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RESEARCH ARTICLE

ADOPTION OF SUSTAINABLE TECHNOLOGIES: A MIXED-METHODS STUDY OF GERMAN HOUSEHOLDS[1]

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Appendix A

Review of the Literature on SMIT Adoption

Authors/Paper	Summary	Comments/Gaps
Kranz et al. (2010)	Kranz et al. empirically test a model of smart metering adoption based on the TAM model and extended by the variable subjective control.	Focuses on socio-psychological constructs in the model, self-selected sample based on an online survey that was linked on an e-energy website.
Kranz and Picot (2011)	Kranz and Picot test a model of smart metering adoption based on the TPB extended by the variable "environmental concern."	Generic model without SMT-specific factors; regional (Munich) student sample.
Wati et al. (2011)	The authors test a model of smart metering adoption based on goal framing theory and the norm activation model. The model is then empirically tested.	No technological or smart meter specific constructs in the model. The sample (Korean households) is very small (n = 100) and consists of 98% male participants.
Wunderlich et al. (2012a)	The authors pretest a model of SMT adoption behavior employing variables of technology acceptance and motivational factors.	No smart meter specific constructs. No representative sample.
Wunderlich et al. (2012b)	The authors test a model of SMT usage behavior employing the TAM model extended by motivational factors.	No smart meter specific constructs in the model. Focus on current smart meter users.
Abu et al. (2014)	The authors review the literature on the extended TAM to form a model for smart metering acceptance.	No quantitative or qualitative data employed to test. No final framework suggested.
Wunderlich et al. (2013)	The authors investigate adoption behavior of transformative services by employing an extended TAM model including behavioral and motivational variables.	No smart meter specific constructs. Focus on differences between users and potential users (adopters) of transformative services.
Wunderlich, Kranz, and Veit (2013)	The authors test a model of smart meter adoption focusing on motivational factors and personal values comparing actual users and non-users of SMT	No smart meter specific variables.
Al-Abdulkarim et al. (2014)	The authors test a model of SMT adoption based on the Unified Theory of the Acceptance and Use of Technology, the innovation diffusion theory and acceptance determinants derived from the Dutch smart metering case.	Small (n = 315), non-representative sample. No further information about response rate. Use of secondary data for model that seems arbitrary; no qualitative validation.
Toft et al. (2014)	The authors test a model of smart grid adoption based on an extended version of TAM (with the inclusion of moral norms). The model is empirically tested in three Scandinavian countries and Switzerland.	No smart meter specific constructs in the model. No qualitative data used.
Warkentin et al. (2017)	The authors develop a model of SMT adoption by drawing on existing models of technology adoption and psyhological ownership of information. The model is tested through a survey of paid qualtrics panel of homeowners in the United States.	No smart meter specific constructs in the model. Specific focus on privacy-related concerns and shared benefits only.

Appendix B

Literature Review for Household Technology Adoption/Use

Authors	Research Objective and Technology Context	Theoretical Underpinning	Methodology	Key Findings	Comments
Venkatesh and Nicosia (1997)	Use of multimedia and other technologies at home	Household technology adoption is facilitated by the "technological space" and "social space."	N/A	*Household activities, gender, and perceived needs* play a role in technology adoption; household activities have a mutually interactive effect with *configuration of household technologies*, *attitudes toward technology*, etc., which in turn affects the nature and patterns of use.	General set of demographic, attitudinal, and technology-related factors proposed; specific factors related to energy-usage and privacy concerns that are applicable to SMT not studied.
Venkatesh and Brown (2001)	Adoption of personal computers at home	Theory of Planned Behavior	Phone survey of household head/primary decision-maker; data collected in two phases	Adoption is driven by *utilitarian, hedonic, and social outcomes*; non-adopters are influenced by *technology changes and fear of obsolescence*.	General set of attitudinal, and technology-related factors studied; specific factors related to energy use and privacy concerns that are applicable to SMT not studied.
Hoffman et al. (2004)	Indispensability of the internet	Fragmented literature on social capital and technology diffusion	N/A	Indispensability of technology (or routinization of technology) in homes are influenced by *individual-level determinant*s (e.g., personality, demographics, needs), *technology determinants, and socio-cultural determinants* (e.g., education, profession).	General set of demographic, individual, social and technology-related factors proposed; specific factors related to energy use and privacy concerns that are applicable to SMT not studied.
Shih and Venkatesh (2004)	Home computers	User diffusion model	Survey of household heads	Patterns of use of home computers are affected by the *household social context* in which the user operates such as *experience with technology*, *household communication needs, the personal dimensions such as use innovativeness*, the *technological factors such as the characteristics associated with the innovation, and external factors*.	General set of demographic, attitudinal, and technology-related factors proposed; specific factors related to energy use and privacy concerns that are applicable to SMT not studied.
Arkesteijn and Oerlemans (2005)	Adoption of green electricity in Dutch residences	Fragmented set of literature on innovation diffusion	Phone survey of adopters and non-adopters of green electricity in a single city in the Netherlands	Several factors such as *ease of use, willingness to pay, level of trust in green electricity supplier* among others were found to affect adoption.	General set of demographic, attitudinal, and technology-related factors proposed; specific factors, for example, those related to privacy concerns that are applicable to SMT not studied.
Brown and Venkatesh (2005)	Adoption of home PC and extension of the MATH model	Theory of Planned Behavior	Survey of households in the U.S. without PCs	*Attitudinal, social, and perceived control beliefs* affect household PC adoption. Further, these beliefs were found to vary with the life cycle stage.	A comprehensive set of demographic, attitudinal, and technology-related factors proposed; specific factors related to energy use and privacy concerns that are applicable to SMT not studied.

