Is It Money Or The Environment? An Empirical Analysis of Factors Influencing Consumers' Intention to Adopt the Smart Metering Technology

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ABSTRACT

The Smart Metering Technology (SMT) is an essential building block of smart grids. It facilitates demand-reduction and -shifting and is supposed to trigger behavioral and economic changes in households' energy consumption. While technology adoption in the workplace has been studied extensively, evidence as to residential settings is rather limited. Likewise, the IS-community has been reluctant in addressing issues regarding environmental sustainability. This study aims at bridging these gaps by investigating the factors influencing consumers' intention to adopt the SMT. Building upon the Theory of Planned Behavior (TPB) and the Technology Acceptance Model (TAM) we propose an interdisciplinary research model. The model was empirically tested using data collected from 284 potential adopters. The results implicate that apart from the major determinant attitude, intention is driven by secondary sources' influence and environmental concerns. The findings will help refining researchers' understanding of SMT-adoption and will be useful for all stakeholders interested in SMT-diffusion.

Keywords

Technology Adoption, Energy Informatics, Smart Meter Technology, Smart Grid

INTRODUCTION

Globally governments seek to mitigate climate change and resource dependency by improving energy supply systems' efficiency and sustainability. Against this backdrop many countries foster the installation of electricity meters which make information regarding current prices and energy consumption available to consumers. The goal of this regulatory provision is to induce behavioral and economic changes on the demand side and to reduce information asymmetry and increase demand elasticity. For achieving these targets the smart metering technology (SMT) is expected to play a key role. This green information system (Green-IS) artifact enables advanced communication and coordination within energy supply systems which work more efficiently, reliably, and sustainably than today's systems, typically referred to as smart grids. For realizing the technology's benefits and justifying the massive investments, it is essential that the majority of private consumers actually adopts and makes use of the SMT. To date technological considerations have dominated over consumer-related issues although the SMT notably impacts peoples' home lives and consumption behaviors. To date the IS community has been reluctant in studying environmental and sustainability issues (Melville, 2010; Watson, Boudreau, & Chen, 2010). Therefore, Watson et al. (2010) call for establishing *energy informatics* as a new subfield within IS research. Energy informatics "*enables and motivates economic and behaviorally driven solutions*" which help reducing energy consumption and thus, greenhouse gas (GHG) emissions by eliminating problems arising from lack of information (Watson et al., 2010).

This paper aims to contribute to the limited body of literature in the areas of energy informatics and residential Green-IS adoption. The remainder of the paper is structured in five sections. In the following paragraph, we review prior adoption research and elaborate on the SMT. In section 3 the research model is presented. We then outline the methodology (section 4) and present the results (section 5). The paper concludes with a discussion of the results and provides implications for research and practice (section 6).

BACKGROUND

Prior Research on IT Adoption in Non-work Settings

Early technology adoption studies focused on work-related technologies in organizational settings (Venkatesh, Morris, Davis, & Davis, 2003). In the 1990's research began to examine IS-adoption also in private and residential settings. These early studies were still influenced by the utility-performance contingency of organizational IT usage which is reflected by the TAM (Davis, Bagozzi, & Warshaw, 1989). Many researchers argued that this one-dimensional orientation restricts the ability to theorize richly about adoption behavior because of disregarding context-specific factors (Williams, Dwivedi, Lal, & Schwarz, 2009). In an effort to address these flaws and to consider the differences between organizational and residential settings, Venkatesh and Brown (2001) developed the Model of Adoption of Technology in Households (MATH). Drawing upon the Theory of Planned Behavior (TPB) their model incorporates constructs from diverse research domains which have been largely omitted by previous studies. Based upon their seminal work further studies augmented our understanding of private and residential technology adoption. A large body of this stream deals with IS-artifacts which are ubiquitous in people's private lives like the SMT. In addition to technology-specific features these studies typically incorporate determinants originating in the fields of marketing and social psychology (e.g., Hong & Tam, 2006). Other studies extended adoption research by analyzing the role of values and suggest that technology adoption is affected by people's values (Lee & Kozar, 2008).

