Progress in IS

Philipp Wunderlich

Green Information Systems in the Residential Sector

An Examination of the Determinants of Smart Meter Adoption

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An Examination of the Determinants of Smart Meter Adoption

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Philipp Wunderlich
Mannheim Business School
University of Mannheim
Mannheim, Germany

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To Charlotte and Anneliese

Foreword

Electricity is becoming a more and more scarce and hence costly resource. In the years ahead, many challenges have to be addressed in order to provide a seamless and sustainable supply of electric energy both in households (B2C) as well as industry (B2B). One of the fundamental problems in this domain is the transmission line capacity in the far-distance energy delivery as well as in the mid-range and regional distribution networks. Another massive impact in the current situation in many countries is the drastic increase of renewable energy in the energy mix and the decrease of other energy production forms, such as from nuclear or conventional power plants. The decision of a phaseout of nuclear power in Germany by 2020 is the most significant step in this direction. Other countries follow with similar examples. Today, most governments have realized that renewable energy sources must play a more pivotal role in the energy mix. This comes along with a number of concerns, one of the major ones of which is the volatility associated with the production of renewable energies. If wind blows, newly installed offshore wind parks produce high amounts of electricity which then have to be transported to the point of consumption. If the sun shines, photovoltaic parks produce a steady energy supply. However, if the sun does not shine and the wind does not blow, alternative electricity supplies have to be provided or, alternatively, the demand has to be reduced. The reason is that the electricity consumed from the network has to match the electricity supplied to the network at all times. In the case of a mismatch of these two parameters, a power outage results.

Another major factor in consumption shift is the expected growth in electric mobility (e-mobility). Electric cars run on a battery. This battery has to be recharged at night. Assuming a sharp onset in the adoption of electric mobility by users in the private segment in near future, load profiles massively change and move towards a higher demand in the residential sector in the evenings and afterwork hours. Hence, the increased shift from traditional to renewable electricity production, e-mobility, and the resulting shifts in production and consumption patterns have led to new concerns in the electricity market. One solution to this is the "conceptualization of smart grids," which is underway in many countries. This serves as an umbrella term for a number of different processes. In essence, it stands for the enrichment of electricity networks with information and communication technologies (ICT) in order to decrease consumption as well as increase flexibility in production.

On the demand side, so-called smart meters, or "smart meter technology" (SMT), are one of the cornerstones of innovation. A smart meter replaces a traditional electricity meter, which has only the feature of measuring the consumed electricity. Smart meters are ICT-enabled devices which track a large number of information, e.g., details of consumption patterns over time. Smart meters also enable a dynamic pricing in the electricity sector, where so far only one (fixed price per kilowatt hour) or a maximum of two price levels (day and night supply) have existed. Furthermore, smart meters enable the customer to choose to switch the consumption to off-peak times and thereby save money since the electricity price will be lower. This is even possible to be automated, since devices (e.g., freezers or fridges, dishwashers, washing machines, or dryers in private households as well as industrial coolers and high-energy-consuming machines) can be enabled to be directly steered by the energy price or even the energy supplier in order to smoothen the demand curve.

All these new possibilities bear a lot of issues to be dealt with before they can take effect. First and foremost, the smart meter technology has to be adopted by a remarkable percentage of end customers in order to enable the energy providers to make use of its many different application possibilities. Regarding the issue of acceptance, several aspects have to be considered. Among others, this concerns data privacy, change of behavioral patterns (i.e., taking notice of the energy price before consuming), cost and benefit calculations of the meter adoption, and many more.

The research field which is currently forming and which is still in its infancy is the field of green information systems (green IS).

In his work, Mr. Wunderlich addresses this field by investigating the determinants of smart meter adoption in the residential sector. His focus is to find out which factors influence the adoption and continued usage decision of individuals in private households regarding smart meters. With his work, Mr. Wunderlich makes a significant contribution to research in this rather underdeveloped field. While in the past, many researchers have focused on the technical aspects of how to implement, optimize, and integrate renewable energies, smart grids, and smart meters, the behavioral side has been neglected at large. However, if today's societies would like to make smart meters a success, behavioral research is playing a key role in understanding motivations and hence consumption decisions of private persons and also businesses. Hence, the work of Mr. Wunderlich contributes to theory building in the information systems with respect to green information systems adoption and usage decisions. Furthermore, it is a valuable source of insights for practitioners who are dealing with the *Energiewende* and its implications.

This book is a very important contribution to the green information systems research, and I would like to wish this book, its author, and all its readers the best success.

Mannheim Professor Dr. Daniel J. Veit
December 2012

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This book is a result of my work as a doctoral candidate at the Dieter Schwarz Endowed Chair of Business Administration, E-Business and E-Government at the University of Mannheim and would not have been possible without the generous help and support of numerous people.

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Mannheim
December 2012

Philipp Wunderlich

List of Abbreviations

AVE	Average Variance Extracted
BNetzA	Bundesnetzagentur
CB-SEM	Covariance-Based Structural Equation Modeling
CET	Cognitive Evaluation Theory
DTPB	Decomposed Theory of Planned Behavior
EnWG	Energiewirtschaftsgesetz
ENTSO-E	European Network of Transmission System Operators for Electricity
FS	Field Study
GO	Grid Operating Division
ICT	Information and Communication Technology
IS	Information Systems
IT	Information Technology
MA	Supply and Marketing Division
MATH	Model of Adoption of Technology in Households
MIS	Management Information Systems
NAM	Norm Activation Model
NGO	Non-Governmental Organisation
OIT	Organismic Integration Theory
PLOC	Perceived Locus of Causality
PLS-SEM	Partial Least Squares – Structural Equation Modeling
S&T	Science and Technology
SDT	Self-Determination Theory
SEM	Structural Equation Modeling
SMT	Smart Metering Technology
TAM	Technology Acceptance Model
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action
UN	United Nations
VBN	Value-Belief-Norm Theory of Environmentalism

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Chapter 1
Introduction

1.1 Motivation

The recent report of the UN Secretary General's Advisory Group on Energy and Climate Change states the following:

> By 2030, there is an opportunity for the world to be well on its way to a fundamental transformation of its energy system, allowing developing countries to leapfrog current systems in order to achieve access to cleaner, sustainable, affordable and reliable energy services. This change will require major shifts in regulatory regimes in almost every economy; vast incremental infrastructure investments (likely to be more than $1 trillion annually); an accelerated development and deployment of multiple **new energy technologies**; and a fundamental behavioral shift in energy consumption. Major shifts **in human** and institutional capacity and governance **will be required to make this happen**..... But handled well – through a balanced framework of cooperation and competition – energy system transformation has the potential to be a source of sustainable wealth creation for the world's growing population while reducing the strain on its resources and climate. (UN AGECC 2010, p. 8) [Emphasis added]

The above quote highlights that there is about to be a huge shift and transformation in energy consumption and of the energy landscape, with the implementation of newer (and greener) energy-related technologies. The quote also highlights that humans and organization will need to play a critical role in ensuring success of such systems.

Electricity consumption continues to grow worldwide (Ellis and Jollands 2009). Finite resources, uncontrollable risks inherent to nuclear power, a rising environmental consciousness, and rapid technological advancements in power engineering concepts for a sustainable energy supply and electricity grid are attracting the attention of governments, and private firms alike. As the UN report (quoted above) highlights, there are many 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

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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, p. 24). This new subfield should focus on how information systems can contribute to the reduction of energy consumption by addressing research questions based on a set of major issues of the stakeholders (i.e. suppliers, consumers and governments).

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 twentieth 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 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 (unlike traditional electricity meters) allow bidirectional communication between the meter and an energy supplier. Further, it enables a set of specific services for the customer. From here on, this study refers to this more advanced technology and its services as smart metering technology (SMT). By providing information about current prices, energy consumption and energy production in the grid, SMT is the first step to allow 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. Furthermore, it enables services such as demand response and load shifting and customer-oriented services and applications such as in-home displays, online presence, and other information- and convenience-based products. Therefore, SMT has the potential not only to increase the energy efficiency of the residential and industrial sector but beyond that to radically alter the way energy is produced and consumed by the wide range of new applications and services it facilitates (e.g., Potter et al. 2009). As the UN report earlier highlighted, success of energy informatics requires the coming together of (and collaboration amongst) all relevant stakeholders. Thus, to fully realize the benefits of SMT and justify the massive investments in it, it is absolutely crucial to not only have a strong technology but also that the end consumers adopt and use the smart metering technology (SMT) and its services (Faruqui et al. 2010; Honebein et al. 2009). Adoption of SMT would also involve customers having to cede some control over consumption to their energy suppliers, and they have to agree with the permanent transfer of consumption data which has to be processed, stored, and analyzed for billing, grid and service management purposes by authorized actors. Adoption of SMT by consumers has run into challenges, with several SMT rollouts facing severe consumer backlash. Notable debates about the smart meter deployment emerged in the US (e.g. California, Texas and Maryland) and in Europe (e.g. the Netherlands), where SMT rollouts have been stopped or delayed by moratoriums (Fox-Penner 2010). One popular example is the case of the city of Bakersfield (CA), where a lawsuit has been filed against the energy supplier as SMT tripled consumers' electricity bills due to new tariff conditions. Further, several consumer-supported webpages exist which protest against SMT deployment, and refuse to use it citing several problems such as overcharging, inaccuracy, privacy, or health risks (Hart 2010). Despite the challenges associated with smart meter adoption, it has found little attention amongst academic researchers. The review of the literature within the IS discipline failed to provide any meaningful studies examining this issue. A search of the broader literature base (outside of the IS discipline) also resulted in few studies on smart meters. These studies have examined demand response (e.g. Abrahamse et al. 2005, 2007), business models (e.g. Jagstaidt et al. 2011; Strüker et al. 2011) or technical and design aspects (e.g. Graml et al. 2011; McDaniel and McLaughlin 2009) with respect to smart meters, ignoring the adoption-related issues. For example, Abrahamse et al. (2005, 2007) reviewed and tested different feedback designs and their effect on energy consumption behavior without focusing specifically on the case of smart meters. Other studies on smart meters e.g., McDaniel and McLaughlin (2009) have examined only the technical aspects, focusing on privacy and security issues. Similarly, Efthymiou and Kalogridis (2010) have examined encryption algorithms with respect to the security of smart meters. The few studies that have focused on smart meter adoption approached the topic from a social point of view only. For example, Kranz et al. (2010a, 2011) tested two models of smart metering adoption examining factors from a socio-environmental point of view, whereas, Wati et al. (2011) examined smart meter adoption from a goal framing point of view. While valuable, these studies have failed to provide an understanding of the technology-related considerations taken by consumers in the context of the adoption of SMT. The following Table 1.1 summarizes existing literature surrounding smart metering adoption.

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 of smart meters. Such an investigation needs to delve deeper into the complex factors influencing the adoption of SMT, ranging from an individual's motivation to their beliefs about technology in general, and energy informatics in particular. In other words, it is important to understand both the social and the technology-related considerations. This study attempts to contribute in this regard by taking a socio-technical perspective and examining consumers' adoption of SMT and the continuance intention of actual SMT users as well. Such a perspective is especially relevant given the debates within the IS discipline regarding a stronger focus on socio-technical elements in the IS research. Consequently, this study examines three specific research questions in this matter:

What are the determinants of consumers' adoption of SMT?
What are the determinants of users' continuance intention of SMT?
Are there significant differences between consumers' and users' behavioral intentions?

In examining these research questions, this study focuses on the residential sector only. Although the residential sector isn't always the largest electricity consuming sector, it is a sector that has witnessed the highest number of SMT

Table 1.1 Literature in the field of SMT adoption

Authors/paper	Summary	Comments/gaps
Watson et al. (2010)	The authors propose a new subfield to IS: energy informatics. This subfield addresses the role that IS can play in reducing energy consumption	Research framework for energy informatics without empirical data, no direct focus on smart grids/smart metering
Melville (2010)	The author proposes a research agenda on information systems innovation for environmental sustainability based on the Belief-Outcome-Action framework	Research framework without empirical data, no direct focus on smart grids/smart metering
Arkesteijn and Oerlemans (2005)	An empirical study examining the influencing factors for the adoption of renewable energy from a technical, individual and economic point of view	Focuses on renewable energies and the problem of fluctuation etc. but ignores any specific technology such as smart meters
Abrahamse et al. (2005)	A review of intervention studies to identify the key factors to change energy consumption behavior	Focusing on how feedback should be designed. Does not examine the adoption of smart meters
Abrahamse et al. (2007)	Test of different feedback designs in an internet-based tool to reduce energy consumption	Focusing on how feedback should be designed. Does not examine the adoption of smart meters
McDaniel and McLaughlin (2009)	The authors discuss about privacy and security issues in the smart grid and the possible consequences. Furthermore they demand new regulatory and technical guidelines	Addresses an important factor of smart metering and the smart grid but only from a technical point of view. Does not examine the adoption of smart meters
Darby (2010)	Analysis of smart metering in different countries including a qualitative study about smart meter usage behavior in households using "affordances" to get further insights on who benefits in which cases	No empirical model, single case study in a small village
Efthymiou and Kalogridis (2010)	The authors describe a method for securely anonymizing frequent (for example, every few minutes) electrical metering data sent by a smart meter	Deals with an algorithm to encrypt data to secure the data transfer
Faruqui et al. (2010)	Study analyses the different penetrations of smart metering in different countries and discusses the potential savings due to demand side management. To evaluate the potentials regulatory, technical and economic factors are identified that could help to raise the adoption of smart metering	Evaluation of the potentials of demand response (enabled by smart metering). No empirical model of smart metering adoption
Kranz et al. (2010b)	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

(continued)

Table 1.1 (continued)

Authors/paper	Summary	Comments/gaps
Graml et al. (2011)	Test of different feedback designs in an internet-based tool to reduce energy consumption for users of smart meters	Focusing on how feedback should be designed. Although it is based on a sample of smart meter users it doesn't deal with any other factors than the feedback design
Jagstaidt et al. (2011)	The authors analyze information management challenges with smart metering and identify a framework of strategic, tactical and operational tasks for the different steps from data generation to data editing and further usage	Looks at the technical issues of information management with smart metering. Does not examine the adoption of smart meters
Kranz and Picot (2011)	Kranz and Picot test a model of smart metering adoption based on the TPB extended by the variable "Environmental concern"	No technology based factors in the model, regional (Munich) student sample
Strüker et al. (2011)	Smart meter data exchange as a new business model: potential benefits and discussion of market size, revenue model and market penetration	The study only deals with the business model and does not examine the adoption of smart meters
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 98% of male participants

implementations, many of which have run into challenges, and thus provides an appropriate platform to examine these issues.

In summary, this study provides highly relevant contributions for both the research community and practitioners. The contribution to theory includes the empirical test of motivational model, applying technology acceptance research to the research field of e-energy and therefore contributing to the development of environmentally sustainable business practices in the field of Green Information Systems. Furthermore, it offers new insights into how endogenous motivations influence system use e.g. how external influences (such as extrinsic rewards and social pressure) are appropriated and transformed into self-guided behavior. Finally, the findings will help utilities when introducing smart meters to their customers by providing the most relevant factors from a customers' perspective. Considering these factors will help to encourage customers' engagement as co-creators of value and improve their satisfaction.