Authors	Research Objective and Technology Context	Theoretical Underpinning	Methodology	Key Findings	Comments
Choudrie and Dwivedi (2005)	Examine the prevalence of research methods used in the area of general technology adoption, especially within household contexts.	Review of existing literature	N/A	Studies on technology adoption within the household context have typically used *survey methods*.	Does not provide a conceptual or empirical model with which to study SMT adoption.
Brown, Venkatesh, and Bala (2006)	Use of PC in households	MATH	Survey of U.S. households	*Utility for children, applications for personal use, utility for work-related use and applications for fun* affect usage of PCs in homes.	General set of demographic, attitudinal, and technology-related factors proposed; specific factors related to energy use and privacy concerns that are applicable to SMT not studied.
Choudrie and Dwivedi (2006)	Adoption of broadband in households	MATH	Survey of households in the London area	*Several relative advantage factors such as faster access, faster download), utilitarian factors such as use of broadband for educational purposes, hedonic factors such as downloading and playing music were found to be enablers of broadband adoption, while costs and lack of satisfaction with current internet packages were found to be the deterrents of broadband adoption; demographic variables had mixed support.*	General set of demographic, attitudinal, and technology-related factors proposed; specific factors related to energy use and privacy concerns that are applicable to SMT not studied.
Brown (2008)	Charting the past, present, and future of household technology adoption, use and impacts	Review of past literature	N/A	Future research on household adoption should examine the *role that digital divides play on adoption of technologies*, and should also examine the adoption of technologies *where fear of risk, privacy loss*, etc. (such as internet) might play a role should be examined.	Does not provide a conceptual model with which to examine SMT adoption, but does highlight the need to examine the adoption of technologies where privacy, etc., could play a role.
Hsieh et al. (2008)	Post-implementation and continued usage of internet via cable television in households	Theory of Planned Behavior	Survey of LaGrange households in Georgia	*Utilitarian outcomes, hedonic outcomes, influence from friends, family, and government, self-efficacy, perceived ease of use, and availability* all affect intention to continue using.	General set of demographic, attitudinal, and technology-related factors proposed; specific factors related to energyuse and privacy concerns that are applicable to SMT not studied.
Venkatesh (2008)	Whether and how contemporary home life is being transformed through the arrival of new digital technologies	Review of existing studies	N/A	Highlights some key issues to the advancement of digital home technologies such as *technology being too complex for most household users*, *lack of incentives from internet providers to push these technologies*, *privacy issues and interface issues*.	Does not provide a conceptual or empirical model with which to examine SMT adoption, though suggests the *importance of focus on privacy concerns for digital technologies.*
Zhang and Maruping (2008)	Examine cultural influences on household adoption of PCs	MATH and Hofstede's cultural variables	N/A	Proposes the *moderating role of all five Hofstede's cultural variables on the factors affecting household adoption* as per the MATH model.	Focus of the study is on cultural influences. General set of demographic, attitudinal, and technology-related factors proposed; specific factors related to energy use and privacy concerns that are applicable to SMT not studied.

Authors	Research Objective and Technology Context	Theoretical Underpinning	Methodology	Key Findings	Comments
Mills and Schleich (2012)	Residential adoption of energy-efficient behaviors and practices	Review of existing literature	Data taken from the Residential Monitoring to Decrease Energy Use and carbon Emissions in Europe Project survey conducted in 11 countries	*Education, age, household composition and other household characteristics*	Focus on the adoption of energy-efficient appliances and light bulbs, and not on any residential adoption of information technologies; general set of household characteristics studied only; specific factors related to energy use were not studied; the authors highlighted that one of the most critical variables, *actual energy consumption*, should be examined in future studies.
Venkatesh et al. (2012)	Use of mobile Internet technology	UTAUT2	Two-stage online survey of 1,512 mobile Internet consumers in Hong Kong; use data collected 4 months after the first survey	*Extension of the UTAUT model by the addition of hedonic motivation, price value, and habit, as well as other moderating effects. Results indicate that these factors produced a substantial improvement in the variance explained in behavioral intention and use.*	Focus of the study was on a general set of factors that affect consumers' adoption of technology; specific factors related to energy use in the household that are applicable to SMT was not studied.
Brown et al. (2015)	PC adoption in homes	MATH models and other theories of technology adoption	Survey of 5400 households in the U.S.	*Comparison of seven different models such as TRA, TPB, MM, MATH; Studied motivation, but intrinsic and extrinsic motivation only; Results indicated that "context-specific" models of household technology adoption "outperforms" other models.*	Focus of the study was on comparing general models of technology adoption with a specific model of technology adoption in the household; specific factors related to energy use and privacy concerns that are applicable to SMT were not studied.