Green-IS and the Smart Metering Technology

The term Green-IS encompasses people, processes, technologies and software that helps to increase environmental sustainability by (1) reducing negative environmental impacts of IS itself (*direct effect*), (2) reducing negative environmental impacts of other economic sectors like industry, households, or agriculture by means of IS (*enabling effect*) (3) developing innovative IS-enhanced products and processes which profoundly change ways of living and result in reorganization of production and consumption towards more sustainability (*systemic effect*) (OECD, 2009). The SMT entails enabling and systemic effects. First, the SMT facilitates the implementation of energy efficiency measures and second a wide range of new products and services, which have the ability to radically alter the way energy is produced and consumed. For instance the SMT enables new services like demand modulation through load- and time-based tariffs (indirect load control) and automatic demand curtailing or increasing in peak or low-load times (direct load control). Further, the SMT is supposed to keep energy prices down and provide consumers with more detailed and prompter information. Our work conceives the SMT to consist of a communication gateway which enables bidirectional communication and an electronic meter which records electricity consumption or production. The SMT is embedded in an Advanced Metering Infrastructure (AMI) which connects to backend systems (see Figure 1).

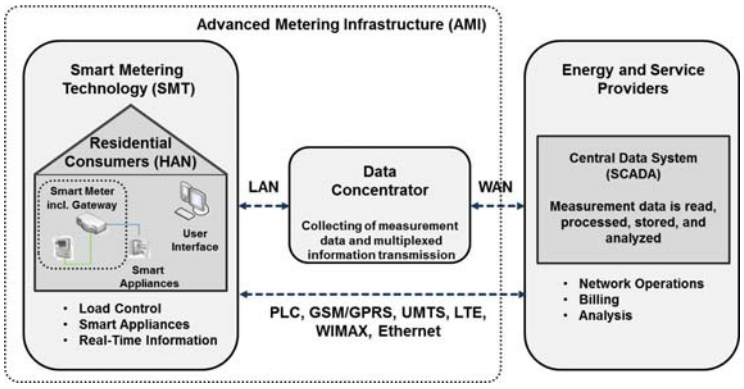

Figure 1. The Smart Metering Technology

RESEARCH MODEL AND HYPOTHESES DEVELOPMENT

The TPB contends that human behavior is a result of the intention to perform a behavior and perceived behavioral control. Intention can be regarded as the subjective probability that a person will perform a certain behavior (Fishbein & Ajzen, 1975: 12). As "*intention is the most proximal influence on behavior and mediates the effect of other determinants on behavior*" (Venkatesh & Brown, 2001) it is frequently found to be a strong predictor of actual usage (Venkatesh et al., 2003). For the

present study we hypothesize that individual intention is mainly predicted by the determinants attitude, environmental concerns, normative beliefs and perceived behavioral control (see Figure 2). Our model additionally incorporates antecedents of attitude. Distinct from prior adoption research we incorporate the variable environmental concern as direct predictor of intention as the positive environmental impact is an important characteristic of the examined Green-IS artifact.

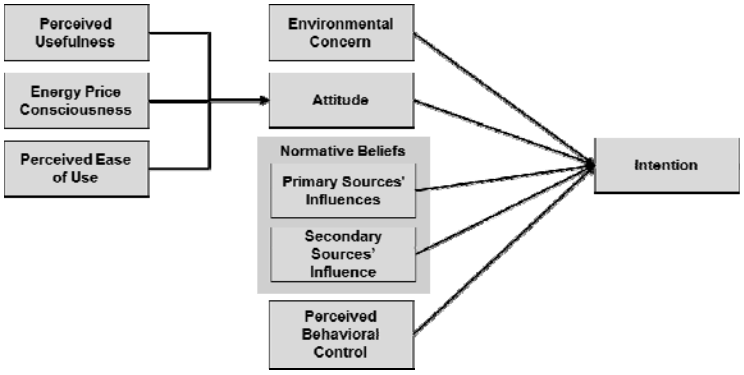

Figure 2. The Research Model

In the domain of environmental psychology constructs relating to one's environmental attitude or concern are widely used as predictors of environmentally-friendly behaviors (Kaiser, Wölfing, & Fuhrer, 1999). Correspondingly, in the consumer behavior literature such variables are used to identify the segment of "green consumers". The most commonly employed construct is the new environmental paradigm which reflects a person's evaluation of the relationship between humans and the environment by measuring social-altruistic and bio-centric values (Dunlap & van Liere, 1978). Literature considers these values as origins of any green consumer behavior. As the construct measures the degree to which a person thinks that the environment is vulnerable to human interference it is referred to as environmental concern in the following. Previous studies suggest that environmental concerns are positively linked to the acceptance of eco-innovations (Keirstead, 2007). Accordingly we state that environmental concern is positively related to SMT-adoption. Further, we expect that with greater environmental concerns attitude has a stronger effect on intention. Therefore, we posit:

Hypothesis 1: Environmental concern positively influences the intention to adopt the SMT.