1.2 Overview of Research Approach, Methodology and Design

To answer the posed questions appropriately this thesis follows a positivistic approach. The research design comprises an extensive literature review and two large scale quantitative analyses conducted in the context of Green IS adoption and transformative technologies and services. It is based in the area of behavioral IS research.

1.3 Thesis Organization

The remainder of the thesis is organized as follows: In the next section, the reader is introduced to the topic of smart grids including an overview of the German energy market, smart grid concepts and the area of transformative services. In Chap. 3, the identified literature streams adjacent to the field of smart metering technology adoption are reviewed and thoroughly described. This review includes relevant literature in the fields of adoption research, motivational research, pro-environmental behavior, risk issues and is completed by a discussion about socio-demographic variables based on existing literature and informal expert interviews that have been conducted in the course of this thesis. In Chap. 4 the conceptual model and its hypotheses are motivated. Chapter 5 then describes the methodology of the thesis. It comprises an overview of structural equation modeling, the development of the measurement scale including a description of the qualitative and quantitative steps and describes the two underlying samples of this study. In Chap. 6 the final empirical field test is depicted. The theoretical model is statistically tested on the non-user and user sample and the results of both samples are statistically tested for significant differences between both groups. Chapter 7 then discusses the findings of both samples and summarizes the theoretical and practical contributions of this work. Further, limitations of this study are briefly outlined. Finally, a summary of the findings concludes the thesis in Chap. 8.

Chapter 2
Smart Grid

In order to establish a common understanding of the IT artifact examined in this study, the following chapter gives a short overview of the domain of this research project. First, the German energy market will be illustrated including a brief summary of the development after the liberalization and of current developments. Second, the smart grid concept and as part of it the smart metering technology will be outlined. This includes a special focus on the challenges that are posed to the grid by volatile energies and how a smart grid can help to overcome these emerging problems. Further, a special focus is given to the smart metering technology and its benefits to the supply side. Finally, the concept of transformative services is outlined describing the area that includes the services offered by the smart metering technology.

2.1 The German Energy Market

The German energy sector is significantly shaped by history. In the beginning of the electrification in the late nineteenth century, companies and cities started to build their own power plants. Soon electrification was seen as a political issue and this large number of small power plants was connected by publically founded utilities, building a second layer. This was followed by another layer of cooperation when regional suppliers recognized that significant economies of scale could be realized in the generation of electricity. These associations connected their independent regional grids and combined their financial resources to build large power plants. Smaller, local players couldn't compete and ceased during the next decades, leading to today's corporate landscape where a few huge companies own the complete transmission grid (BMWi 2006).

To guarantee competition and to avoid high prices in a monopolistic market, the EU Electricity Market Directive initiated the liberalization of the European energy market as a step towards a unified single market in Europe (European Parliament and Council of the European Union 1996). This decision was incorporated in a

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revision of the German Energy Economy Law (EnWG) and started the successive liberalization of the German energy market in 1998. To allow competition and free access to the transmission grid, the grid needed to be separated from integrated energy suppliers and moved to economically independent operators, which guarantee discriminatory-free “third party access” (BMWi 2006, p. 13) to the electricity grid. This first led to a large number of new competitors selling energy and a fall of profitability for most established energy suppliers. This was then followed by a huge wave of consolidation between 2000 and 2002 reducing the number of transmission system operators from eight to four, namely E.ON, RWE, Energie Baden-Württemberg (EnBW) and Vattenfall. These four transmission system operators not only fully own the transmission grid but also control more than 80 % of domestic electricity production leading to a regulatory dilemma (Bower et al. 2001).

To overcome these still existing market entry barriers a second directive of the European Commission, 2003/54/EC, has been passed, reflecting on the 5 years since the opening of the market (European Parliament and Council of the European Union 2003). In Germany, these requirements were implemented in another revision of the EnWG in 2005 leading to the establishment of a regulatory authority the so called Bundesnetzagentur (BNetzA). Whereas unbundling first only meant to separate accounts for different business units it now included the creation of separate business units under corporate law and hence separate administration.

Traditional integrated planning of generation and transmission becomes obsolete in the liberalized market and is replaced by informational cooperation between market partners to ensure a match between demand and supply of electricity. It also poses a major issue for large investments affecting the whole energy value chain consisting of production, transmission and distribution, and sales. As costs and profits cannot be calculated for the whole company but only for the subdivisions the regulation hinders investments such as the enhancement of the grid with modern information and communication technology.

Besides the regulation of the market, the German energy market is characterized by a high penetration of decentralized and volatile renewable energy. This characteristic is mainly caused by the targets of the European Union (EU) which are formulated in the Directive 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. This target is broken down on the individual member states and results in a target of 18 % share of renewable energy within the German energy mix. 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).

Finally, after the tragedy in Fukushima, Germany decided to phase out of nuclear power until 2022. Further, as part of the energy transition, the share of renewable energy will be raised to 50 % until 2030 and to 80 % until 2050 imposing new challenges to the balancing of the grid.

2.2 Smart Grid Concepts

As mentioned in Sect. 2.1 Germany is not only phasing out very stable and non-volatile energy sources like nuclear power while raising the proportion of renewable and often volatile energies, it also has only very limited natural electricity storage as e.g., reservoirs. Electricity is grid-bound and the possibilities to store electric power are both, inefficient and costly and strongly restricted. Further, supply and demand need to be balanced at all time to secure stability of the grid. Consequently, the energy system has to be able to react to variations on the demand side at all times. This stabilization process is accomplished in three steps with so called balancing energy that is contracted via a separate market (Verhaegen et al. 2006) at usually high price levels (Rebours et al. 2007). In a first step the primary reserve energy is used. In Europe, this energy is provided by the ENTSO-E ("European Network of Transmission System Operators for Electricity"). It has to be available within the first 30 s to prevent a power outage and is normally regulated by the power plants themselves as they automatically react to smaller fluctuations in the frequency. After the first 30 s the second reserve has to be available. In Germany, the four transmission system operators (see Sect. 2.1) are in charge to provide this reserve for their own control zone. After 15 min the third reserve comes into play. Again the four transmission system operators are in charge to provide the necessary energy. This energy is often produced by so called peaking power plants that normally are both: costly to operate and causing higher pollution. Further, due to high technical requirements, only six providers can supply primary and secondary reserves in Germany (Monopolkommission 2009). Building further capacities would be highly costly and inefficient.

To reduce these costs, household energy conservation and a change of the energy consumption behavior in the household sector have been discussed since the 1970s. Various social and environmental psychological studies have embarked on issues related to household energy use and tested the effectiveness of intervention strategies aiming to change energy-related behaviors. These studies have shown that by manually providing customers with consumption feedback and/or financial incentives can result in considerably reduced peak demands (Abrahamse et al. 2005; see Darby 2006 for an overview; Valocchi et al. 2007). This behavioral change is normally referred to as demand side management and describes the process of augmenting demand elasticity and influencing load curves in a beneficial way. Demand side management can influence the load curves in three major ways: peak clipping, load shifting and valley filling. Peak clipping refers to a case where consumption is reduced in peak load periods. This can either be accomplished by directly switching off devices through control mechanisms or indirectly through high energy prices during peak load periods. Load shifting is quite similar to peak

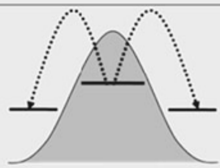
Type	Description	Illustration
Peak Clipping	Reduction of consumption in peak periods	
Valley Filling	Increase of consumption in low load periods	
Load Shifting	Shift of consumption in low load periods	

Fig. 2.1 Typical shifts in load curves due to demand side management (Source: Based on Gellings et al. 1987)

clipping but instead of trying to reduce overall demand, the consumption is mitigated into low load periods. Examples of shiftable loads could be washing machines, air conditioning, etc. Finally, as electricity can hardly be stored, it should be used when it is available. Therefore, valley filling tries to store surplus power in e.g. freezers or plug-in hybrid electronic vehicles. Figure 2.1 illustrates the typical shifts in load curves due to demand side management.

Given the higher amount of volatile and renewable energies in the grid, not only the demand side but also the generation site gets harder to predict and ways to influence both consumption behavior and the decentralized feed-in of electricity gain more attention than ever. To secure the stability of the grid, the need for an intelligent coordination further increases (Bartels 2009). This enhancement of the electricity grid with information and communication technology is widely referred to as smart grid. It is characterized by enabling communication between the supply and the demand side by connection all actors and components of the electricity system. Therefore, it offers the technology to automate feedback processes and thus enabling demand side and feed-in management. It further collects, processes and analyzes data on power generation, transmission, distribution and consumption in real time and therefore is expected to provide a wide range of benefits across the entire electricity value chain. These comprise an increase in reliability, security, power quality, resilience, energy and economic efficiency and environmental sustainability of the energy system (e.g., Potter et al. 2009; Faruqui et al. 2010). They can be further broken down for the supply side, the transmission network and the demand side.

On the supply side, the use of responsive operating protocols can contribute to the optimization of power flows along existing transmission structures. Thus, it not only helps to improve the reliability of the system but also helps to defer capital expenditures on transmission grid extension. Further, using variable tariffs and demand side management, peak loads could be reduced, again resulting in lower expenditures on transmission grid upgrading but as well in a reduced need for expensive balancing power and the respective flexible generation technologies needed. Finally, after the liberalization of the energy market, smart metering technology is a step back into the lives of the customers allowing the suppliers to gain customer loyalty.

Regarding the transmission network, the benefits comprise preventive maintenance and remote grid management through better monitoring and control features. With the use of sensor networks the system could respond to stimulus without limited human interaction. Therefore, it could react much faster to interruptions and even automatically identify the affected areas and reconfigure the power system to mitigate potential contingencies (e.g., Potter et al. 2009). This would result in a semi-autonomous grid with so called "self-healing" capacities. Further, a smart grid could minimize energy losses through efficient energy routing. Finally, through advanced communications and metering technologies, the grid is aware where and how much energy will be consumed or produced thus facilitating a better integration of distributed energy resources such as photovoltaic or wind mills.

As this study focuses on the demand side, the benefits and technical specification of the smart grid on the customer side are further outlined: On the customer side, the smart grid is visible to the user through the so called smart metering technology (SMT). For the scope of this study SMT is defined as an artifact consisting of two facets: the metering and the service side. On the one hand a digital electricity meter will be installed. Compared to today's common mechanical meters, it will be able to record time and power specific consumption information. This allows the customer to access one's consumption information and helps to identify so called "power eaters". It is needed to bill time and power variable tariffs compared to today's flat tariffs. On the other hand a second device is needed that is referred to as smart box. The smart box receives and processes electricity cost and availability information by the energy provider. It enables home automation and allows the customer to operate the system in e.g., a cost or CO_2 neutral way. Further, it allows better, semi-autonomous demand side management in a way that the system operator can be given control of the loads in the system in certain situations. Thus, whereas the smart box enables most of the services, the smart meter is mainly needed for the billing of the consumed electricity. Both parts of the technology can be used independently from each other but only with partial utility.

Accordingly, the benefits on the customer side comprise better information about energy usage, the possibility to identify ways to save energy, an enhanced efficiency through better management options and greater awareness of energy consumption and a set of innovative services and applications. Owing to their sustainable character these services are also referred to as transformative services.

2.3 Transformative Services

So far, research on transformative technologies and services has predominantly been conceptual in nature. The core of transformative services is the notion of a "transformation" toward a higher individual and collective well-being. The idea of transformation builds on the concept of sustainable development, which the *Brundtland Commission* defined as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations 1987). The normative idea of transformation, therefore, is that marketing scholarship and practice need to embrace the concept of sustainability as a major aspect of the marketing paradigm (Huang and Rust 2011). That is, "marketing science should be about creating a healthy consumption environment as well as about protecting the consumer from overconsumption" (Achrol and Kotler 2012, p. 44). From a managerial point of view this includes, for example, minimizing wasteful consumption, increasing environmental awareness, and demarketing certain harmful products and technologies (Achrol and Kotler 2012). The same idea can be found in IS research: "As IS researchers, educators, journal editors, and association leaders, we need to demonstrate how the transformative power of IS can be leveraged to create an ecologically sustainable society" (Watson et al. 2010, p. 23).

Whereas research on sustainable and transformative technologies is still in the beginning in the IS field (e.g., Melville 2010; Watson et al. 2010), in marketing, research on transformative consumer research has gained increasing attention (Mick et al. 2012) over the past few years. Most such research so far deals with health and nutritional issues and with the question of how insights from consumer research can be applied to increase welfare, for example by fighting obesity (Chandon and Wansink 2007; Wansink 2007). However, research on consumer actions in benefit of the environment is still sparse (for an exception see Goldstein et al. 2008). The same holds for transformative services, which generally address a "triple bottom line" of economic, ecological, and social outcomes (Elkington 1998). Services are considered to be crucial for transformation and able to be more effectively transformed than physical goods, because they are by definition customer-centric and co-created (Ostrom et al. 2010). In particular, investigators have identified the following major areas of transformation to be addressed by services research (Ostrom et al. 2010, p. 9): (1) sustainability of consumption and production, (2) health care and education, (3) the environment, (4) service infrastructure for urban living, (5) public services, and (6) services at the base of the customer pyramid. Transformative services can aim at more than one of these areas simultaneously, and are not limited to a particular context, such as professional or consumer services. In the following consumer services are further addressed.

Transformation can result from modification of existing services or from development of new services. Prior work has shown that message framing or persuasion effects (e.g., Cornelissen et al. 2008; Goldstein et al. 2008; Kronrod et al. 2011), as well as psychological "nudges" (Thaler and Sunstein 2008), are effective mechanisms for modifying existing services and influencing consumer behavior in a way that (1) individual and collective well-being can be increased (Huang and Rust 2011), and (2) consumers do not feel limited in their choices and their way of living.

When new transformative services are being developed, IT is able to fulfill these two conditions by enabling creation of "smart services" through the infusion of technology (Kunz and Hogreve 2011; Schumann et al. 2011). Smart services, which are services "delivered to or through intelligent products that feature awareness and connectivity" (Wünderlich et al. 2012, p. 1), include smart energy management services, which is a part of an assortment of services that are facilitated by SMT. Consumers can access these services via different channels using, for example, displays in the living area, the electronic meter, applications running on mobile devices, or the internet. The definition of SMT used in this study does not differentiate between services and the IT devices, but treats these as a holistic whole. SMT enables energy consumers to check their home energy consumption and eventually their production in real time, to modulate demand according to load- and time-based tariffs (indirect load control), to automatically curtail or increase demand in peak or low-load times (direct load control), or to use marketplaces for in-home consumer technologies or related support services. Thus, SMT helps to control and reduce consumers' costs, provide detailed information about electricity use, and supply value-added services such as home automation or assisted living.