Appendix C

Elaboration of Decision Choice of Mixed-Methods Study (Adapted from Venkatesh et al. 2016)

	Property	Decision Consideration	Other Design Decision(s) Likely to Affect Current Decision	Design Decision and Reference to the Decision Tree
Step 1: decide on the appropriateness of mixed-methods research	Research questions	Qualitative or quantitative method alone was not adequate for addressing the research question. Thus, we used a mixed-methods research approach.	None	Identify the research questions • We wrote the qualitative and quantitative research questions separately first and a mixed-methods research question second. • The qualitative research question was: "What are the salient factors that determine the household adoption of SMT?" • The quantitative research question was:"Does the STARS model explain household adoption of SMT?" • The mixed-methods research question was: "Are the factors identified in the qualitative study and as captured through the STARS model supported by the results of the quantitative study?" • We wrote the research questions in the question format. • The quantitative research question was based on results from the qualitative research questions, and the mixed-methods research question depended on the results from both the quantitative and qualitative research questions. • The relationships between the questions and the research process were predetermined.
	Purpose of mixed-methods research	The purpose of our mixed-methods design was to help develop hypotheses for empirical testing using the results of the qualitative study given the lack of research on this topic.	Research questions	Developmental purpose and the results from the qualitative strand were used to develop the research model and the hypotheses tested in the quantitative strand.
	Epistemological perspective	The qualitative and quantitative components of the study used different paradigmatic assumptions.	Research questions, purposes of mixed methods	Multiple paradigm stance.
	Paradigmatic assumptions	The researchers believed in the importance of research questions and embraced various methodological approaches from different worldviews.	Research questions, purposes of mixed methods	Dialectic stance (we used more of the interpretive and grounded-theory perspective in the qualitative study and then applied a positivist perspective and deductively tested the developed model in the quantitative study).

	Property	Decision Consideration	Other Design Decision(s) Likely to Affect Current Decision	Design Decision and Reference to the Decision Tree
Step 2: develop strategies for mixed-methods research designs	Design investigation strategy	The mixed-methods study was aimed to develop and test a theory.	Research questions, paradigmatic assumptions	• Phase 1: exploratory investigation. • Phase 2: confirmatory investigation.
	Strands/ phases of research	The study involved multiple phases.	Purposes of mixed-methods research	Multistrand design.
	Mixing strategy	The qualitative and quantitative components of the study were mixed at the data-analysis and inferential stages.	Purposes of mixed-methods research, strands/phases of research	Partially mixed methods.
	Time orientation	We started with the qualitative phase, followed by the quantitative phase.	Research questions, strands/ phases of research	Sequential (exploratory) design.
	Priority of methodological approach	The qualitative and quantitative components were not equally important.	Research questions, strands/ phases of research	Dominant-less dominant design with the quantitative study being the more dominant paradigm.
Step 3: develop strategies for collecting and analyzing mixed-methods data	Sampling design strategies	The samples for the quantitative and qualitative components of the study differed, but they came from the same underlying population.	Design investigation strategy, time orientation	Purposive sampling for the qualitative study given limited general knowledge on SMT, probability sampling for the quantitative study.
	Data collection strategies	• Qualitative data collection in phase 1. • Quantitative data collection in phase 2.	Sampling design strategies, time orientation, strands/ phases of research	• Qualitative study: a mix of both closed- and open-ended questioning using a pre-designed interview guideline. • Quantitative study: closed-ended questioning (i.e., traditional survey design).
	Data analysis strategy	• We analyzed the qualitative data not by "transformation" but by *reducing* it to broad categories using a software, ATLAS.Ti • We analyzed the qualitative data first and the quantitative data second.	Time orientation, data collection strategy, strands/ phases of research	Sequential qualitative-quantitative analysis.
Step 4: draw meta-inferences from mixed-methods results	Types of reasoning	In our analysis, we focused on developing and then testing/confirming hypotheses.	Design-investigation strategy	Both inductive and deductive theoretical reasoning.
Step 5: assess the quality of meta-inferences	Inference quality	• The qualitative inferences met the appropriate qualitative standards. • The quantitative inferences met the appropriate quantitative standards. • We assessed the quality of meta-inferences.	Mostly primary design strategies, sampling-design strategies, data-collection strategies, data-analysis strategies, type of reasoning	• We used conventional qualitative and quantitative standards in ensuring the quality of our inferences. • Design and explanatory quality; sample integration; inside-outside legitimation; multiple validities.
Step 6: discuss potential threats and remedies	Inference quality	We discussed all potential threats to inference quality in the form of limitations.	Data-collection strategies, data-analysis strategies	Threats to sample integration; sequential legitimation