Attitude is referred to as the degree to which an individual assesses a behavior as (un-)favorable (Fishbein & Ajzen, 1975). Concerning SMT-adoption, attitude reflects a person's evaluative judgment about using the SMT as either being harmful or beneficial. In line with previous studies which found that attitude was a strong predictor of intention (Kranz, Gallenkamp, & Picot, 2010) we suggest that one's favorable attitude towards using the SMT is positively related to adoption intention:

Hypothesis 2: Attitude positively influences the intention to adopt the SMT.

Human behaviors are embedded within social contexts. Thus, they are highly susceptible to interactions with one's social environment. "*To capture the nuances of the social environment*" (Srite & Karahanna, 2006) we distinguish between primary (e.g., friends) and secondary (e.g., media) sources' influence. Owing to the diversity of potential interpersonal and impersonal influences in private settings we assume that normative beliefs are an important adoption-driver. Moreover performing eco-friendly behaviors often means conforming to social norms. Hence, we contend that people receiving positive feedback about the SMT or social pressure from primary or secondary sources are more likely to intend adopting the SMT:

Hypothesis 3a: Primary sources' influence positively impacts the intention to adopt the SMT.

Hypothesis 3b: Secondary sources' influence positively impacts the intention to adopt the SMT.

Perceived behavioral control reflects the extent to which a person believes to control internal and external factors that either enable or confine performing a behavior in question (Ajzen, 1991). Hence, for the present study's context perceived behavioral control is related to the consumer's subjective degree of control over adopting and using the SMT. We suggest that the higher the perceived level of behavioral control the greater the intention to adopt the SMT:

Hypothesis 4: Perceived behavioral control positively influences the intention to adopt the SMT.

As pre-test interviews have indicated that the SMT is merely perceived as a utilitarian technology we include the TAM-based variables perceived usefulness and perceived ease of use. The TAM contends that the salient beliefs perceived usefulness and perceived ease of use determine an individual's attitude toward usage. Across various models and studies these constructs have been consistently found to be strong determinants of adoption and usage behavior in both workplace and private settings (Hong & Tam, 2006). Perceived usefulness is defined as the "*prospective user's subjective probability that using a specific application system will increase his or her job performance*" (Davis et al. 1989). For the context of our study, usefulness is related to energy efficiency, potential cost savings, and real-time information about power consumption. Perceived ease of use "*refers to the degree to which the prospective user expects the system to be free of effort*" (Davis et al. 1989) respective to mental and physical efforts as well as ease of learning (Yang et al. 2004). In line with numerous studies in IS adoption research (e.g., Davis, 1989) we hypothesize that the easier it seems to use the SMT, the more positive is people's attitude towards using the SMT. Thus, we contend:

Hypothesis 5: Perceived usefulness positively influences the attitude towards the SMT.

Hypothesis 6: Perceived ease of use positively influences the attitude towards the SMT.

Consumer decisions are based on a combination of rational and social factors blending behavioral and economic considerations (Simon, 1957). After an upfront investment the use of Green-IS is typically associated with decreasing costs through efficiency gains. Surveys show that consumers make a strong connection between the SMT and cost saving opportunities (Wimberly, 2011). Thus, to investigate the role of economic considerations we include energy price consciousness which reflects one's inclination to focus on reducing energy expenditures (Lichtenstein, Ridgway, & Netemeyer, 1993). We contend that consumers with a greater focus on reducing energy bills are more likely to perceive the SMT as a valuable technology. Hence, we state:

Hypothesis 7: Energy price consciousness positively influences the attitude towards the SMT.