Beyond these direct benefits for users, SMT is transformative in nature, in that the services offered are eco-efficient services that aim at contributing to sustainable development (Halme et al. 2006; Ostrom et al. 2010). SMT is sustainable because it aims at reducing energy consumption and higher polluting peak demand and enables more effective integration of often volatile renewable energy sources, leading to direct benefits for the consumer (e.g., lower expenditures) and indirect benefits for society (e.g., lower greenhouse gas emissions). Finally, it is part of a new service infrastructure of urban living. Thus it addresses the first, third and fourth area of transformation.

Chapter 3
Theoretical Foundations

In developing this model, this research draws on a range of theories from existing research on environmental behavior, adoption, motivation psychology, risk, and smart meters in general. It draws on multiple theoretical perspectives as opposed to one theoretical paradigm for three major reasons: (1) to capture the socio-technical factors affecting SMT adoption, (2) the absence of any existing (and meaningful) study on SMT, and (3) the uniqueness of SMT itself, wherein consumers' motivation and several other consumer-related variables such as their age, and their preference for green technologies play a critical role. Such model development is fairly common in adoption research. For example, Sherif et al. (2006) drew on coordination theories, conflict theories, and studies on organizational learning to examine adoption and post-adoption effects of disruptive IT innovations. Therefore, the following chapter is structured according to the different theoretical lenses considered in this study. First, an overview of adoption studies in the IS area is given. This is followed by an overview of the concept of incentives and motivations, emphasizing the work of Malhotra et al. (2008) in particular. Third, literature on environmental behavior is reviewed, explaining reasons why individuals act environmentally sustainable. Fourth, the role of risk in adoption settings is explained and different types of risks are outlined. Finally, a short summary of variables related to SMT is given. In this subchapter findings out of different studies about energy conservation as well as the results of discussions within a superregional German energy supplier are outlined.

3.1 Technology Adoption of Individuals

In today's organizations the presence of computer and information technologies has expanded dramatically. Some estimates indicate that about half of all new capital investment in organizations since the 1980s has been in information technology (Westland and Clark 1999). Yet, if technologies aren't accepted and used by the employees they cannot improve productivity. In the last decades, adoption research

P. Wunderlich, *Green Information Systems in the Residential Sector*, Progress in IS,
DOI 10.1007/978-3-642-36769-4_3,

has helped to understand a variety of antecedents to behavioral intentions more thoroughly. To identify these antecedents many different research models have been applied (see Venkatesh et al. (2003) for an overview). The majority of these models are based upon theories originating in behavioral science or social psychology. The expectancy-value theory by Ajzen and Fishbein (1980) is a model drawn from the social psychology which links external variables and beliefs about the outcome of performing a behavior, which in turn influences the attitude toward performing a behavior. Attitude itself influences intention to perform the behavior and therefore the behavior itself (Fishbein and Ajzen 1975). The role of intention in predicting behavior (e.g. usage) is critical and has been widely researched in IS and the reference disciplines (Ajzen 1991; Sheppard et al. 1988; Taylor and Todd 1995a). According to the theory of reasoned action (TRA) these relationships can be used to predict behavior if both, the attitude and the belief factors are specified in a consistent manner (in terms of time, target and context) with the behavior to be explained (Ajzen and Fishbein 2005; Fazio and Olson 2003; Fishbein and Ajzen 1975). Davis (1989) applied the TRA to the IS context resulting in the technology acceptance model (TAM). TAM was designed to predict the adoption of information technology and links the behavior of interest (system usage) to attitudes and beliefs (ease of use and usefulness).

In the beginning, the main focus of adoption studies was on work-related technologies in organizational settings (e.g., Venkatesh et al. 2003; Williams et al. 2009). It took until the early 1990s for the first set of studies to investigate technology adoption in private and residential settings (Brown 2008). Whereas early studies on adoption (e.g., Venkatesh and Vitalari 1992; Venkatesh 1996) were heavily influenced by the utility-performance contingency of organizational IT use, 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). A recent study examined the boundary conditions of seven prominent adoption models when applied to the household context (see Venkatesh et al. 2012a). Findings showed that the model of adoption of technology in households (MATH) (Brown and Venkatesh 2005), the theory of planned behavior (Ajzen 1991; Fishbein and Ajzen 1975), and the decomposed theory of planned behavior (DTPB) that was derived from TPB and TAM to a certain extent (Taylor and Todd 1995a) performed similarly well in the household context. All three models were able to explain 37 % (user case) and 44 % (non-user case) of the variance of the dependent variables, with MATH and DTPB being able to provide more comprehensive explanations on why household technology adoption takes place (Venkatesh et al. 2012a).

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).

Given the technical and application-specific character of SMT, the widely applied technology acceptance model and the theory of planned behavior seem to offer a better fit for research in this new area. Further, both models have been used as basis in adoption and continuance research. Consequently, this study choses these models as its basis as well.

Although the technology acceptance literature provides sound predictions of usage, it provides only limited guidance about how to encourage usage through design and implementation (Taylor and Todd 1995a; Venkatesh et al. 2003). Hence, Venkatesh et al. (2003) stress the need to do further research considering system and information characteristics and the way in which they might indirectly shape system usage. 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. Below, this is discussed in further details.

3.2 Incentives and Motivation Literature

3.2.1 Incentive Alignment and Motivation in IS

Whereas IS research dealt at least with two major dimensions in the design and implementation of information systems in the last decades (software engineering and user-acceptance), Ba et al. (2001) stress the need to introduce a third dimension which they call incentive alignment (Table 3.1). They believe that "as organizational processes are increasingly embedded in information systems, one of the key considerations of many business processes – organizational incentives – should become the third dimension of any information systems design and evaluation" (Ba et al. 2001, p. 226).

Incentive alignment is "when the system has embedded features that induce its users to employ the system in a manner consistent with the design objective, and hence the organization's overall goals" (Ba et al. 2001, p. 227). The user should still be able to freely determine his behavior but it shouldn't be the most rational action if it doesn't correspond with the organizational goals (Ba et al. 2001).

In the case of SMT, variable tariffs offer exactly this opportunity. Variable tariff structures not only provide financial incentives to use electricity in off-peak times, but also based on how much energy is used at the same time. On the other hand, environmental awareness is also becoming more and more important in our society (Poortinga et al. 2004). Therefore, the idea of incentives may not provide us with a full picture of the motivations behind the adoption of SMT. Motivation psychology on the other hand takes a broader lens to identify the triggers of certain behaviors.

Table 3.1 The three dimensions for information systems design and their attributes

First dimension software engineering	Second dimension technology acceptance	Third dimension incentive alignment
Error-free software	User friendliness	Incentives influencing user behavior and the user's interaction with the system
Documentation	User acceptance	Deference of use for personal gain
Portability	Perceived ease-of-use	Use consistent with organizational goal
Modularity and architecture	Perceived usefulness	Robustness against information misrepresentation
Development cost	User satisfaction	
Maintenance cost	Cognitive fit	
Speed	Task/technology fit	
Robustness		

Source: Ba et al. (2001)

Instead of focusing on only one aspect, that is external influences (e.g. incentives, external pressures), motivation psychology provides an understanding of the whole spectrum ranging from external to internal behavioral triggers.

3.2.2 *Incentives and Motivation in Social Psychology*

> Motivation concerns energy, direction, persistence and equifinality – all aspects of activation and intention. Motivation has been a central and perennial issue in the field of psychology, for it is at the core of biological, cognitive, and social regulation. Perhaps more important, in the real world, motivation is highly valued because of its consequences: Motivation produces. It is therefore of preeminent concern to those in roles such as manager, teacher, religious leader, coach, health care provider, and parent that involve mobilizing others to act. (Ryan and Deci 2000a, p. 69)

Incentives and motivations are relatively new to IS research they have been widely studied in social psychology in the last few decades (e.g., Eccles and Wigfield 2002; Freud 1923; Harackiewicz et al. 2002; Locke et al. 1981; Ryan and Deci 2000a). Motivation is often regarded as a singular construct, although people are moved to act by very different types of factors. They can be intrinsically or extrinsically motivated (e.g. Calder and Staw 1975; Deci 1971, 1972a; Pinder 1976; Porac and Meindl 1982; Pritchard et al. 1977; Scott et al. 1988). Performing an activity without any other reinforcement than the process of performing the activity per se is referred to as intrinsic motivation (Berlyne 1966; DeCharms 1968; White 1959). It reflects the positive potential of human nature to seek for challenges and novelty, to learn and explore – the natural inclination toward assimilation, mastery and spontaneous interest, which is critical to cognitive and social development and grants joy and vitality throughout life (Csikszentmihalyi and Rathunde 1993; Ryan 1995). Intrinsic motivation applies to activities that have the appeal of novelty, challenge or aesthetic value. Especially after childhood people get more and more externally influenced by social influences and responsibilities to do activities that are not interesting (Ryan and La Guardia 2000). This so called extrinsic motivation is to perform an activity out of the perception that it is instrumental in achieving another goal (e.g., Lawler and Porter 1967; Mitchell and Biglan 1971; Vroom 1964). If the behavior was reinforced only by contingent rewards, studies highlight that these rewards only induce an activity as long as they last. There is no enduring change in behavior to be expected (e.g., Glucksberg 1962, 1964; Miller and Estes 1961; Spence 1970, 1971). Other studies show that financial rewards can even reduce the intrinsic motivation of performing an activity (e.g., Curry et al. 1991; Deci 1971, 1972a, b; Pritchard et al. 1977). Furthermore psychological studies in the last decades showed, that rewards can not only be ineffective but even detrimental to success and performance quality (e.g., Boggiano 1998; Danner and Lonky 1981; Deutsch 1985; McGraw 1978; Pritchard et al. 1977). Johnson (1993) showed that being driven by either interests and values or external reasons to the self is significant in every culture. Further it represents a basic dimension for people to make sense of their own and others' behavior (DeCharms 1968; Heider 1982; Ryan and Connell 1989). In the case of SMT adoption, motivations could play a critical role. SMT does not only result in benefits for users, such as lower expenditures or increased consumption control, but also in benefits for society, such as lower greenhouse gas emissions or improved air quality. Consequently, the traditional "carrot-and-stick" notion that incentives motivate behavior neglects the impact of consumers' internalized principles and values on behaviors (see also Dholakia 2006). Investigating this impact should be especially important for behaviors that are assumed to improve the well-being of consumers and society.

Several theories focus on the reasons individuals have for engaging in different tasks. These researchers follow three highly correlated perceptions of enduring intrinsic motivational orientation (Matsumoto and Sanders 1988, p. 114): (1) fondness for hard or challenging tasks; (2) curiosity or interest-driven learning; and (3) striving for competence and mastery. Whereas the second point is most central to the idea of intrinsic motivation, the others are close to either extrinsic or more general need-achievement motivation. The following Table 3.2 gives a short summary of different theories and the constructs they are using.

The self-determination theory (SDT) doesn't only deal with the causes of human behavior but also has a deeper look into the design of social environments that stimulate people's development, performance and well-being (Deci and Ryan 1985, 1991; Ryan 1995). SDT investigates people's sources for personality development and behavioral self-regulation (Ryan et al. 1997). The research identified three essential needs that facilitate optimal development, integration, personal well-being and constructive social development: the needs for competence (Harter 1978; White 1963), relatedness (Baumeister and Leary 1995; Reis 1994) and autonomy (DeCharms 1968; Deci 1975). Comparing people, who are intrinsically motivated with those who are merely externally controlled for an action, typically shows that those who are intrinsically motivated have more interest, excitement and confidence. This is indicated by enhanced performance, persistence and creativity (Deci and Ryan 1991; Sheldon et al. 1997) and by heightened self-esteem and vitality (Deci and Ryan 1995; Nix et al. 1999) and general well-being (Ryan et al. 1995a).

Table 3.2 Theories focused on the reasons for engagement

Theory	Constructs	Sources
Flow theory	Challenging tasks, expand one's competence	Csikszentmihalyi and LeFevre (1989) Csikszentmihalyi (1991) Csikszentmihalyi and Rathunde (1993) Ghani and Deshpande (1994)
Interest theories	Individual interest, situational interest; feeling-related and value related valences	Hidi and Harackiewicz (2000) Schiefele (1991, 1999)
Goal theories	Performance goals, learning/mastery goals, performance-approach and performance-avoid goals	Bandura (1997) Dweck (2000) Elliot and Church (1997) Elliot (1999) Freud (1923)
Attribution theories	Causal attributions for achievement outcomes – locus of control, stability, controllability	Graham (1991) Weiner (1985)
Self-determination theory	Competence, relatedness, autonomy	Deci and Ryan (1985, 2002) Ryan and Deci (2000a) Ryan et al. (1995a)

Source: Updated based on Eccles and Wigfield (2002)

Most studies have considered motivation to differ only in terms of amount (e.g., Bandura 1997), in the sense that more motivated individuals "will aspire to greater achievement and be more successful in their efforts than people with less motivation" (Cadwallader et al. 2010, p. 221). In contrast, the SDT contends that in predicting behaviors the type of motivation – that is, autonomous versus controlled motivation – is more important than the mere amount of motivation (see Deci and Ryan 2002; Ryan and Deci 2000a). People who perceive their actions as autonomously driven experience a sense of volition and choice, whereas people whose behaviors are linked to feelings of pressure and coercion originating from external sources perceive themselves as being controlled. Empirical research shows that perceived autonomous motivation has a greater effect on behavior than motivation through control (e.g., Cadwallader et al. 2010; Chan and Lam 2011; Dholakia 2006; Malhotra et al. 2008; Venkatesh 1999).

According to the SDT, motivation is endogenous, since individuals volitionally initiate all behaviors (Ryan and Deci 2000a; Skinner 1953). This explanation contrasts with mechanistic motivation theories, which consider behaviors as being triggered either extrinsically by rewards or intrinsically when the activity itself is the reward (exogenous motivation). The SDT considers behavior as being motivated not directly by external stimuli, but rather by the subjective psychological meaning of these stimuli. This perspective treats behavior not as a result of expected rewards, but rather as an act of individual volition that may even be undermined by extrinsic rewards (Curry et al. 1991; Deci 1971; Dholakia 2006; Frey and Oberholzer-Gee 1997; Pritchard et al. 1977).

Most studies on IT draw on the mechanistic approach, treating extrinsic motivation in instrumental terms -that is, with respect to its perceived usefulness – and considering intrinsic motivation as enjoyment or playfulness (Roberts et al. 2006; Venkatesh et al. 2003). This view limits our understanding regarding the question of the extent to which different types of motivations affect behavior. This question is important, because the same external stimuli can have different effects, which explains why some users more readily accept technologies and services than other users do (Malhotra and Galletta 2003, 2004).

