMT is entirely in my control. Given the resources, opportunities and knowledge it takes to use SMT, it would be easy for me to use SMT.

	It is inconvenient for me to use SMT.* I have control over using SMT.
Perceived Usefulness (Davis et al. 1989)	Using SMT helps me to better survey my energy consumption. Using SMT it is easier for me to lower my energy consumption. Using SMT is useful to regulate my energy consumption more efficiently. Using SMT helps me to faster survey my energy consumption.
Note: * Items were dropped as they had low factor loadings on respective constructs.	

Appendix II. Cross Loadings

Construct	Item	1	2	3	4	5	6	7	8
Attitude	A1	**.95**	.25	.49	.51	.28	.32	.44	-.23
	A2	**.94**	.24	.49	.53	.30	.34	.45	-.22
	A3	**.95**	.24	.52	.55	.33	.36	.46	-.24
External PLOC	EPLOC1	.07	**.52**	.17	.14	.03	.00	.15	-.20
	EPLOC2	.18	**.83**	.31	.28	.12	.16	.31	-.17
	EPLOC3	.28	**.89**	.36	.34	.13	.19	.34	-.22
Internal PLOC	IPLOC1	.48	.30	**.90**	.54	.40	.47	.55	-.23
	IPLOC2	.39	.29	**.82**	.44	.36	.36	.44	-.20
	IPLOC3	.49	.40	**.85**	.50	.30	.35	.50	-.28
Continuance Intention	CI1	.61	.32	.57	**.87**	.36	.44	.52	-.24
	CI2	.45	.31	.51	**.91**	.39	.50	.47	-.20
	CI3	.39	.31	.45	**.88**	.37	.44	.42	-.18
Perceived Behavioral Control	PBC1	.31	.12	.38	.37	**.91**	.70	.41	-.20
	PBC2	.30	.12	.40	.43	**.91**	.66	.41	-.17
	PBC3	.21	.13	.29	.27	**.79**	.48	.32	-.20
Perceived Ease of Use	PEoU1	.30	.14	.39	.44	.65	**.91**	.42	-.14
	PEoU2	.34	.18	.42	.49	.67	**.90**	.46	-.17
	PEoU3	.32	.18	.45	.47	.63	**.90**	.46	-.23
Perceived Usefulness	PU1	.45	.31	.55	.46	.42	.46	**.91**	-.32
	PU2	.35	.35	.46	.46	.34	.39	**.84**	-.30
	PU3	.48	.37	.54	.51	.39	.44	**.91**	-.35
	PU4	.40	.27	.51	.48	.41	.45	**.87**	-.28
Perceived Privacy Risk	PPR1	-.21	-.21	-.27	-.19	-.20	-.19	-.30	**.74**
	PPR2	-.17	-.20	-.19	-.18	-.16	-.16	-.26	**.85**
	PPR3	-.23	-.20	-.23	-.20	-.17	-.15	-.31	**.88**