RESEARCH METHODOLOGY

Sample and data-collection procedure

We collected data via an online survey. A pretest of the initial survey instrument was conducted. Due to the feedback some items and the initial presentation of the SMT's most important features were modified. This additional information (textual description and governmental information video about SMT's features) was included because of the public's low degree of familiarity with the technology (Wimberly, 2011) which could act as an interfering variable. To ensure non-biased responses we controlled for whether respondents watched the whole video. The corresponding t-test conducted for the two groups of viewers and non-viewers showed no significant differences in intention. Subjects were recruited by e-mail to 1.000 randomly selected post- and undergraduate students soliciting participation in the survey. Within the e-mail a direct link to the questionnaire was incorporated. 284 students fully completed the survey (response rate: 28.4%). 52% of the sample is male. The average age was 24.8.

Measures

Each of the scale items employed was derived from previously validated measures widely used in their scientific domains. We restated each item carefully to reflect the characteristics of the research context. All items, apart from environmental concerns (four-point) were rated on a seven-point Likert-scale with the anchors "strongly agree" (1) and "strongly disagree" (7). Additionally data for the control variables age (coded as 1 = < 21, 2 = 21-30, 3 = 31-40, 4 = 41-50, 5 = 51-60, 6 = > 60) and gender (coded as 0 = female and 1 = male) was obtained from the survey. As shown in Table 1 each of the constructs showed good internal consistency.

Variable	Abbreviation	Number of Items	Measure Source	Cronbach's α
Intention to use	INT	3	Davis (1989)	.75
Attitude toward use	ATT	4	Davis (1989)	.89
Environmental concern	ECO	4	Dunlap and van Liere (1978)	.76
Primary sources influence	PSI	3	Mathieson (1991)	.94
Secondary sources influence	SSI	3	Brown and Venkatesh (2005)	.90
Perceived behavioral control	PBC	3	Taylor and Todd (1995)	.64
Perceived usefulness	PU	4	Davis (1989)	.78
Perceived ease of use	PEU	4	Davis (1989)	.92
Energy price consciousness	EPC	4	Lichtenstein et al. (1993)	.75

Table 1. Constructs and items

RESULTS

To test the model multiple regression analyses were conducted. We chose regression analysis because of its comprehensibility and its superior applicability for studying interaction effects (Goodhue, Lewis, & Thompson, 2007). Table 2 provides the descriptive statistics and correlation coefficients.

		Mean	STD	1	2	3	4	5	6	7	8	9	10
1	INT	2.35	1.12	-									
2	ATT	1.82	1.03	.65*	-								
3	ECO	1.70	.42	.23*	.11*	-							
4	PSI	4.90	1.84	.16*	.15*	-.09	-						
5	SSI	3.71	1.76	.28*	.17*	-.02	.40*	-					
6	PBC	2.16	1.02	.26*	.34*	.10	.05*	.12*	-				
7	PU	1.69	.85	.51*	.67*	.11*	.17*	.15*	.35*	-			
8	PEU	2.51	1.21	.35*	.51*	.10*	-.12*	.08	.50*	.44*	-		
9	EPC	4.02	1.40	.31*	.22*	.09	-.02	.09	.18*	.14*	.18*	-	
10	AGE	2.40	1.06	-.25	-.10*	-.16*	.19*	-.03	-.02	-.04	-.05	-.23*	
11	GEN	.68	.47	-.12*	.02*	-.01	.11*	-.04	-.18*	.06	-.03	-.11*	.28*

Note. N = 284. * p < .05.

Table 2. Mean, standard deviations and correlations for study variables

Some of the variables of interest are correlated. Hence, in order to assess construct validity, a confirmatory factor analysis was conducted employing principal component analysis with varimax rotation and Kaiser normalization. All items loaded appropriately and above the threshold of .40 (Straub, Boudreau, & Gefen, 2004). Moreover, the eigenvalues of all constructs were greater than 1.0. Thus, the results of the factor analysis fulfill the criteria for both convergent and discriminant validity (Straub et al., 2004). We also tested for multicollinearity (see Table 3). The results give no indication for multicollinearity contaminating the results (Neter, Kutner, Wasserman, & Nachtsheim, 1996). Further, the means of the variance inflation factors (VIF) were not significantly greater than 1 in any of the models. Table 3 also shows that the tolerance values do not point to multicollinearity being an issue (Brace, Kemp, & Snelgar, 2003). The regression results are depicted in Table 3.