Deci and Ryan (1985) developed the cognitive evaluation theory (CET) as a subtheory within SDT. The CET describes factors that explain variability in intrinsic motivation. CET focuses on the needs for competence and autonomy and describes the effects of rewards, feedback and other external effects on intrinsic motivation. Social-contextual events (e.g. feedback, communication, rewards) can enhance a feeling of competence during an action and thus facilitate intrinsic motivation. It identifies optimal challenges, effectance-promoting feedback and freedom from demeaning evaluations as facilitating factors for intrinsic motivation (Deci 1975; Ryan and Deci 2000a).

Further studies have shown (Fisher 1978; Ryan 1982) that besides competence, a sense of autonomy or an internal perceived locus of causality (DeCharms 1968) is needed to enhance intrinsic motivation. Hence to facilitate intrinsic motivation people must not only feel competence but they must feel their behavior as self-determined. These findings are supported by numerous studies showing that extrinsic tangible rewards made contingent on task performance can undermine intrinsic motivation by e.g., facilitating a more external perceived locus of causality (and therefore diminished autonomy) (e.g., Deci 1975; Deci et al. 1999). The same diminishing effect could be found for threats, deadlines, directives, pressured evaluations and imposed goals (Deci and Ryan 1985; e.g., Deci et al. 1981; Flink et al. 1990).

A third weaker factor is relatedness. Several studies indicate that contexts characterized by a sense of security and relatedness can enhance intrinsic motivation too (e.g., Anderson et al. 1976; Bowlby 1979; Frodi et al. 1985).

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. Furthermore SDT considers extrinsic motivation to vary greatly in its relative autonomy (Ryan and Connell 1989; Vallerand 1997). In understanding the influence of the perceived degree of self-determination on behavior, the organismic integration theory (OIT), another subtheory to the SDT has proved to be valuable in different scientific areas (Deci and Ryan 2002). The OIT deals with these different forms of extrinsic motivation and the contextual factors that impact internalization and integration of the regulation for these behaviors (Deci and Ryan 1985).

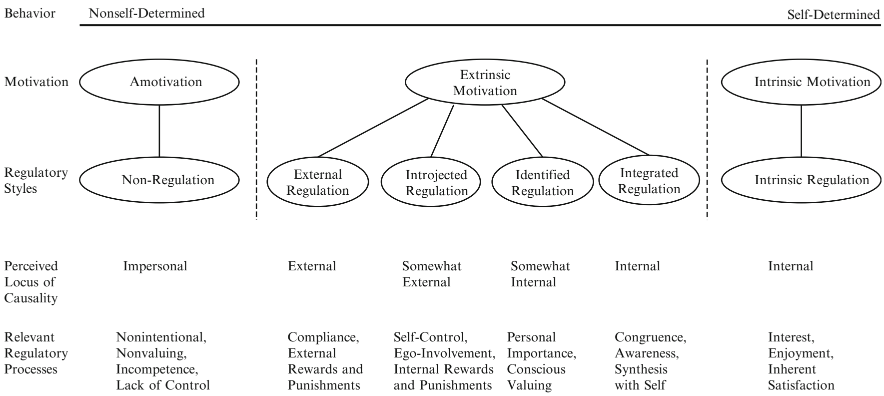


Fig. 3.1 The self-determination continuum showing types of motivation with their regulatory styles, loci of causality and corresponding processes (Source: Ryan and Deci 2000a)

On the far left of the picture (Fig. 3.1) is amotivation that describes the state of lacking the intention to act. People then either do not act at all or just perform without intent. It can result from not valuing an activity (Ryan 1995), a perceived lack of competence (Bandura 1986) or the expectation not to yield a desired outcome (Seligman 1975). On the right side of the spectrum intrinsic motivation can be found. The different cases of extrinsic motivation cover the continuum between these two extreme cases, varying in the extent of how autonomous it is.

Externally regulated extrinsic motivation is the least autonomous. In this case individuals normally act to satisfy external demand or to achieve rewards (Ryan and Deci 2000a). They experience such behaviors as controlled or alienated (DeCharms 1968). The second form is called *introjected regulation*. People do not fully accept a regulation as their own. Rather they act to avoid guilt or anxiety or to attain ego enhancements (Ryan and Deci 2000a). This still relatively controlled form of regulation includes behavior motivated by ego involvement such as pride (DeCharms 1968; Nicholls 1984; Ryan 1982). *Regulation through identification* is an already quite autonomous or self-determined form. In this case people accept and value a behavioral goal or regulation (Ryan and Deci 2000a). *Integrated regulation* happens when identified regulations are fully internalized. People experience this behavior as very similar to intrinsic motivated actions although they act to attain separable outcomes as inherent enjoyment.

Through internalization of regulations people experience greater autonomy in action. This process does not follow any strict sequence. Rather people can internalize a new behavioral regulation based on prior experiences and current situational factors. Along this continuum of relative autonomy, different kinds of extrinsic motivation lead to different experiences and outcomes. Studies in the educational sector (e.g., Connell and Wellborn 1991; Grolnick and Ryan 1987; Miserandino 1996; Vallerand and Bissonnette 1992), in health-care (e.g., Ryan et al. 1995b; Williams et al. 1998a, b) and other domains including political activity (Koestner et al. 1996), environmental activism (Green-Demers et al. 1997), religion

(Ryan et al. 1993) and physical exercise (Chatzisarantis et al. 1997) associate more autonomous extrinsic motivation (and therefore higher internalization) with more behavioral effectiveness, greater volitional persistence, enhanced subjective well-being and better assimilation of the individual within his social group (Ryan et al. 1997).

As extrinsically motivated behaviors are not typically interesting and given the significance of internalization for one's intimate experience and the behavioral outcomes, it is crucial to identify the enhancing factors of autonomous regulation (Ryan and Deci 2000a). According to the SDT contexts can yield autonomous regulation only if they are autonomy supportive, which means that the person needs to feel competent, related and autonomous (Ryan and Deci 2000a).

The OIT conceptualizes individually experienced levels of autonomy as existing along a continuum of motivation referred to as the perceived locus of causality (PLOC) (Ryan and Connell 1989), which is the degree to which an individual experiences a behavior as initiated and endorsed by the self (Ryan and Connell 1989). The continuum ranges from *external PLOC* characterized by feelings of compulsion at the one end to *internal* PLOC*,* which is linked to feelings of volition at the other end.

The degree to which individuals appropriate and internalize external influences determines the perceived locus of causality they experience when performing a behavior ranging from external to internal regulation. Regulation refers to an internalized principle or value (e.g., an individual sense of autonomy) that controls behavior (Cadwallader et al. 2010). The more a value is appropriated and internalized, the more the regulation is perceived as autonomous. Hence, external regulation describes controlled forms of behavior that are performed because of external influences or pressures. In contrast, internal regulation implies that people perceive themselves as the origin of their behavior. That is, they experience the behavior as self-determined and as reflecting higher degrees of internalization.

3.2.3 How Endogenous Motivations Influence User Intentions

> Do not hire a man who does your work for money, but him who does it for the love of it. (Henry David Thoreau)

Malhotra et al. (2008) follow this perception of motivation. They argue that IT adoption research has only limited possibilities to discern if and when user behavior results either from personal volition or perceived external influences. Some ways to measure these influences are variables such as subjective norm or managerial mandates. Further, the impact of these external stimuli and social influences has been questioned in recent work (Bhattacherjee and Sanford 2006; Davis et al. 1989; Hartwick and Barki 1994; Melone 1990; Warshaw 1980). It has been argued that the same external influences and stimuli have different effects on different users, such that some of them are willing to adopt a system while others won't (Davis et al.

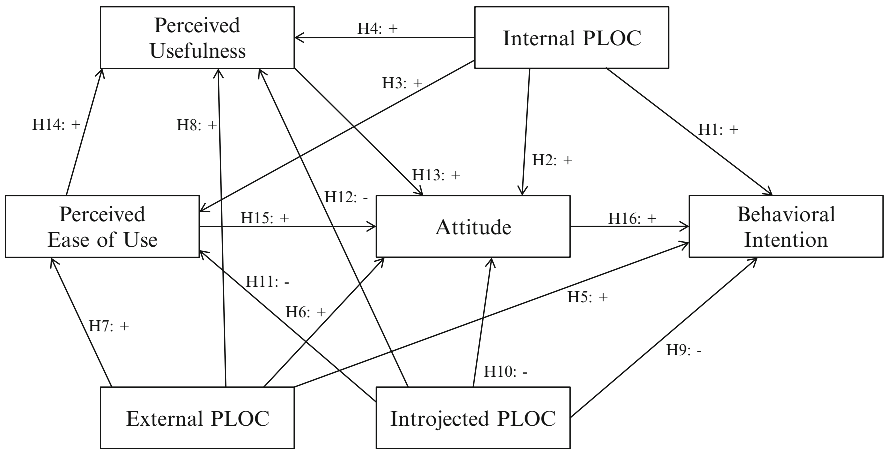


Fig. 3.2 PLOC model (Source: Malhotra et al. 2008)

1992; Hartwick and Barki 1994; Malhotra and Galletta 2003, 2004; Warshaw 1980). Consequently, Malhotra et al. (2008) follow Roberts et al. (2006), and argue that behavior is influenced by "collections of motivations" (Deci and Ryan 2002; Vallerand 1997), instead of following the dichotomy of motivation (extrinsic versus intrinsic).

External stimuli can be seen as affordances and opportunities that can be used to satisfy one's needs (Deci and Ryan 1985, 2002). Using the theoretical lens provided by the OIT that explains how social values are internalized to self-regulate behavior (Deci and Ryan 2002), Malhotra et al. (2008) follow the argumentation that productive behavior may be volitionally motivated without extrinsic rewards and that these rewards can even undermine motivation (Deci and Ryan 2002; Ryan and Deci 2000a). They emphasize the endogenous notion of volitional extrinsic motivation proposed by the OIT. If users feel autonomy, external pressure or a combination can be determined by examining users' psychological states in terms of perceived locus of causality (PLOC).

In their model (Fig. 3.2) they enhance the TAM by three new factors: "Internal PLOC", "External PLOC" and "Introjected PLOC". All three are influencing the four TAM constructs "Perceived Ease of Use", "Perceived Usefulness", "Attitude" and "Behavioral Intention".

PLOC pertains to the self. It refers to the degree to which action is initiated and endorsed by the self, and therefore describes the relative autonomy of the act (Ryan and Connell 1989). Users may feel compulsion due to feelings of guilt or obligation even when external pressures (e.g., social norms) are clearly absent. Hence, user's perceptions of volition and compulsion can be understood as functions of PLOC (Malhotra et al. 2008). Compulsion is characterized as an external PLOC while an internal PLOC refers to volition. The different types of PLOC have qualitatively different influences on behavior, and have a cumulative effect on intentions (Deci and Ryan 1985). The OIT allows examining different feelings of autonomy and external pressure and their combined effects on behavior. Therefore, different types of endogenous motivation characterize different PLOCs.

Internal PLOC is represented by the Identified PLOC and the intrinsic PLOC. Both are characterized by "feelings of volition where actors perceive themselves as the "origin" of their behavior" (Malhotra et al. 2008, p. 273). The intrinsic PLOC is based on "what comes instinctively and spontaneously. Such spontaneous behavior is typically characterized by self-perceived reasons for behavior performed simply for inherent enjoyment or fun" (Malhotra et al. 2008, p. 273). The Identified PLOC represents "users' actions based on personal values and meaningful goals and outcomes. It is characterized by feelings of autonomy and associated behavior is performed freely. As it results from internalization and integration of external regulations adopted by individuals as personally important or valuable, it is a type of extrinsic motivation" (Malhotra et al. 2008, p. 273). Despite its extrinsic nature, it is still very similar to intrinsic motivation and therefore these two types are sometimes combined into a composite of autonomous motivation (Black and Deci 2000; Malhotra et al. 2008; Vansteenkiste et al. 2004, 2006). As it is focused on regulations, values and outcomes, it is independent from rewards. For instance if someone adopts a system to achieve personal goals, the behavior is extrinsically motivated but based on feelings of volition.

External PLOC represents "an important intermediate step through which social influences are internalized and integrated. [. . .] [It] represents extrinsic motivation in its most basic form and is based on attainment of immediate consequences administered by others. It 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, p. 275f). This may lead to feelings of control or alienation of the user. Furthermore, as intentions are contingent upon external rewards, they tend to last only as long as the rewards stay relevant (DeCharms 1968; Malhotra et al. 2008; Ryan and Deci 2000b). This kind of PLOC can be found if someone only performs to achieve financial or social rewards.

Introjected PLOC describes the state where there is an apparent conflict between "perceived external behavioral influences and personal norms and values. [. . .] The conflict in introjected PLOC is theorized to be caused by misalignment of perceived social influences and personal values. Such extrinsic motivation spawns perceived reasons for one's behavior that are related to affective feelings of guilt and shame, and esteem-based pressures to act. [. . .] Introjected PLOC involves strong violation of personal values" (Malhotra et al. 2008, p. 277). This state occurs e.g. if users feel obligated to use a system by social norms.

This underlying PLOC framework offers a broader perception of how intrinsic and extrinsic motivation influence users' volition and self-determined behavior. Hence, it helps to predict and explain the internalization of social norms and values as endogenous motivations, and how this guides user intentions. The area of smart metering offers the energy suppliers the possibility to use more complex and variable tariffs, and therefore allows companies to offer direct financial incentives to the customers. Further incentives could be given by recommending smart meters as their use can help to protect the environment (e.g., by reducing peak demand). Considering a rising environmental awareness on the customer side, the latter case offers a possible example of an internalization of such regulations as smart metering. As mentioned above, such a wide range of possible incentives and reasons to use SMT cannot be reflected by the dichotomy of (extrinsic vs. intrinsic) motivation. Using the continuum of motivation offers researchers the possibility to get a much deeper understanding of how these different incentives and reasons influence the adoption of SMT.

3.3 Pro-environmental Behavior

It is a well-acknowledged fact that all over the world environmental awareness is rising (Poortinga et al. 2004). People are accepting climate change as one of the most severe problems in the world and are willing to pay more to protect the environment and stop climate change (e.g. European Commission 2008). A smart grid could not only help to better integrate renewable energies, but by providing smart meters to residential customers and allowing variable tariffs, it has the ability to influence the consumption behavior in a way that could help to reduce inefficient and expensive peak demands. Therefore, SMT can have a direct influence on how energy is consumed in the future, and thus, environmental aspects are likely to play an important role in the adoption of SMT.

Behavior based on environmental aspects has been researched since the 1970s. Environmentalism may be defined behaviorally as "the propensity to take actions with pro-environmental intent" (Stern 2000, p. 411). Pro-environmental behavior can be seen as a mixture of self-interest (e.g. minimizing one's own health risk) and of concern for others (e.g. climate change or air pollution that may cause risks for others or the next generation) (e.g., Bamberg and Möser 2007; Brandon and Lewis 1999; Hines et al. 1987; Lindenberg and Steg 2007; Thøgersen 2003). The motivation can be split in a gain-oriented or hedonistic and a normative framework (Bamberg and Möser 2007; Hines et al. 1987; Lindenberg and Steg 2007). Popular models within environmental psychology normally focus on one kind of motivation. Researchers focusing on pro-environmental behavior as pro-socially motivated, often apply the norm-activation model (NAM) (Schwartz and Howard 1981; Schwartz 1977) in an environmental context (e.g., Gärling et al. 2003; Hopper and Nielsen 1991; Vining and Ebreo 1992) whereas researchers focusing on the motive of self-interest tend to use rational choice models and expectancy-value models such as the theory of planned behavior (TPB) (Ajzen 1985, 1991).