Appendix D

Mixed-Methods Approach and Criteria (Adapted from Venkatesh et al. 2013

Quality Aspects	Quality Criteria	Authors' Response to Venkatesh et al. (2013) Guidelines
Purpose of mixed method approach	Development	This study is divided into two phases: (1) qualitative study involving interviews to understand some of the core SMT-specific factors critical to adoption, and (2) a large quantitative survey. The qualitative study was used to identify factors for model development and hypotheses justification, which was subsequently tested in the quantitative study.
	Sequential less-dominant qualitative followed by dominant quantitative investigation	The scope and objectives of the qualitative investigation using a set of interviews with SMT adopted is very limited; it is primarily to support the quantitative investigation.
Design quality	Design adequacy	The study used qualitative interviews along with limited documentary analysis followed by a quantitative survey. This strategy of examining "raw" data from the phenomenon as a "prelude" to the larger quantitative study ensured that the research model tested using the quantitative study was relevant to the phenomenon of interest (Yin 1993). In doing so, it sought to combine the advantages of the two approaches, achieving depth and insight into the phenomenon as well as the breadth of coverage.
		Qualitative • *Selecting suitable interviewees*: The interviewees were either members of the grid operating division of large energy suppliers who were initiating much of the SMT roll-out in Germany, or other individuals who were potential adopters of SMT, and were thus seen as suitable. • *Entering the field with credibility:* The interviews were conducted by the first two authors of the manuscript, one who is professor (a highly respected individual in the German societal hierarchy), and another who is an analyst in a reputed international organization with a Ph.D. (also seen in high respect in the German society). • *Conduct of interviews:* Based on a protocol, but being sensitive to the principles of flexibility, non-direction, specificity, and range (Flick 1998).
	Analytical adequacy	**Qualitative** • Transcription of the relevant and fruitful (and majority) of interviews, that is interview #8-24(Walsham 2006), the use of interview outline (though evolving and customized for different participants), detailed interview notes from interview #s 1-7, and other documents formed part of the qualitative database that was stored in Dropbox. • Relevant factors codes first generated by Atlas.Ti. • Labeling and re-labeling of the relevant concepts by all three authors after the generation of the codes. The process was iterative, and roughly resembled a *constant comparative analysis*, ending when *theoretical saturation* occurred (Glaser and Strauss 1967). • While no notion of inter-rater reliability was used, the identification and selection of the concepts represented a consensus among the three researchers involved in data collection and analysis, implying some form of convergence and/or reliability. • Triangulation of data from the many interviews; comparison of responses, especially across locations and levels. • Illustration of the themes/factors using quotations may further enhance *plausibility* • Given the exploratory nature of the study, which were geared toward discovery by engaging with "raw" data, and the limited scope of the qualitative nature of the study, the notion of *theoretical validity* is not applicable here.

		Quantitative • Justification of the choice of analysis technique (that is, hierarchical regression). • Sample size of 930 to ensure reasonable power. • Professionally collected data, ensuring that bias in sampling of subjects in avoided or at least minimized. Tests were conducted to compare sample with the entire German population to ensure that the patterns seen in age, gender, etc., were similar to the averages and patterns within the German population.
Explanation quality	Qualitative inference	• The constructs identified through the qualitative study were not only plausible, but many of them were seen to be relevant in a large survey of German SMT adopters.
	Quantitative inference	• *Internal validity* concerns were addressed by developing a model that was theoretically robust, reliability of the data collection process and measurements, and appropriate statistical tests. • *Statistical conclusion validity,* considered to be a "special case of internal validity," was ascertained by ensuring construct validity, and appropriate level of significance for tests, and testing for mulicollinearity appropriately. • *External validity* was ascertained to some degree by ensuring that the sample represented the entire German population by comparing the sample with data of German citizens from the Statistisches Bundesamt (www.destatis.de). We summarize these in Table 4.
	Integrative inference	Much of the originality in the study in terms of *specific antecedents of SMT adoption* can be attributed to the qualitative interviews that was conducted in the introductory phase, but offered the researchers an experience-near view of the phenomenon, given that many of the interviewees were members of the grid operating division of a large German energy supplier. Many of the identified factors were significant in the quantitative study. *The R-square of the model was good, and the addition of the SMT variables to a purely motivational model increased the r-square by .012, and the difference in the r-squares between the first and second models was significant. Based on the above, we can say that* we have been able to achieve a reasonable degree of balance between comprehensiveness and parsimony in the model, and hence *integrative efficacy*. The synergy between the qualitative interviews of SMT adopters, followed by survey of the adopters in Germany, the results of which could be understood in light of the qualitative study indicates a satisfactory level of *integrative efficiency* and *integrative efficacy*.

Appendix E

Details of Interviewees

#	Role in the Family	Role in Organization	Potential Adopter?	Current User?	Prior Experience
R1	Household head	Teamlead in the grid operating division, German energy provider	Yes	No	No
R2	Household head	Coordinator Smart Grid, German energy provider	Yes	No	No
R3	Household head	Employee grid operating division, German energy provider	Yes	Yes	Yes
R4	Household head	Employee in the marketing division (smart metering), German energy provider	Yes	Yes	Yes
R5	Household head	Employee in the marketing division (smart metering), German energy provider	Yes	No	No
R6	Household head	Coordinator field study (MeRegio), German energy provider	Yes	No	No
R7	Household head	Employee division corporate development/field studies Smart Grid, German energy provider	Yes	Yes	Yes
R8	Household head	Project manager M&A at utility, German energy provider	Yes	No	Yes
R9	Household head	Head of department smart metering, German energy provider	Yes	No	Yes
R10	Household head	Project Manager, consulting	Yes	No	Yes
R11	Household head	Innovation manager, regional energy provider	Yes	No	Yes
R12	Household head	Head of department electricity grid management, Germany energy provider	Yes	No	Yes
R13	Household head	Head of department smart meter technology, German energy provider	Yes	No	Yes
R14	Household head	Manager on duty smt rollout, German energy provider	Yes	No	Yes
R15	Household head	Manager smt rollout division, German energy provider	Yes	No	Yes
R16	Household head	Department Head Asset Management Net-division, regional energy provider	Yes	No	Yes
R17	Household head	Department Head, Sales and Distribution Strategy, German energy provider	Yes	No	Yes
R18	Household head	Team lead in the area electricity grid management, Germany energy provider	Yes	Yes	Yes
R19	Household head	Employee in the area electricity grid management, German energy provider	Yes	Yes	Yes
R20	Household head	Specialist Smart Grid, German energy provider	Yes	No	Yes
R21	Household head	Political journalist, German public television / Adjunct Professor of Mass Media	Yes	No	No
R22	Household head	Consultant in the area digital, consulting	Yes	No	No
R23	Household head	Consultant in the area retail, consulting	Yes	No	No
R24	Household head	Principal in the area Energy and Utilities, consulting	Yes	No	Yes