	Variable						
Model	Dependent	Independent	β	t	R^2_{adj}	Tolerance	VIF
1	ATT	Age	-.02	-.45	.59	.99	1.01
		Gender	.00	.09		.99	1.02
		PU	.66	15.43 ***		.81	1.24
		PEU	.20	4.65 ***		.80	1.25
		EPC	.06	1.97 *		.97	1.03
2	INT	Age	.04	.77	.43	.97	1.03
		Gender	-.09	-1.91 *		.91	1.10
		ATT	.56	11.34 ***		.84	1.19
		PSI	.08	1.72 *		.79	1.26
		SSI	.16	3.21 ***		.81	1.23
		ECO	.16	3.40 ***		.97	1.03
		PBC	-.03	-0.06		.81	1.24

Note. N = 284. * p < .10, ** p < .05, *** p < .01.

Table 3. Multiple regression results

Model 1 shows that the hypothesized positive relationships between attitude and perceived usefulness ($\beta = .66$, $p < .01$), perceived ease of use ($\beta = .20$, $p < .01$) were supported by the data. Energy price consciousness ($\beta = .06$, $p < .10$) only had a moderate impact. In total the variables of model 1 accounted for a considerable amount of variance ($R^2_{adj} = .59$). The results of model 2 confirm the predicted positive relationships of environmental concern ($\beta = .16$, $p < .01$), attitude ($\beta = .56$, $p < .01$), and secondary ($\beta = .16$, $p < .01$) sources influence on intention. Only moderate support was found for the hypothesized positive relationship between primary sources influence ($\beta = .10$, $p < .01$) and intention. No support was found for perceived behavioral control influencing intention. All variables accounted for a significant proportion of the variance in intention ($R^2_{adj} = .43$).

DISCUSSION AND IMPLICATIONS

Private consumers' acceptance and usage of the SMT is a prerequisite for enabling advanced coordination and communication in smart grids. Hence, understanding consumers' SMT-adoption is both a business asset and a societal

imperative. Our study aimed at examining how attitude and its antecedents, environmental concerns, normative beliefs and perceived behavioral control affect intention. Thereby the paper contributed to research in energy informatics and residential IS adoption.

Consistent with previous findings in private adoption research, attitude proved to be the most influential determinant of intention. The three antecedents of attitude accounted for a remarkable percentage of the variance in attitude (R^2_{adj} = .59). In particular, we found that perceived usefulness is the strongest predictors of attitude. The major effect of perceived usefulness shows that consumers regard the SMT as a utilitarian technology. As proposed by the TAM also the perceived ease of use was found to impact attitude significantly. Energy price consciousness was also found to significantly impact attitude. The study also provides evidence that normative beliefs, especially from secondary sources, are an important adoption driver.

An intriguing finding is that environmental concerns significantly impact intention. People with greater concerns regarding economy's incessant growth and nature's vulnerability are found to be more likely to adopt the SMT. The approach used to measure environmental concern operationalized the decision to act environmentally-friendly as a trade-off between one's self-interest and that of others. Therefore, the findings suggest that social-altruistic and bio-centric values and motives positively affect Green-IS adoption. Similarly, the non-significant effect of perceived behavioral control on intention was unexpected. This finding suggests that consumers' adoption decisions are independent from their perceived control to adopt and use the SMT. This finding may be explained by the strong impact of attitude which is likely to attenuate the effect of perceived behavioral control (Ajzen, 1991). Given that one is disposed to perform a behavior, inhibiting factors seem to play a subordinate role (Bandura, 1997).

As with any other empirical study, this paper has limitations that should be considered when interpreting the results. One limitation originates from collecting data online from a student sample. This approach resulted in that the sample included a disproportionately high number of young and educated participants which may cause selection bias. However, this limitation should not undermine the results since early adopters tend to be young and educated (Rogers, 1983). As the deployment of the SMT as defined in our study is still in its infancy we had to rely on intention rather than on actual adoption. We examined SMT-adoption by a single-study design in a geographically confined context. Thus, to verify the results future research should conduct longitudinal studies in different cultures. Further, by using a survey as research method the ability to imply causality from establishing relationships is restricted.

Despite these limitations the study presents some encouraging and useful findings on which future research might build upon in numerous ways: Our study suggests that investigating the role of moral values and motives is a promising area of IS research. We encourage researchers to investigate the influence of variables related to personality, values, attitudes, interests, or lifestyles on the adoption and usage of Green-IS. For policy makers and practitioners the findings implicate that additionally to potential cost savings information for consumers should particularly highlight the positive environmental impact associated with SMT-usage.

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