According to the NAM moral or personal norms are direct determinants of pro-social behavior (Schwartz 1977). Individuals perceive them as moral obligations, when they are aware of adverse consequences of behavior to others or the environment and when they think they can avert these consequences. These findings have been applied in several fields as energy conservation, recycling, travel mode choice and pro-environmental buying (e.g., Black et al. 1985; Guagnano et al. 1995;

Hunecke et al. 2001; Thøgersen 1999). Stern (2000) extended the NAM into the value-belief-norm theory of environmentalism (VBN). Both theories appear to be successfully explaining low-cost environmental behavior and "good intentions" (e.g. willingness to sacrifice, policy acceptability, willingness to change) (e.g., Nordlund and Garvill 2003; Steg et al. 2005; Stern et al. 1999) but have less explanatory power on high-cost behavior i.e. when behavioral change causes a lot of effort, inconvenience, money or time (e.g., Bamberg and Schmidt 2003; Guagnano et al. 1995; Hunecke et al. 2001). Moral norms appear to be triggered by an interplay of cognitive, emotional and social factors: awareness of environmental problems or a harmful behavior can cause feelings of guilt (Weiner 2000). Guilt as a strong pro-social emotion can result in a felt obligation to compensate for the caused damage (Baumeister 1998).

In a hedonistic/gain-oriented framework, people are very sensitive to incentives (e.g. costs, time and status). The TPB assumes that people are trying to avoid costs and to gain benefits. According to the TPB intention depends on the three variables (1) attitudes towards the behavior, (2) social norms and (3) perceived behavioral control. Attitude can be defined as the sum of perceived costs and benefits of engaging in the behavior. Social norms are conceptualized as perceived social pressure to engage in the behavior and reflect social costs and benefits. The perceived behavioral control construct aims at the perceived ability/possibility to perform the behavior i.e. "How difficult would be the performance of the pro-environmental option compared to other options?". The explanatory power of the TPB was especially high in the case of "high-cost" behavior (Bamberg and Schmidt 2003). It was applied in the fields of travel mode choice, household recycling, composting and feedback on energy use (e.g., Bamberg and Schmidt 2003; Harland et al. 1999; Taylor and Todd 1995b).

SMT could heavily influence users' energy consumption behavior and therefore familiar habits. Although both theories have been applied in the area of pro-environmental behavior, the TPB seems to offer a better fit in this case of "high-cost" behavior. Consequently, this study focuses on the TPB.

3.4 Risk Issues

Apart from environmentalism, risk is also likely to play a role. Every time personal data is transferred privacy and data security issues arise. These issues are widely discussed in the context of smart-metering (e.g., McDaniel and McLaughlin 2009). Several governments and companies such as the Dutch government, Pacific Gas & Electric Co. already had to stop the roll out of smart meters, because consumer groups raised privacy and health concerns. Similar problems occur in the fields of e-business and e-government. Perceived trust and risk constructs have been identified as influencing factors in these research areas (e.g., Carter and Bélanger 2005; Pavlou 2003; Wang 2003).

Table 3.3 Description and definition of perceived risk facets

Perceived risk facet	Description – definition
Performance risk	"The possibility of the product malfunctioning and not performing as it was designed and advertised and therefore failing to deliver the desired benefits." (Grewal et al. 1994)
Financial risk	"The potential monetary outlay associated with the initial purchase price as well as the subsequent maintenance cost of the product" (Grewal et al. 1994). "The current financial services research context expands this facet to include the recurring potential for financial loss due to fraud." (Featherman and Pavlou 2003)
Time risk	"Consumers may lose time when making a bad purchasing decision by wasting time researching and making the purchase, learning how to use a product or service only to have to replace it if it does not perform to expectations." (Featherman and Pavlou 2003)
Psychological risk	"The risk that the selection or performance of the producer will have a negative effect on the consumer's peace of mind or self-perception (Mitchell 1992). Potential loss of self-esteem (ego loss) from the frustration of not achieving a buying goal." (Featherman and Pavlou 2003)
Social risk	"Potential loss of status in one's social group as a result of adopting a product or service, looking foolish or untrendy." (Featherman and Pavlou 2003)
Privacy risk	"Potential loss of control over personal information, such as when information about you is used without your 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)
Overall risk	"A general measure of perceived risk when all criteria are evaluated together." (Featherman and Pavlou 2003)

Source: Featherman and Pavlou (2003)

Perceptions of risk inherent in product adoption and usage in commercial relations have been studied for many years (Bauer 1960; Dowling and Staelin 1994). Perceived risk can be defined as "a combination of uncertainty plus seriousness of outcome involved" (Bauer 1960). Perceived risk is relevant in information system adoption decisions when feelings of uncertainty, discomfort and/or anxiety (Dowling and Staelin 1994), conflict aroused in the consumer (Bettman 1973), concern or psychological discomfort (Zaltman and Wallendorf 1979), pain due to anxiety (Taylor 1974) and cognitive dissonance (Festinger 1957; Gemünden 1985) occur. This dissonance emerges from different perceptions and weighting of benefits and costs. Cunningham (1967) divided perceived risk into six dimensions: performance, financial, opportunity/time, safety, social and psychological loss. These risks are measured separately and add up to an overall perceived risk (Featherman and Pavlou 2003; Jacoby and Kaplan 1972). Featherman and Pavlou (2003) summarize seven very similar facets of perceived risk in their work (Table 3.3).

3.5 Technology and Energy-Related Issues

Recent studies (e.g., Gatersleben et al. 2002; Poortinga et al. 2006, 2004) show that household energy use is related to socio-demographic variables that influence people's ability to act in an environmentally conscious way. These variables include household size and income. Other variables such as age and education only had a minor and less significant effect. These variables especially came to light during the attendance of several meetings of the different working groups of the organization committee of a field study (FS), in the grid operating division (GO) and the supply and marketing division (MA) of a large German energy supplier. Analyses on the socio-demographic variables (as understood from the attendance in the different meetings), highlighted that "the average participant was slightly below the average household owner in age and the majority of the participants had an electricity consumption of more than 4000 kWh" (interviewee FS1). Further, the meetings notes highlighted, that "the household size was above the German average [2.03] but two to four person households were nearly equally distributed" (interviewee FS2). The vast majority was living in their own freehold, which could suggest that they have an above average income. During the discussions in the meetings, it further came to light that "many of the participants seemed to be extraordinarily interested in the technological aspects and the new possibilities offered by the smart meters" (interviewee FS2).

In the working groups of the grid operating division there was a high interest in socio-demographic variables to identify customer clusters. Specifically, the grid operating division is interested "in identifying key customers for a partial rollout of smart meters" (Interviewee GO1). Based on their concept of a voluntary smart meter with an extra fee, they think that "especially customers with above average electricity costs will be interested in the new meters" (interviewee GO1). Further, "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" (interviewee GO2). Also the importance of income and flexibility was highlighted. For example, one interviewee mentioned: "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" (interviewee GO3).

The supply and marketing division of the same German energy supplier already has about 30.000 smart meter customers. These smart meters are digital meters which offer feedback through an online platform but are not as mature as those used in the field study. First market analyses confirmed that buyers normally had an above average income, household size, and an above average electricity consumption. Further, interest in new technologies was also seen as an important antecedent. For example, an interview mentioned that the "customers asked us about technical aspects and were interested in the new opportunities offered by the new meters" (interviewee MA1). Besides the above, the possibility to save energy and money was also a major point of interest. Another interviewee mentioned, "Many of our customers had applied for price guarantees in their tariffs before they switched to the new meters and seemed very price sensitive when asking about the new tariffs offered" (interviewee MA2).

Based on these results of studies on household energy use and the discussions and interviews in the working groups of this large German energy supplier, this study includes a set of several energy-related variables that could play a critical role in the context of smart meter adoption. Given that smart meters can heavily influence household energy use and as first market analyses identified similar variables, "income" and "household size" are included in the research model. Smart meters are also relatively new innovations, and thus consumers' "interest in new technology" and the "willingness to pay for energy efficiency innovations" will also play a role. Further, "participants' age" could also play a role, with younger consumers being more environmentally conscious, and more flexible in changing their lifestyles and behavior. Finally, "average monthly electricity costs" was added to the model, as consumers with very low electricity costs are probably less likely to focus on more possibilities to save electricity. This cluster of variables offers the opportunity to examine the role of SMT-specific factors, beyond the obvious drivers such as risk issues and environmental or financial incentives, which are incorporated in the internal and external PLOC constructs, among others. It offers the possibility to target specific consumer groups when implementing this new technology to establish it faster in our society.

Chapter 4
Conceptual Model

In the following, the research model (see Fig. 4.1) of this study is developed. Traditional research on the adoption of innovations and information technology emphasizes that characteristics of the innovation or technology affect consumers' adoption or intention to adopt (Arts et al. 2011; Davis et al. 1989). However, researchers have argued that consumer-related factors might be more important than innovation characteristics in explaining adoption behavior (e.g., Im et al. 2007; Kleijnen et al. 2005). For example, prior research has highlighted that the consumer's technology readiness in terms of intrinsic and extrinsic motivations is a major determinant of adoption (Meuter et al. 2005; Parasuraman 2000). Moreover, research has demonstrated that these motivations mediate the effects of innovation characteristics, such as relative advantage, complexity, or compatibility, on adoption and are thus powerful predictors of adoption (Meuter et al. 2005).

Based on the reviewed literature, this study proposes a modified version of the adoption model introduced by Malhotra et al. (2008), since it offers the combination of the technology adoption and motivational aspects. The original model is based on the TAM (Davis 1989; Davis et al. 1989) and the Organismic Integration Theory (OIT) (Deci and Ryan 1985). The OIT allows one to understand how a user's internal psychological perception about autonomy shapes his or her intentions and behaviors. Hence, it can help explain why some technologies are more readily accepted by some users than by others.

Based on the literature review and the discussions with the energy suppliers, this study proposes several modifications and new variables to the model making this work specific to the case of SMT adoption. Compared to the model of Malhotra et al. (2008) it includes the constructs of the TPB. The model is no longer based singularly on TAM and OIT, rather TPB and TAM are interwoven similar to the decomposed theory of planned behavior (Taylor and Todd 1995a) and offer a set of technical and (pro-environmental) behavioral aspects. This study therefore proposes to include perceived behavioral control and subjective norm to the model, as it adds important facets of the environmental behavior to the study, and thus enriches the understanding of how much users feel in control to adopt and use SMT and how social pressure and moral obligations pressure the adoption and use

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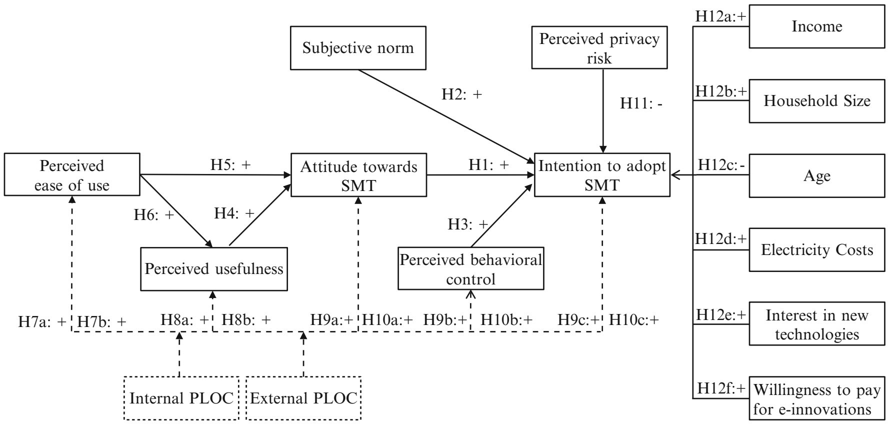

Fig. 4.1 Conceptual model

behavior. This is especially important as new variable tariffs could be associated with financial constraints by the customers. Further, this study proposes to add perceived privacy risk as a variable, as not only research but many practitioner-specific articles have also identified privacy issues as one of the main inhibitors of SMT adoption. Finally, the set of smart meter related socio-demographic variables such as "income", "household size", "age", "average monthly electricity costs", "interest in new technology" and the "willingness to pay for energy efficiency innovations" is included in the model, as they incorporate different personal factors concerning energy innovations and costs. This set of new variables can offer new insights in the adoption of SMT. Figure 4.1 shows this study's conceptual framework.

4.1 Adoption Literature and Ecofriendly Behavior

The TPB has proved to be a compelling social cognitive framework applicable in a variety of research domains to explain the situation-specific influences on intentional behaviors (see Armitage and Conner 2001). Among those areas are IS research on technology adoption (Brown and Venkatesh 2005; Taylor and Todd 1995a) and service research (e.g., Curran et al. 2003). The TPB contends that actual behavior is a result of an intention to perform a particular behavior. Behavioral intention is a motivational construct that reflects the amount of effort an individual is willing to exert in pursuing a behavior and is consequently a strong predictor of actual behavior (Chau and Hu 2001; Sheppard et al. 1988; Venkatesh et al. 2003; Vijayasarathy 2004). This study relies on intention as dependent variable since "intention is the most proximal influence on behavior and mediates the effect of other determinants on behavior" (Venkatesh and Brown 2001, p. 76). It refers to the consumers' intention to adopt SMT as the subjective probability that a person will perform a certain behavior in the near future or continue performing a certain behavior (Fishbein and Ajzen 1975).

The TPB states that individual intention rests on three belief-based judgments: attitude toward the behavior, subjective norms, and perceived behavioral control (Ajzen 1991). Attitude refers to the degree to which an individual assesses a behavior in question as favorable or unfavorable (Fishbein and Ajzen 1975). In the context of this study, attitude is conceptualized as a consumer's judgment of whether using SMT is harmful or beneficial.

Prior research has found ample support for the impact of attitudes on the intention to adopt information technologies (e.g., Hsu and Chiu 2004; Taylor and Todd 1995a) and self-service technologies (Curran et al. 2003). A consumer's attitude is one of the most influential determinants of the intention to use Green-IS (Kranz and Picot 2011; Wunderlich et al. 2012). Thus,

Hypothesis 1. Consumers' attitudes will positively influence consumers' intentions.