Appendix F

Emergent Themes/Quotes by Respondents

Higher Level Category of Variables	Emergent Themes/ Variables	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24
Attitude	Attitude	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PLOC	Ecological interest		X	X		X	X	X	X	X	X	X			X	X	X		X	X		X			X
PLOC	Love to tinker around with new technol-ogies/services	X		X	X				X	X	X	X		X	X	X	X	X			X			X	
PLOC	Creation of financial incentives and rewards for adoption	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PLOC	SMT as enabling technology	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
PLOC	Sustainability of financial incentives						X			X					X				X	X	X	X	X	X	
PLOC	Cost/ benefit expectations on financial incentives	X							X		X	X												X	
PLOC	Social pressure based on public opinion	X	X					X		X						X	X	X							
PLOC	Political pressure					X	X		X	X														X	X
Household demographics	Income level		X						X		X		X	X	X	X	X								X
Household demo-graphics	Household size		X	X	X		X					X			X		X							X	X
Household demo-graphics	Age	X		X	X	X					X	X		X	X	X									X
Household demo-graphics	Level of education		X		X				X					X	X	X	X							X	X
Electricity consumption-related characteristics	Electricity costs			X	X	X	X								X								X	X	
Inherent inno-vativeness	Interest in new innova-tions	X			X			X	X		X				X	X			X				X	X	
Electricity consumption-related characteristics	Willingness to pay for energy efficient innovations	X	X	X	X	X			X	X	X	X		X	X	X	X	X		X	X	X			X

Electricity consumption-related characteristics	Switching behavior			X											X	X							
Electricity consumption-related characteristics	Electricity consumption	X			X	X	X		X		X				X			X	X				
Electricity consumption-related characteristics	Perceived privacy risks	X	X	X		X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Electricity consumption-related characteristics	Consumption-related factors	X		X	X	X				X		X					X		X			X		X	X

Appendix G

Selected Quotes Substantiating the Different Themes

Subcategory	Selected Quotes on First Order Codes (Open Codes)
Attitude	"Currently I am not using SMT, but I would definitely be interested in using it." (R22) "For me it is more like a nice gimmick that could help me a bit. However, I think nobody really needs it." (R9) "Right now SMT rather has a negative touch for me." (R14)
Ecological interest	"Factors such as an ecological awareness, the willingness to save the environment, are much more important." R8) "I think it would be great if I could say that if I used SMT electricity is getting a bit greener again." (R11) "To enable someone to participate in shaping the energy transition from home, this is how you address people with eco affinity." (R14)
Love to tinker around with new technologies/ services	"Well, if I get any fun out of the money that I spend, it will definitely positively influence my decision. I just love tinkering around and exploring possibilities." (R15) "The key reason was the desire for something new or the interest, to see something new." (R20)
Creation of financial incentives and rewards for adoption	"In the end you need to offer me some monetary benefits." (R9) "… when I get such a technology and have to commit myself to something, changing my habits or just providing data, then I want to get a monetary benefit out of that." (R15) "Out of the three reasons why I would use SMT, the monetary incentive is the most important one for me." (R23) "I would love to see more differentiated tariffs based on the new meters. In the end I want to save some money when I adapt my behavior." (R20)
SMT as enabling technology	"… I can imagine SMT as an enabling technology for the whole internet of things. In the end it all needs to come together and work together and I want to be a part of that." (R22) "I think that SMT and the whole smart home universe need to be tightly interwoven to actually maximize usability. In the end smart home and the comfort effect is what would drive me to get SMT." (R23)
Sustainability of effects/ financial incentives	"In the beginning I will check my electricity consumption but after a while I optimized it and what will happen then? Are these effects sustainable? Will they continue developing an app or something or will I just stop using it?" (R22) "Initially I used it very regularly—that is the first year or something. And then it became slowly less and I have to say; now I actually no longer look on it which reduces my benefits as well." (R18)
Cost/ benefit expectations on financial incentives	"If it would be cost neutral, then I would choose to use SMT in any case." (R8) "The standard user and that is the majority of households will not see any immediate effects on either cost or benefit side." (R10)
Social pressure based on public opinion	"There are a lot of influencing factors that determine the intention of a potential customer.… and in today's society that can be either that you want to save the environment or that social pressure that you have to save the environment." (R17)
Political pressure	"I think that if society believes that SMT is a useful instrument to enforce their environmental policy, then you have to accept that." (R8) "And on the other side you have some politicians and they decide we need SMT. And in the end you have to use it and someone has to pay the bills." (R9)