Subjective norms are important because human behaviors are embedded in a social context. Thus, they are highly susceptible to interactions with one's environment (Childers and Rao 1992; Rosen and Olshavsky 1987). The extent to which influential others' expectations and pressure affect an individual's behavior depends on the individual's inclination to conformity (Venkatesh and Davis 2000). Several theories in social psychology (Fulk et al. 1987), behavioral research (Childers and Rao 1992; Fishbein and Ajzen 1975; Rosen and Olshavsky 1987), and innovation diffusion (Rogers 1995a) emphasize the impact of social influences on individual behavior. A subjective norm is defined as a "person's perception that most people who are important to him think he should or should not perform the behavior in question" (Fishbein and Ajzen 1975, p. 302). Referring to social psychology this construct is tightly interwoven to the specification of the introjected PLOC, which is aligned to self- and other approval and avoidance of disapproval. The introjected PLOC extends subjective norm by the dimension of self-approval.

Taking into consideration that the diversity of interpersonal influence is greater in private settings and that adoption is voluntary, Brown et al. (2002) argue that the impact of subjective norms on technology adoption is more important in private than in workplace contexts. An important aspect of green technologies is that performing ecofriendly behaviors often means conforming to social norms (Bamberg 2003). Further, given the rising environmental awareness (e.g., Poortinga et al. 2004), people could feel in conflict with themselves and these social values, instead of looking only for other-approval. In line with previous findings (e.g., Pavlou and Fygenson 2006; Venkatesh and Brown 2001), it is assumed that the subjective norm significantly affects the intention to adopt SMT:

Hypothesis 2. Subjective norm positively influences consumers' intentions.

Perceived behavioral control reflects the extent to which an individual believes he or she has the ability to control internal and external factors that either enable or restrict performance of a certain behavior (Ajzen 1991). Venkatesh et al. (2012b) recommend incorporating facilitating conditions when studying technology adoption in the consumer context. In this respect, behavioral control is a key determinant of consumers' adoption of self-service technologies (Zhu et al. 2007) and positively influences the intention to use such technologies (Collier and Sherrell 2010; Reinders et al. 2008). In this study's context, perceived behavioral control is related to the consumer's subjective degree of control over adopting and using green technologies such as SMT. In line with prior research, this study thus suggests that the greater the perceived behavioral control, the greater the intention to adopt these technologies (Lee and Kozar 2008; Liao et al. 2007). Hence,

Hypothesis 3. Perceived behavioral control positively influences consumers' intentions.

Regarding the context of SMT especially technological aspects could be of interest. Based on belief-attitude-behavior models of the theory of reasoned action (Fishbein and Ajzen 1975), Davis et al. (1989) suggested that perceived ease of use and perceived usefulness predict intentions to use. Perceived ease of use influences behavioral intentions through two causal pathways: an indirect effect through perceived usefulness and an indirect effect through attitude. In case of SMT, the user interface will influence the perceived usefulness on the one hand and the attitude on the other. Perceived usefulness is posited to influence behavioral intentions through attitude as well. The perception of how useful SMT is in terms of energy efficiency and energy control, will therefore influence consumers' intention to use SMT through the attitude towards SMT. This is in line with the decomposed theory of planned behavior (Taylor and Todd 1995a), which attempts to decompose the underlying belief structures that determine the primal variables. Thus,

Hypothesis 4. Perceived usefulness will positively influence consumers' attitude towards SMT.

Hypothesis 5. Perceived ease of use will positively influence consumers' attitude towards SMT.

Hypothesis 6. Perceived ease of use will positively influence consumers' perceived usefulness of SMT.

4.2 The Organismic Integration Theory

This study suggests that the different types of PLOC exert cumulative effects on behavioral intentions that can be assigned to different types of endogenous motivations (Deci and Ryan 1985). Internal PLOC comprises feelings of volition, through which actors perceive themselves as the origin of spontaneous and instinctive behaviors, occurring for reasons like enjoyment, as well as self-determined actions taken in line with personal values and goals (Ryan and Connell 1989). By internalizing external regulations, individuals embrace the regulations as personally meaningful, which should notably be important in terms of the adoption of transformative services.

Prior work has shown that when individuals engage in a particular behavior because it yields enjoyment or is personally meaningful, they perceive a lower cognitive burden than when they engage in behaviors associated with feelings of coercion (Csikszentmihalyi 1990). When experiencing pleasure while performing an activity, people are willing to invest more time and effort (Agarwal and Karahanna 2000; Deci 1975). In the context of SMT, the adoption can be expected to appear as less burdensome or annoying since users could be interested to learn more about how SMT is working and if they have the capability to master it (intrinsic drivers) or that they are driven by internalized values of our society like the protection of the environment. This behavior would therefore be associated with positive feelings and values. On the basis of the motivation and technology adoption literature (Csikszentmihalyi 1997; Venkatesh and Speier 1999), this study presumes that higher degrees of intrinsic motivation and self-determination will have a favorable impact on the perceived level of effort and thus increase ease of use (see also Sun et al. 2010).

In contrast, feelings of ease of use are less likely to occur when individuals perform an activity that is associated with feelings of coercion or pressure. Consumers find activities they perceive to be less meaningful and less autonomously initiated, as characterized by external PLOC, rather unappealing. Hence, the willingness to invest time and effort in performing these activities is presumed to be lower than for behaviors occurring under the influence of internal PLOC. However, consumers may still perceive less appealing and self-endorsed behaviors as important because of personally meaningful external incentives. In the context of this study, external incentives could be financial, environmental, and societal benefits. If individuals consider these incentives to be personally significant, they may still perceive performing externally regulated behaviors as less burdensome. Examples could be that mastering 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 or getting some money for using SMT or feeling good by following recommendations by public institutions can help to overcome possible weaknesses in the usability of a device such as SMT. Thus,

Hypothesis 7a. Internal PLOC positively influences perceived ease of use.

Hypothesis 7b. External PLOC positively influences perceived ease of use.

OIT also implies that internal and external PLOC should directly affect perceived usefulness (Malhotra et al. 2008). While some individuals may perceive usefulness solely in terms of its instrumental value, others may perceive it in terms of the development of the self (Schwarz and Chin 2007). The latter perspective has recently attracted attention among researchers examining service (Cadwallader et al. 2010; Chan and Lam 2011) and IS (Bagozzi 2007; Benbasat and Barki 2007; Schwarz and Chin 2007). The developmental focus of OIT thus suggests that consumers can be expected to assess adoption of transformative services as more useful if adoption meets personally meaningful goals and fosters self-development (Deci and Ryan 1985, 2000, 2002).

Accordingly, internal PLOC should directly affect the perceived usefulness of SMT. The key rationale for this effect is that an individual's intrinsic motivation and self-determination to engage in a certain behavior should also increase its instrumentality (Dholakia 2006). Thus, individuals should also attribute performance-related characteristics to behaviors they perceive as personally meaningful and contributing to self-development (Malhotra et al. 2008). The developmental focus of OIT therefore implies that consumers will assess adopting SMT as more useful if the adoption fulfills personally meaningful goals and fosters self-development (Deci and Ryan 1985, 2000, 2002). In the context of the SMT, this could be either something more global such as protecting the environment or one of the services that is enabled by it. This can range from the possibility to overview one's energy consumption to benefits like security options offered through analyzing energy consumption patterns allowing indicating irregularities during times of leave. The device that helps consumers in achieving this (that is, SMT), tends to look much more useful than otherwise. Further, if external regulations are not perceived as coercive but rather as providing individually meaningful incentives, they are regarded as useful (Deci and Ryan 1985). That is, if SMT provides compelling external incentives, such as self-fulfillment or monetary benefits, and external regulations are not perceived as coercive, consumers will evaluate these services as more useful (Deci and Ryan 1985). Thus,

Hypothesis 8a. Internal PLOC positively influences perceived usefulness.

Hypothesis 8b. External PLOC positively influences perceived usefulness.

The TPB and SDT aim to predict behavior through different approaches. The TPB posits that immediate belief-based constructs can predict performance of a specific behavior. In contrast, the SDT's lens focuses on the type of motivation and environmental influences that affect behavior in a particular context (Deci and Ryan 1985). According to Vallerand's (1997) hierarchical model of motivation the two theories can be distinguished in terms of their degree of generality. The TPB's constructs are bound to a specific target behavior at a future point in time, whereas SDT's internal and external PLOC refer to context-related motivations. Thus, PLOC is hypothesized to influence behavior not only through "the here and now of motivation" (Vallerand 1997, p. 293), but beyond that various behaviors in a particular context through more generalized motivations pertaining to broad life contexts such as interpersonal relationships, the environment, or technology (Cadwallader et al. 2010).

The hierarchical model of motivation proposes that motivation at the contextual level affects cognitions and motivation at the situation level operates in a top-down fashion (Vallerand 1997). Except for the subjective norm, the TPB's constructs are linked to expectations of performing a particular behavior in a particular time frame. Thus, the motivational constructs at the contextual level (i.e., internal and external PLOC) are expected to be antecedents of the TPB's situational level constructs like attitude or perceived behavioral control (Vallerand 1997).

Integrating the TPB with SDT hence offers complementary explanations as to the underlying motivational processes of intentional behavior. Research in health and educational contexts has provided empirical support for this view, in that results suggest that different types of PLOC affect behavioral intention both directly (Standage et al. 2003; Wilson and Rodgers 2004) and indirectly through attitude and perceived behavioral control (Chatzisarantis et al. 2003; Hagger et al. 2006). Individuals who are autonomously motivated to engage in a particular domain usually perceive their behavior in that context as personally meaningful and valued and as congruent with their psychological needs (Sheldon 2002). Contextual motivation is expected to lead to greater awareness, interest, and value regarding the respective behavioral outcomes. As a result, individuals are more likely to recognize related information that delineates the benefits of the behaviors and they thus form a positive attitude. Further, behaviors motivated by internal PLOC tend to be associated with positive feelings of volition, freedom, and autonomy (Melancon et al. 2011). In the case of SMT, autonomously motivated users are more likely to experience adoption of this technology as meaningful to themselves and society and additionally to feel good while using related services. That means the greater the users' interest in SMT for their own inherent reasons (e.g. interest in SMT, protection of the environment), the better their attitude towards SMT:

Hypothesis 9a. Internal PLOC positively influences consumers' attitudes.

In addition, individuals who experience their behavior as self-endorsed and relevant to themselves have a greater tendency to feel more confident about having the resources necessary to perform a target behavior. Literature in the health care domain has provided support for the positive relationship between autonomous motivation and perceived behavioral control (e.g., Williams et al. 2004). Thus it can also be expected that adopting SMT from a higher level of autonomous motivation will positively affect people's perceived competence about operating these services and their expectations about required abilities and potential barriers.

Hypothesis 9b. Internal PLOC positively influences perceived behavioral control.

Internal PLOC may lead consumers to adopt green IS technologies like SMT either because of intrinsic motivation or via the internalization of external regulations. In the former case, people are autonomously motivated because of curiosity (e.g., the ability to obtain detailed energy use information) or self-development (e.g., the ability to reduce home energy consumption). In the latter case, SMT's characteristics (e.g., improving environmental sustainability) should be important. If consumers internalize external regulations by federal institutions, NGOs, or influential others that highlight the positive outcomes of SMT and as a result perceive adoption as a self-determined choice, they should be more likely to adopt:

Hypothesis 9c. Internal PLOC positively influences consumers' intentions.

As outlined, OIT distinguishes between degrees of perceived autonomy of extrinsically motivated behavior (Ryan and Deci 2000b). For example, an individual may adopt or use SMT because external regulations are personally important. In the case of SMT these could be financial incentives or following official recommendations or social recognition for acting as an environmentally responsible person. If these external motivations are personally important to consumers they should still have a positive influence on attitude (Melancon et al. 2011). Thus,

Hypothesis 10a. External PLOC positively influences consumers' attitudes.

Externally regulated behaviors are controlled by externally governed constraints such as rewards, prescriptions, and payments. This study expects these external regulations, which originate for example from influential others, mass media, or private and governmental institutions, to have a positive influence on consumers' perceived competence if the regulations are personally important and in line with personal values and principles. Thus, although perceived control over a target behavior is not autonomously motivated, it should be positively affected by external PLOC. Hence,

Hypothesis 10b. External PLOC positively influences perceived behavioral control.

External PLOC represents extrinsic motivation in its most basic form. Individual behavior is then a result of satisfying demands of others (Ryan and Connell 1989), assuming that no contradiction exists between other external stimuli and individual values. External PLOC represents the least autonomous form of extrinsic motivation. Thus, individuals experience extrinsically motivated behaviors as controlled. In the case of SMT, external stimuli could be financial rewards or recommendations by public institutions (Melancon et al. 2011). Although less sustainable and dependent on external regulation, consumer intentions are still contingent on these external factors, although presumably to a lower extent than on internal PLOC (Dholakia 2006). Thus, external PLOC should also have a positive impact on intention. Therefore,

Hypothesis 10c. External PLOC positively influences consumers' intentions.

4.3 Privacy and Socio-demographic Variables

4.3.1 Perceived Privacy Risk

Perceived privacy risk refers to the potential loss of control over personal information, such as when information about one is used without ones knowledge or permission (Featherman and Pavlou 2003). 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 intention. In the context of the SMT, it is related to consumers' anxiety of abuse of their private consumption data by the energy suppliers. Hence,

Hypothesis 11. Perceived privacy risk negatively influences the intention to adopt SMT.

4.3.2 Socio-demographic Variables

The cluster of smart meter related variables offers a unique set of socio-demographic variables that influence consumers with regard to SMT. These variables are added to the model based on experts' opinions and recent energy related studies as discussed earlier (e.g., Gatersleben et al. 2002; Poortinga et al. 2004, 2006).

Higher incomes give individuals the opportunity to focus on less immediate needs and therefore the possibility to act in environmentally conscious ways (Gatersleben et al. 2002; Poortinga et al. 2004). Thus, consumers with high incomes have the luxury to invest in environmentally friendly devices such as SMT. Hence,

Hypothesis 12a. Income positively influences the intention to adopt SMT.

Findings in earlier studies suggest a positive correlation between household size and home energy usage (Gatersleben et al. 2002; Poortinga et al. 2004). Further, the more people living in a household, the more energy is used. In such contexts, any energy saving option such as SMT is seen as more attractive. Thus,

Hypothesis 12b. Household size positively influences the intention to adopt SMT.

In the discussions with the experts from the energy supplier, these experts often mentioned that customers need to be flexible in changing their lifestyle and consumption behavior to adapt to new tariffs and possibilities offered by SMT. Analyses of the participants in the field study showed, that younger consumers are more flexible in changing their lifestyles and behavior especially those that will result owing to the implementation of SMT. Thus,

Hypothesis 12c. Age negatively influences the intention to adopt SMT.

In every discussion group the average monthly electricity costs were named as an important factor. Regarding the possibilities that SMT offers to consumers is a significant reduction in energy consumption, thereby reducing average monthly electricity costs. Thus those with a high average electricity cost are more likely to adopt SMT. Hence,

Hypothesis 12d. Average monthly electricity costs positively influence the intention to adopt SMT.

The willingness to adopt innovative technologies such as SMT also needs interest in new technologies. As one of the interviewees said, "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" (interviewee MA1). Thus, *Hypothesis 12e.* Interest in new technology positively influences the intention to adopt SMT.

Finally, as SMT is still in its infancy and only voluntary in Germany, it is still more expensive than a regular metering device. Consumers willing to adopt the new technology therefore need to be willing to pay for it. Thus,

Hypothesis 12f. Willingness to pay for energy efficiency innovations positively influences the intention to adopt SMT.

Chapter 5
Methodology

In order to test and quantify the previous findings and the hypothesized relations, a quantitative approach was chosen. To collect the data a large-scale quantitative study was conducted. This chapter describes the methodological approach, the development of the questionnaire and the samples used in this study. It consists of four sections and is structured as follows: In Sect. 5.1, the research method for this study, namely structural equation modeling, is introduced. Section 5.2 then describes the development and validation of the measurement scale. Section 5.3 summarizes the measures used in the final test of this study and finally, Sect. 5.4 describes the data collection approach and the resulting sample characteristics of both, the non-user and user sample.

5.1 Structural Equation Modeling

In the following section the method used for the quantitative analysis, namely structural equation modeling (SEM) is introduced. This includes a general explanation of the methodology as well as the choice of measurement mode, which is reflective or formative. Finally, the two alternative estimation approaches namely covariance- versus variance-based SEM are explained. This section comprises a comparison of both approaches as well as a set of rules to motivate the choice of either technique.

5.1.1 Introduction of Structural Equation Modeling

Structural equation modeling (SEM) belongs to the group of multivariate techniques mainly used for confirmatory analysis (Backhaus et al. 2008). Chin (1998a) describes it as an extension or generalization of several multivariate techniques and it has potential advantages over linear regression models that

P. Wunderlich, *Green Information Systems in the Residential Sector*, Progress in IS,
DOI 10.1007/978-3-642-36769-4_5,

made SEM the method of choice in analyzing path diagrams. Today, SEM is seen as the quasi-standard in marketing research (e.g., Babin et al. 2008; Hulland 1999). It is used for analyzing path models when these involve latent variables with multiple indicators and several relations between latent variables. A latent variable describes a theoretical construct that (excluding neuroscience techniques) cannot be measured directly (such as feelings, beliefs, and intentions). Therefore they are normally measured by several characteristics that are attributed to them. Churchill (1979) consequently demands that such variables and their attributed measurement variables should be based on relevant theory and expressed in e.g., questionnaire scales. When measuring latent variables, it is important to recognize the distinction between the measures and the measured variables, the so called measurement error (Rigdon 1994). Therefore, it is important to either recognize this distinction or to use techniques to at least ameliorate the consequences of measurement error.

In summary, following Chin (1998a) SEM provides three key advantages compared to other methods: it allows (1) to model complex relationships among multiple dependent and independent variables, (2) to analyze latent variables, and (3) to account for measurement errors in the model (in the case of covariance based SEM).

To assess latent variables, i.e. not directly observable variables, SEM distinguishes between two measurement levels. The latent variable itself is assessed on the observation level (outer or measurement model) whereas the relationships between the latent variables are analyzed on the theoretical level (inner or structural model) (Bollen 1989).

The inner or structural model specifies the theoretical relationships between the latent variables. In the structural model, latent variables are split into endogenous and exogenous variables. If a latent variable is influenced by other latent variables according to the theoretical relationships in the structural model, it is referred to as endogenous variable. An exogenous variable however is not explained within the structural model, but only determined from its observable manifest variables. As mentioned above, one of the key advantages of SEM is that it has the capability to analyze models with multiple dependent (endogenous) variables and their interconnections at the same time (see also Barclay et al. 1995; Chin 2010; Gefen et al. 2000).

The outer or measurement model specifies the exogenous variables. It estimates how a latent variable is determined by several observable manifest variables. These manifest variables are also referred to as indicators or items. For each latent variable, a separate measurement model is required.

Figure 5.1 illustrates the interaction of the inner and outer model with the endogenous and exogenous variables and the respective error terms.

In literature the emphasis is mostly put on the presentation of the structural model, as the relationships between the latent variables are often the main contributions from a researcher's and a practitioner's point of view. However, the relations in the measurement model are of major importance, too: "These relationships are of paramount importance because they constitute an auxiliary theory that bridges the gap between abstract theoretical constructs and measureable

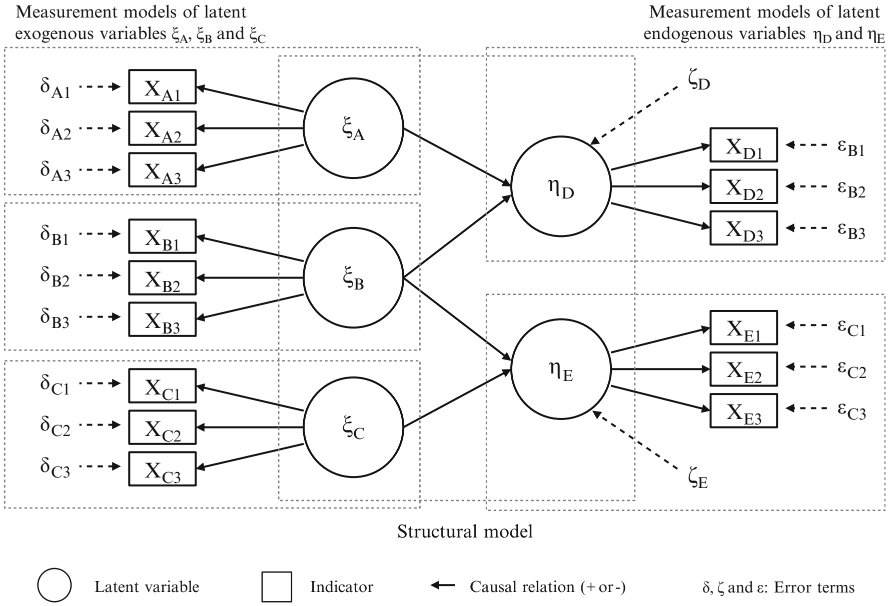

Fig. 5.1 SEM including structural and measurement models (Source: Based on Backhaus et al. 2008, p. 513)

empirical phenomena" (Edwards and Bagozzi 2000, p. 155). If such auxiliary theories do not exist, the structural model and thus the underlying theories could not be meaningfully tested (Edwards and Bagozzi 2000). Further, MacKenzie et al. (2011) note that it is absolutely critical to validate the measures in order to build cumulative knowledge in MIS and the behavioral sciences.

SEM offers two alternative possibilities to specify the measurement of latent variables by the use of indicators. The reflective measurement mode describes a latent variable that causes its indicators. The indicators constitute a reflection of the latent variable. In contrast, in the formative measurement mode, the latent variable is formed by its indicators in a composite manner (Petter et al. 2007). Thus, the key difference between both measurement modes is a reversed causality (Cenfetelli and Bassellier 2009). These two terms do not specify the nature of a construct; rather they describe the nature of the relationship between a latent variable and the respective indicators (MacKenzie et al. 2011). One of the most famous examples explaining the two alternative measurement modes is the one of "drunkenness" that is illustrated in Fig. 5.2.

Measured reflective, drunkenness causes its indicators. These could be the blood alcohol level, bad driving ability or bad performance on mental calculations. If a person is drunk, all measures will indicate the same. In a formative measurement mode, drunkenness is determined by measuring the different formative indicators, i.e., the number of alcoholic beverages (one indicator for every type) a person has drunk. In this case, the latent variable drunkenness is clearly influenced by the

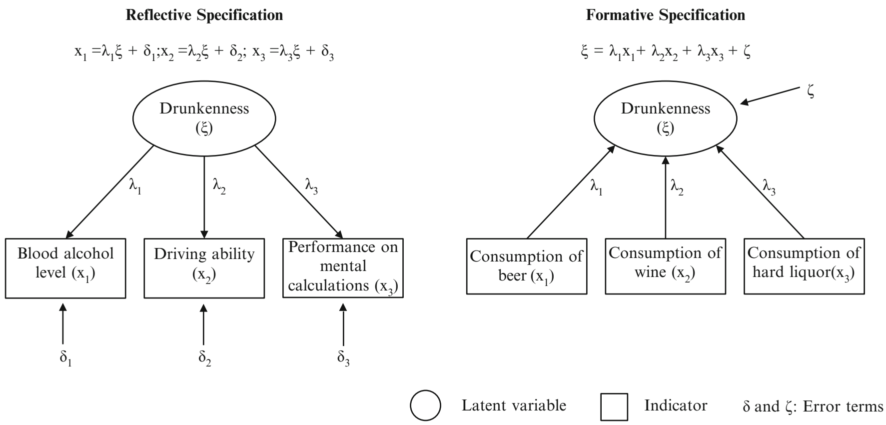

Fig. 5.2 Reflective versus formative measurement specifications in SEM (Source: Based on Backhaus et al. 2008 and Chin 1998a)

indicators, rather that the drunkenness influences the number of drinks. As already suggested above, this example highlights another difference between the reflective and the formative measurement mode: Although the reflective items cover different spheres (blood alcohol level, ability to drive) they all reflect the same thing. If scaled correctly, one of the three above mentioned methods suffices to identify the level of drunkenness. In contrary, the formative mode requires multiple items to cover all facets or dimensions of the measured latent variable to constitute a valid measurement model. If someone drank some beer, wine and liquor throughout the evening and then only counts the number of beers, while not considering wine and liquor, the accurate level of drunkenness cannot be calculated. In SEM, the intersection and correlation between the reflective measurement items is intended, and needed for evaluating and modeling the measurement error.

5.1.2 Covariance Versus Variance-Based Structural Equation Modeling

To finally test the theorized relationships between the variables, the unknown parameters of the structural and measurement model have to be estimated. SEM does this by integrating the structural and the measurement model into a simultaneous assessment. This integrated measurement and structural model is then estimated (Gefen et al. 2011). There are two different SEM approaches that can be distinguished based on their estimation algorithm: the so called *covariance-based approach* (CB-SEM) and the *variance-based partial least squares approach* (PLS-SEM).

For many researchers, SEM was equivalent to carrying out CB-SEM. The covariance-based approach analyzes structural and measurement model in one step by developing a theoretical covariance matrix based on the underlying specified set of structural equations. It estimates a set of model parameters with the purpose of minimizing the difference between the theoretical and estimated covariance matrix (e.g., Rigdon 1998). This is achieved by minimizing the discrepancy as calculated by a selected discrepancy-function, such as maximum likelihood or generalized least squares (Homburg and Baumgartner 1995; for a more detailed description of the algorithm see Homburg 1992). Popular software packages to carry out CB-SEM analyses are LISREL, Amos, EQS and Mplus among others.

In the last decade, the less popular PLS-SEM has gained more and more acceptance in academia and practice. PLS-SEM was originally developed by Wold (1975) and then extended by Lohmöller (1989) as an alternative to CB-SEM that would put more emphasis on prediction and relax the demands on data and specification of relationships (Dijkstra 2010; Jöreskog and Wold 1982). Again, PLS-SEM presents the results as one unified estimated model in which the estimates of the measurement and structural model are presented as a whole. But in contrast to CB-SEM, PLS-SEM first estimates the latent variable scores as exact linear combinations of their associated manifest variables. In an iterative step, it then maximizes the explained variance of the endogenous latent variables by estimating partial model relationships in an iterative sequence of ordinary least squares (OLS) regressions (Fornell and Bookstein 1982). For this iterative process, it is also referred to as *partial* least squares. A more detailed description of the variance-based algorithm can be found in Chin and Newsted (1999) or Hair et al. (2011). Popular variance-based software packages are e.g., PLS-Graph or SmartPLS.

As suggested above, both approaches differ significantly in their underlying philosophy, distributional assumptions, and estimation objectives (e.g., Chin 1998a, b, 2010; Fornell and Bookstein 1982; Gefen et al. 2000; Lohmöller 1989). Therefore, both approaches have some advantages and disadvantages and should be chosen based on the attributes of the research goals, measurement model specification, structural model, data characteristics and the model evaluation (e.g., Gefen et al. 2011; Hair et al. 2011).

The following Table 5.1 gives an overview of rules of thumb for selecting CB-SEM or PLS-SEM mentioned in the literature.

It is important to note that Gefen et al. (2011) see some of these rules as obsolete reasoning. Especially the Mplus software package includes new approaches that allow CB-SEM for (1) better possibilities to model latent variable interactions and moderations and (2) to work with distributions that are non-normal, censored or even discrete. In addition, it should be noted that, in general, PLS-SEM parameter estimates are not optimal regarding bias and consistency. This is often referred to as PLS-SEM bias. Therefore, there is no compelling reason to motivate the choice of PLS-SEM based only on either the need to model interactions/moderations or distribution assumptions.

Table 5.1 Rules of thumb for selecting CB-SEM or PLS-SEM

Research goals
If the goal is predicting key target constructs or identifying key "driver" constructs, select PLS-SEM
If the goal is theory testing, theory confirmation, or comparison of alternative theories, select CB-SEM
If the research is exploratory or an extension of an existing structural theory, select PLS-SEM
Measurement model specification
If formative constructs are part of the structural model, select PLS-SEM
Note that formative measures can also be used with CB-SEM but to do so requires accounting for relatively complex and limiting specification rules
If error terms require additional specification, such as covariation, select CB-SEM
Structural model
If the structural model is complex (many constructs and many indicators), select PLS-SEM
If the model is nonrecursive, select CB-SEM
Data characteristics and algorithm
If your data meet the CB-SEM assumptions exactly, for example, with respect to the minimum sample size and the distributional assumptions, select CB-SEM; otherwise, PLS-SEM is a good approximation of CB-SEM results
Sample size considerations
If the sample size is relatively low, select PLS-SEM. With large data sets, CB-SEM and PLS-SEM results are similar, provided that a large number of indicator variables are used to measure the latent constructs (consistency at large)
PLS-SEM minimum sample size should be equal to the larger of the following: (1) ten times the largest number of formative indicators used to measure one construct or (2) ten times the largest number of structural paths directed at a particular latent construct in the structural model
If the data are to some extent nonnormal, use PLS-SEM; otherwise, under normal data conditions, CB-SEM and PLS-SEM results are highly similar, with CB-SEM providing slightly more precise model estimates
If CB-SEM requirements cannot be met (e.g., model specification, identification, nonconvergence, data distributional assumptions), use PLS-SEM as a good approximation of CB-SEM results
CB-SEM and PLS-SEM results should be similar. If not, check the model specification to ensure that CB-SEM was appropriately applied. If not, PLS-SEM results are a good approximation of CB-SEM results
Model evaluation
If you need to use latent variable scores in subsequent analyses, PLS-SEM is the best approach
If your research requires a global goodness-of-fit criterion, then CB-SEM is the preferred approach
If you need to test for measurement model invariance, use CB-SEM

Source: Based on Hair et al. (2011, p. 144) and Gefen et al. (2011)

This study uses a PLS-SEM instead of CB-SEM for three reasons. First, PLS-SEM better predicts and identifies key "driver" constructs (Hair et al. 2011; Völckner et al. 2010). Second, using PLS is not constrained by model identification concerns, even if models become complex, which typically restricts CB-SEM (Hair et al. 2011). Third, studies show that the so called PLS-SEM bias resolves at large sample sizes and a large number of indicators. Differences of CB-SEM and

PLS-SEM are at very low levels under the "consistency at large" argument (e.g., Reinartz et al. 2009).