Subcategory	Selected Quotes on First Order Codes (Open Codes)
Income level	"… the question of the age as well as income level and education are important points in adoption.… And it is clear that a household of 7-8.000 EUR net income per month can more easily carry the additional costs of 70 EUR per year than others who earn less." (R13) "I think a student in his first apartment won't really care about such things as he has other needs like having enough money to get drunk on a party. But later on with a higher income you have the money and you start thinking about the big picture…. Everyone thinks yes we need to reduce energy consumptions… At least it's like this for me and my friends." (R24) "Due to the higher fix costs we think that customers with higher incomes and a higher flexibility in their lifestyles will be more willing to adopt the new meters." (R2) "It will be related to the income although I would not necessarily see it as the dominant factor." (R8) "Well, I think, with increasing household income also the willingness increases." (R16)
Household size	"I think in two cases it does make sense: If it's one commercial unit it's easier to coordinate your consumption patterns and then I think it will scale a bit but not that much. The other case is if you live in a shared apartment because then it's just so much simpler to fairly split the bills which I guess could be very helpful." (R24) " If I would modernize a house and not a small flat—I am currently living in a 70 square meter flat in which I am switching off all consumers by extension plugs with switches—but if I would live in a larger house with more persons, who would maybe not so much have the sense for when to switch off the light, when to lower the radiator, which you also cannot expect from everyone, since everyone has a different affinity to this. Then, if I would live in such a household or in such a flat, then I would indeed try to steer larger [appliances] automatically so to run them automatically. So that these would run when the energy prices are lower or I have e.g. a high electricity production from my photovoltaic installation on the roof. So when generally the energy costs are low in my individual case. Therefore, I, of course, would need smart metering technology for one or the other task." (R11) "In any case the household size influences the probability of the adoption of a smart meter. One has to say clearly that a single household has of course less potential to optimize its electricity consumption compared to a family with four persons."(R14)
Age	"I can imagine that a younger … group, which has a certain techno-budget, that these can imagine to use the smart meter for certain controls and analyses for a certain monitoring and presentation and that they are interested in that." (R10) "… the question of the age as well as income level and education are important points in adoption." (R13) "Young people are always a bit more open towards new technologies compared to more settled people." (R14) "The age plays a role if you say that e.g. you can offer some new features via the smart metering technology, which is interesting for the younger generation like household steering via mobile phone etc. Based on this, the age will play a role." (R15)
Level of education	"I believe that electricity and energy efficiency has a higher weight in societal classes with a higher education compared to less educated classes.… I believe that, a lot in the technology arena and in particular in smart metering which for me is also a technical product, that at the end of the day a lot of decisions are influenced by the education level someone has." (R8)
Electricity costs	"…especially customers with above average electricity costs will be interested in the new meters." (R3) "I see a positive correlation between annual electricity costs of a household and the interest in smart metering technology." (R14)
Inherent Innovativeness	"I believe that a … techno-readiness-group in the customers, who have a certain techno-budget, that these can imagine that they can conduct a certain steering, analyses and monitoring as well a certain presentation of the consumption, that they are interested in smart meter technology." (R10) "I personally would be very interested in monitoring and steering my energy consumption. Maybe only for a few months but right now I would be really interested in doing so." (R22) "Many of the participants seemed to be extraordinarily interested in the technological aspects and the new possibilities offered by the smart meters." (R7) "Technoreadiness, the question of the age as well as income level and education are important points in adoption." (R18) "I think that the groups of people who are technology oriented have a positive attitude towards adopting smart metering technology.… This group will not only have interest in the smart metering technology or the gateway but they are more interested in the utility of this communication connection and that they will be keener on smart home or even more things of this kind." (R15) "As the technology is still in its infancy, the early adopters will probably be especially interested in new technologies and they will probably have a high willingness to pay for them." (R1) "Many of our customers asked how they could use the new technology and which devices could be operated by it automatically and how it will develop in the future." (R4)

Subcategory	Selected Quotes on First Order Codes (Open Codes)
Willingness to pay for energy efficient innovations	"If I had the choice of course, if the smart meter costs 10 Euro more per year than the classical analog meter I would maybe continue to use the analog meter. In my today's life situation this really always depends on what I can effectively do with the smart meter." (R11) "In so far I believe that there is a certain segment of the society whom one can convince of paying for a smart metering device based on environmental protection topics. That is if it can be shown to these customers when exactly green energy can be consumed and when it is energy from nuclear or coal plants. That is a customer group which, I believe can be reached." (R9) "The SMT is strengthening the consumer. This effect can be seen as a savings component, an educational component (in the sense of an ecological rising) and a psychological component, which is that one becomes a protagonist instead of being a passive consumer. Hence, the individual consumer can steer something and is empowered regarding her or his decisions with respect to energy consumption and the impact to the ecosystem. The more expensive electricity is becoming the more important these components are going to be with regard to the consumption decision. Hence, with growing electricity costs, the willingness to pay for a fixed amount to receive SMT is going to rise." (R21)
Switching behavior	"If it is told to households today that in some future they will sometimes have the possibility to save costs using smart meters, this will in most cases not lead to a higher adoption rate right now. But other private customers, who are changing providers frequently, may also see that by adopting the new technology there is a possibility to save money and reduce costs. But that will probably be the group of households who, at this given point in time do not see a big problem in an increase of their electricity bill by 10 EUR per month for buying the smart meter itself." (R15) "Why do customers switch the energy provider? Mainly because of the costs again. So if the smart meter leads to save costs, I believe there will be a correlation between the switching behavior of a customer and the smart meter adoption." (R16)
Electricity consumption	"And I believe that, for example, a smart meter together with applying additional services would maybe be something that might become accepted at the consumer because the consumer realizes that it is helping to reduce the electricity consumption." (R8) "The groups who in the first step will in fact receive intelligent measuring systems [SMT], … these groups are groups with a higher energy consumption. There it is more meaningful to monitor those and then to offer them also the possibilities to steer their energy consumption better." (R10) "It has already proven itself well and it is really very helpful. We definitely used to have an above average electricity consumption." (R18) "Our electricity consumption [as a household] was in the area of 7,000 to 8,000 kilowatt hours per year [about three times higher than the average of a German household]. … We have a fully air-conditioned house [which only have very few German households].… Then I received a smart meter with application software which is installed also locally on our family PC … with this I was able to see the current consumption data afterwards and then also display it on the PC. That information I also used to research the current consumption and then to motivate my family to save electricity by looking after small things like switching off the light after you. I did this by monitoring my monthly consumptions and ran them also into excel-based evaluations … I even incentivized my children and gave them the amount of money which they saved in the electricity consumption at the end of the month on top of their pocket money." (R19)
Perceived privacy risks	"I think knowing what exactly you are using is great … but e.g. my wife sometimes had the feeling to be observed." (R18) "Standards have to be set in a way that hackers don't have the possibility to shut down apartments or to access the consumption data." (R18) "Data protection, especially in regard to taking control over some of my devices, is the only real concern that I have." (R22) "In my opinion the mass of transferred data to the supplier is critical." (R20) "Privacy concerns have to be taken seriously and have to be dealt with actively. It is a topic where I have to say that we as a company decided to actively deal with it and take it up explicitly with our customers. We cannot put this under the carpet since we believe that this will be an important point in the adoption behavior." (R14)
Consumption-related factors	"… a smart meter is reaching out to the customers who would like to simply have transparency regarding their consumption behavior." (R16) "Seeing how much electricity is consumed per room and per device would be very interesting for me. Overall having transparency on my electricity consumption would help me a lot." (R23)

Appendix H

Distribution of Sample and German Citizens

Dimension	Subgroup	Distribution		
		Sample		Germany
		Absolute	Share in %	Share in %
Age [in years]	15–25	45	5%	13%
	25–45	310	33%	30%
	45–65	502	54%	34%
	> 65	73	8%	24%
Gender	Male	466	50%	49%
	Female	464	50%	51%
Education	No graduation	8	1%	4%
	Certificate of secondary school	275	30%	37%
	Certificate of polytechnical school (DDR)	52	6%	7%
	General certificate of secondary education/professional	234	25%	23%
	University-entrance diploma/university degree	333	36%	28%
	Other	28	3%	1%

Appendix I

Distribution of Survey Participants by Federal State

Federal State	In Sample		Germany
	Absolute	Share in %	Share in %
Baden-Württemberg	114	12%	13%
Bavaria	145	16%	15%
Berlin	37	4%	4%
Brandenburg	24	3%	3%
Bremen	7	1%	1%
Hamburg	20	2%	2%
Hesse	65	7%	7%
Mecklenburg-Western Pomerania	18	2%	2%
Lower Saxony	106	11%	10%
North Rhine-Westphalia	212	23%	22%
Rhineland-Palatinate	40	4%	5%
Saarland	7	1%	1%
Saxony	47	5%	5%
Saxony-Anhalt	25	3%	3%
Schleswig-Holstein	38	4%	3%
Thuringia	25	3%	3%

Appendix J

Scale Items for Construct Measures

Attitude:

(1) I assume that it is a good idea to use SMT.
(2) I think, that it is reasonable to use SMT.
(3) All in all, I think it is a bad idea to use SMT.
(4) I like the idea, to use SMT.

Intention:

(1) I can imagine using SMT regularly in my household.
(2) I plan to use SMT in the future.
(3) I intend to use SMT in everyday life.

For PLOC items, each item was preceded by "I use the system …" to capture the self-perceived reasons of behavior.

External PLOC:

(1) … because it is recommended by my energy supplier.
(1) … because it is recommended by governmental institutions.
(3) … because using SMT offers me financial incentives.
(4) … because the European Union recommends using SMT.
(5) … because I can avoid price peaks in peak load times.

Internal PLOC:

Identified PLOC

(1) … because I want to help protecting the environment.
(2) … because I personally like using SMT.
(3) … because I think it is personally important to myself.
(4) … because I want to learn how to use SMT.

Intrinsic PLOC

(1) … because I enjoy using SMT.

Introjected PLOC:

(1) … because I would feel bad if I would not.
(2) … because people who are important to me think that I should use SMT.
(3) … because it is trendy to be green.
(4) … because people who influence my behavior think that I should use SMT.
(5) … because people whose opinions that I value prefer that I use SMT.

Perceived Privacy Risk:

(1) Using SMT could lead to a loss of control over the privacy of my personal data.
(2) Using SMT could lead to a loss of my privacy, because my energy consumption data could be used without my knowledge.
(3) My personal data won't be used for any purposes not related to SMT.
(4) My personal data that is gathered due to the usage of SMT would not be sold to third party providers.
(5) I am concerned about the data security of SMT.
(6) Internet hackers might take control of my payment and consumption data if I would use SMT.
(7) The databases that are used to save my consumption data are protected against unauthorized access.

Net Household Income:

How high is your total monthly net household income? We mean the amount that is a total of salary, wages, income from self-employment, annuity or pension, each after tax and deduction of social security contributions. Please add any income from public aid sources, income from rent, lease, housing benefit, child benefit and other forms of income.

Household Size:

How many persons live in your household, including yourself? Please also think of any children living in your household.

Age:

How old are you?

Average electricity costs per month:

Approximately how high is your monthly payment for electricity?

Inherent Innovativeness:

To what extent do you have an interest in general in technical innovations?

Willingness to pay for energy efficient innovations:

How much are you willing to spend annually on technical innovations, with which you can lower the energy consumption in your household?

Annual Electricity Consumption

How much electricity does your household use each year? For this, please check your last electricity bill (annual bill). The electricity consumption will be stated in kWh (Kilowatt hours). Should the consumption period be more or less one year, please calculate the consumption for one year.

Extent of Switching of Electricity Supplier

Since 1998 consumers in Germany have been given the choice of which electricity supplier they want to use. How is this regulated in your case? How often have you switched electricity supplier since 1998?

Appendix K

Loadings of the Multi-Item Constructs

	Loading	Mean Loading	Standard Error (STERR)	T Statistics	P Values
Intention1	0.911	0.911	0.009	107.066	0.00
Intention2	0.945	0.945	0.005	182.053	0.00
Intention3	0.946	0.946	0.006	168.668	0.00
Attitude1	0.944	0.944	0.007	144.492	0.00
Attitude2	0.943	0.944	0.006	169.645	0.00
Attitude3	0.785	0.784	0.022	36.46	0.00
Attitude4	0.944	0.944	0.006	171.555	0.00
External PLOC1	0.769	0.768	0.018	42.831	0.00
External PLOC2	0.783	0.782	0.018	43.491	0.00
External PLOC3	0.717	0.717	0.024	30.43	0.00
External PLOC4	0.719	0.718	0.025	28.933	0.00
Extenral PLOC5	0.779	0.78	0.016	50.187	0.00
Internal PLOC1	0.816	0.815	0.013	60.48	0.00
Internal PLOC2	0.882	0.883	0.008	105.429	0.00
Internal PLOC3	0.751	0.752	0.019	40.41	0.00
Internal PLOC4	0.785	0.785	0.015	52.449	0.00
Internal PLOC5	0.882	0.882	0.009	97.078	0.00
Introjected PLOC1	0.716	0.715	0.025	28.132	0.00
Introjected PLOC2	0.827	0.825	0.017	49.281	0.00
Introjected PLOC3	0.756	0.754	0.024	31.315	0.00
Introjected PLOC4	0.868	0.868	0.013	65.371	0.00
Introjected PLOC5	0.861	0.861	0.015	57.698	0.00
Perceived Pr. Risk1	0.624	0.62	0.043	14.559	0.00
Perceived Pr. Risk2	0.637	0.634	0.04	16.056	0.00
Perceived Pr. Risk3	0.516	0.513	0.047	11.011	0.00
Perceived Pr. Risk4	0.682	0.682	0.028	24.078	0.00
Perceived Pr. Risk5	0.688	0.683	0.038	18.309	0.00
Perceived Pr. Risk6	0.696	0.697	0.04	17.282	0.00
Perceived Pr. Risk7	0.687	0.688	0.04	17.12	0.00

Appendix L

Reliabilities of Multi-Item Constructs

Construct	Composite Reliability	Cronbach's Alpha
Attitude	.948	.926
Intention	.954	.927
Internal PLOC	.914	.882
External PLOC	.868	.816
Introjected PLOC	.903	.867
Perceived privacy risk	.835	.775
Income	NA	NA
Household size	NA	NA
Age	NA	NA
Education	NA	NA
Avg. elec. costs/month	NA	NA
Avg. elec. comsumption	NA	NA
# of times switched elec. supplier	NA	NA
Inherent innovativeness	NA	NA
WTP for EI	NA	NA

Appendix M

Fornell–Larcker Criterion for Discriminant Validity of Multi-Item Constructs

	EPLOC	IJPLOC	INTPLOC	Intention	PPRISK	Attitude
External PLOC	0.754*					
Introjected PLOC	0.336	0.808				
Internal PLOC	0.660	0.316	0.825			
Intention	0.571	0.250	0.704	0.934		
Perceived priv. risk	-0.293	-0.234	-0.390	-0.345	0.650	
Attitude	0.603	0.162	0.693	0.701	-0.363	0.907

*Diagonal numbers represent the square-root of the AVEs.

Appendix N

Interview Guideline

1. What is the judged gross electricity consumption of your household per annum?
2. Do you use a smart meter—if yes, since when?
3. Can you report on your experience with a smart meter? With what you heard about the usage of smart meters?
4. Which aspects in smart meters do you like? Which don't you like?
5. Which reasons would play a role in deciding for a installing a smart meter?
   a. Which role does your interest in the technology as such play?
   b, Which role do tariff/financially oriented reasons play?
   c. Which role do smart metering services (e.g. consumption control or possibilities of the domain of home automation) play?
   d. Which role do demographic/ innovation-related factors play?
6. Which demands could/can be fulfilled by applying a smart meter?
7. What are your current sorrows with regard to using a smart meter?
8. What are your thoughts on the privacy and data security debate regarding smart meters?
9. How would/do you use a smart meter?
   a. Do you/would you use it regularly?
   b. How did/would your behavior change over the time?
   c. Why did your behavior change?
10. Which role does user friendliness play with regard to this (potential) change in your attitude?
    a. How does user friendliness of the device itself (potentially) influence this change?
    b. Which influence does the quality of the smart metering software interface have?
11. Is there a difference between reasons for continued usage and reasons for initial adoption?
    a. What is/was your perception of smart meters before adoption?
    b. What is your perception adoption of smart meters after adoption (if applies)?
12. How can providers in your opinion improve the devices in a way so that their user experience is improved?
13. What would be a help for you in order to adopt smart metering technologies?
14. What would you do if tomorrow a smart meter would be installed in your home (mandatorily)?

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