5.2 Instrument Validation

As structural equation modeling heavily depends on the quality of the dataset used, a valid measurement model is required or as MacKenzie et al. (2011, p. 293) put it: "Despite the fact that validating the measures of constructs is critical to building cumulative knowledge in MIS and the behavioral sciences, the process of scale development and validation continues to be a challenging activity". In literature, a wide range of scale development approaches have been proposed (e.g., Churchill 1979; Gerbing and Anderson 1988; Hensley 1999; Hinkin 1998; Moore and Benbasat 1991) following the same objective to establish optimal indicators to measure the latent variables and to reach construct validity. Construct validity refers to whether an operationalized measure reflects the concept it is supposed to measure (Cook et al. 1979). It is established by discriminant, convergent and nomological validity (Peter 1981). Further, content and face validity should be established by a panel of expert judges (Churchill 1979, p. 69; Moore and Benbasat 1991). Finally, as SMT is still in its early stages in Germany and therefore not known to everyone, an introduction text was added to the survey that was tested for potential biases during the measurement validation.

To achieve a valid measurement model this thesis builds on the seminal work of Moore and Benbasat (1991) that comprehensively describes a three stage development procedure to establish a measurement instrument. Further, it is complemented by the work of MacKenzie et al. (2011). Although most of the constructs in this study have often been applied and a set of standard items for most of these is established, there was no "ready-to-use" measurement instrument for the complete theoretical model in the energy informatics domain. Therefore, the following section will summarize the three stage development of the measurement scale used in this study. An overview of the process can be seen in Fig. 5.3:

At this point, it is important to note that all constructs specified in this study are measured using a reflective measurement logic. As MacKenzie et al. (2011, p. 302) note: "Constructs are not inherently formative or reflective in nature, and most can be modeled as having either formative or reflective indicators depending upon the researcher's theoretical expectations about how they should be related based on the conceptual definition of the construct. [. . .] The key point is that the way in which the construct and the indicators are linked depends on the content of the indicator and how the construct is conceptualized by the researcher." As the measurement of all constructs used in this study builds on reflective scales, this study conceptualizes them based on the theoretical grounding as reflective as well.

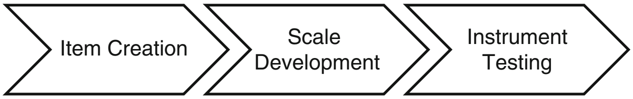

Fig. 5.3 Scale development process

5.2.1 Stage I: Initial Item Pool Generation Based on the Constructs' Conceptualization

In the first stage of the development the clear conceptualization and articulation of the construct domain is absolutely essential. MacKenzie et al. (2011) especially stress this point as many of the guidelines found in the literature do not describe the characteristics of a good construct definition and the implications of that definition for measurement model specification. As all constructs and measures are already existent in literature, the following paragraphs offer an overview of the definitions and the foundation for item generation for each construct. Further, Table 5.2 offers an overview of all constructs' definitions used in this study.

Intention to adopt or to continue using SMT is defined according to the seminal work of Fishbein and Ajzen (1975) and to the work of Bhattacherjee (2001). Intention to use/adopt has been widely employed in different domains and the definition as well as the measurement instrument had only to be slightly adapted to the energy domain and are based on the work of Davis et al. (1989).

Attitude towards a technology as well has been widely employed in different domains. As the behavioral intention, the definition of this construct is according to the seminal work of Fishbein and Ajzen (1975). The measures of this construct are derived from the work of Davis et al. (1989) as well.

Perceived behavioral control is a construct from the theory of planned behavior by Ajzen (1985, 1991). It is defined accordingly and was adapted to different domains in the whole IS field. The measurement scale only had to be slightly adapted and was derived from the items used by Fishbein and Ajzen (1975) and Taylor and Todd (1995a).

Subjective norm is a construct from the theory of planned behavior as well (Ajzen 1985, 1991). It reflects a person's perception that most people who are important to him think he should or should not perform the behavior in question. Adapted to the field of energy informatics another dimension comes into play. Mainly drawing on the idea of introjected PLOC that already incorporates this dimension the definition in this study has been extended by feelings of self-approval. As studies show (e.g., Poortinga et al. 2004) environmental awareness becomes more and more important in todays' society resulting in possible feelings of shame for nor performing adequately. The measurement of this construct was built out of different scales mainly derived from Ryan and Connell (1989), Ajzen (1985, 1991) and Venkatesh et al. (2012a).

Perceived usefulness is defined according to Davis et al. (1989). Again, this construct has been widely applied in IS research and been adapted to different

Table 5.2 Definition of constructs

Construct	Definition	Source
Perceived usefulness	*Perceived usefulness* is the degree to which a person believes that using SMT would enhance his or her energy efficiency	Davis et al. (1989)
Perceived ease of use	*Perceived ease of use* is the degree to which a person believes that using SMT would be free of effort	Davis et al. (1989)
Perceived 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)
Subjective norm	*Subjective norm* refers to the person's perception that most people who are important to him think he should or should not perform the behavior in question	Ajzen (1991)
Perceived privacy risk	*Perceived privacy risk* describes the potential loss of control over personal information, such as when information about you is used without your 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)
Intention to adopt SMT	*Intention to adopt SMT* is the subjective probability that a person will perform a certain behavior	Fishbein and Ajzen (1975)
Attitude toward SMT	*Attitude toward SMT* is the affective or evaluative judgment of the consumer towards SMT	Fishbein and Ajzen (1975)
Internal PLOC	*Internal PLOC* refers to feelings of volition where consumers perceive themselves as the "origin" of their behavior	Malhotra et al. (2008)
External PLOC	*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)

domains. In developing the measurement construct this study draws on the items of Davis et al. (1989) that had to be adapted to the field of smart metering technology.

Perceived ease of use as well was defined according to Davis et al. (1989). As perceived usefulness, perceived ease of use has been widely applied in IS research. The measurement instrument for this construct again draws on the study of Davis et al. (1989) adapting the items to the field of smart metering technology.

Internal perceived locus of causality is defined according to the work of Ryan and Connell (1989) and its adaption to the IS field by Malhotra et al. (2008). The measurement scale has been applied to several areas in social psychology but only once been adapted to the IS field. Following the guidance given by Malhotra et al. (2008) the items for this study have been slightly adapted to fit the energy and smart metering technology context.

External perceived locus of causality is as well defined according to the work of Ryan and Connell (1989). In this case the measurement scale had to be adapted to fit the influencing spheres reflected by external PLOC. These spheres are specified by

Ryan and Connell (1989) as “rule following” and “avoidance of punishment”. As in the case of most technologies there are not any strict rules or ways to punish, these spheres had to be interpreted with respect to the characteristics of the smart metering technology. In discussions with Edward Deci and Richard Ryan, the measurement scale of this study was adapted to reflect financial incentives as “punishment” and recommendations by the energy supplier and/or governmental institutions as “punishment” and “rule following”.

Finally, perceived privacy risk was defined according to Featherman and Pavlou (2003). Privacy issues have been widely researched in e-business (see Angst and Agarwal 2009; Awad and Krishnan 2006 for reviews). Regarding the measurement scales the instruments are often contextualized. Again, to the knowledge of the author, no energy specific measurement scale existed and the measurement instrument used in this study was based on the definition and an adaption of the items used in the study of Featherman and Pavlou (2003).

As the measurement scales employed in this study are all built on existing reflective scales, all items were measured as reflective items again.

Based on the construct definitions and the existing measurement scales overall roughly 100 items were generated in the initial item pool. These items mainly consisted of different adaptations and translations of the existing measurement scales and a few newly created items out of discussions with several authors (e.g., Edward Deci, Richard Ryan). This initial item pool was then the basis for further refinement and measurement scale reduction.

The measurement of the socio-demographic and control variables used the measures provided by the professional market research company. These are measured as reflective single-item constructs and for reasons of simplicity not discussed any further in the scale development section of this thesis. A full list of control variables can be found in the Appendix 2.

5.2.2 Stage II: Scale Development

In the second stage of the scale development procedure, a series of qualitative pretests have been conducted. In four rounds of interviews the items were further refined and bad items excluded from the item pool. The objective of this stage was therefore twofold: (1) to improve the quality of the measurement instrument by establishing the content and face validity of the various scales and (2) to further refine the scales and cull ambiguous items.

Content validity can be defined as the degree to which a measure’s items represent a proper sample of the theoretical content domain of a construct (Nunally and Bernstein 1994). Face validity is defined as the extent to which a measure reflects what it is intended to measure (Nunally and Bernstein 1994). Therefore, items first have to be face valid to be content valid. A dartboard can be used as an example to distinguish between face and content validity. Content validity is given, if the darts hit the whole dartboard instead of covering only specific areas of it.

Therefore, items should not be too similar as otherwise the full domain of the constructs may not be covered. Face validity is given, if the darts hit only the dartboard and not the wall behind it. Therefore, researchers must ensure, that the items used reflect the desired construct.

To establish face and content validity, first following the recommendations by DeVellis (2003, pp. 85–86) the items were reviewed by a panel of experts, i.e., researchers with solid method knowledge and the items were adjusted accordingly. In the second step, as recommended by Moore and Benbasat (1991), the items were validated in a sorting procedure by a panel of judges consisting of researchers and employees of a large Southern-German energy supplier. This range of backgrounds was chosen to ensure that a range of perceptions would be included in the analysis. In all four rounds, a different set of judges was used. The items were then printed on cards, shuffled and handed to the judges. Before the sorting procedure began a trial run was conducted with ten items unrelated to the constructs of the study to ensure judges understood the procedure. Two different types of sorting procedures were conducted. First, the judges would be handed the cards and then had to sort them according to their own perceptions of how these items were related. Further, they had to label the dimensions they sorted the items into. The second set of judges would then be handed the cards with the items but this time the underlying definitions of the constructs were given and the judges were asked to place the items in the underlying dimensions which best reflected the underlying construct. After each round the judges were interviewed on how and why items were sorted to identify critical items. These critical items were then either rephrased or omitted. Round 1 and round 3 employed the first sorting procedure, whereas in round 2 and round 4 judges were given the definitions of constructs.

To assess the reliability of the sortings, two different measures were calculated. First, for each pair of judges the level of agreement was measured using Cohen's Kappa (1968). Further, an assessment was made of the level of agreement across all the judges. The common threshold for Cohen's Kappa is considered to be greater than .65 (e.g., Todd and Benbasat 1992). The second measurement was the inter-rater reliability as described in Moore and Benbasat (1991). This measure is calculated by comparing how many items have been placed in the target construct of two raters. As there is no established guideline for determining "good" levels of placement, the matrix can be used to identify potential problem areas. Again, after assessing every pair of judges, the inter-rater reliability was calculated across all the judges in that round. Table 5.3 offers an overview of both reliability measures for round one to four as well as the placement ratios for the specific constructs.

In summary, the qualitative pretest yielded interesting insights for the improvement of the items and very good results concerning the reliability measures. During the process the number of items for the constructs was reduced from roughly 100 to 74 and the wording of many items was refined. Especially the measurement instrument of perceived behavioral control was revisited and iterated a lot in the process.

As recommended for behavioral research, a seven-point Likert scale was chosen to measure most of the items. The exceptions were some of the control variables

Table 5.3 Results of the scale development in the qualitative pretest

Agreement measure	Judges	Round 1	Round 2	Round 3	Round 4
Cohen's kappa	A + B	.68	.88	.79	.88
	A + C	.64	.82	.86	.79
	A + D	.75	.82	.92	.88
	B + C	.73	.85	.79	.79
	B + D	.83	.82	.77	.85
	C + D	.81	.78	.88	.85
	Average	.74	.83	.84	.84
Raw agreement	A + B	.77	.91	.87	.93
	A + C	.76	.88	.90	.88
	A + D	.82	.88	.91	.93
	B + C	.81	.90	.86	.88
	B + D	.87	.90	.87	.93
	C + D	.86	.87	.91	.87
	Average	.81	.89	.89	.90
Placement ratios summary					
Intention		.86	1.00	1.00	1.00
Attitude		.84	.94	.97	.83
Usefulness		.90	.94	1.00	.97
Ease of use		.91	.91	.97	.91
Risk		.98	.95	.93	1.00
Behavioral control		.47	.66	.59	.69
Internal PLOC		.92	.86	.94	.94
External PLOC		.68	.93	.82	.93
Subjective norm		.72	.83	.75	.83

such as age, where the use of Likert scales would have been absurd. Likert scales are one of the most common item formats and have been applied frequently in behavioral research (Hinkin 1998).

5.2.3 *Stage III: Quantitative Pretest and Pilot Study*

The final part of the measurement scale development consisted out of two quantitative tests. One small quantitative pretest with a sample size of n = 20 and the quantitative pilot study with a final sample size of n = 110.

In the first small quantitative pretest the questionnaire was handed out to 30 experts i.e. employees of the energy supplier and researchers. Twenty completed questionnaires were returned and used for further evaluation. This final pretest consisted of the introduction and the 74 items that remained after the qualitative sorting procedures. Besides answering the questions, the participants were asked to comment on the items and the introduction. Afterwards, the item loadings were calculated using SPSS 20 and SmartPLS 2.0 M3 (Ringle et al. 2005). Then, the items with the lowest loadings and the most comments were trimmed resulting in a

40 item instrument (excluding single item constructs) that was tested in the larger pilot test. Further statistical tests were not conducted, as the small sample size would not have yielded statistically reliable results.

The pilot test was then conducted using an updated introduction and the 40 item instrument. The participants were recruited and invited by a professional market research company. 178 participants were recruited in Germany with 110 questionnaires used for the evaluation resulting in a response rate of 62 %. This pilot study was used to conduct several tests to establish the reliability of the measurement tool on the construct and indicator level. Further, the measurement tool was evaluated for construct validity with the main focus on convergent and discriminant validity. Also, the data allowed to quantitatively check for content validity by conducting an exploratory factor analysis for each construct as recommended by Krafft et al. (2005, p. 75). As requested, only one single underlying factor could be identified for each construct, thus supporting content validity. Finally, to check for nomological validity, some of the hypothesized relationships were tested to evaluate if they were in the predicted direction (Campbell 1960, p. 547).

To establish reliability, one has to distinguish between two kinds of quality criteria, the so called first generation and the second generation quality criteria. Whereas the first generation differentiates between measures for the reliability on construct and indicator level, the second generation measures the reliability holistically. Based on restrictive assumptions (e.g., assumption of one-dimensionality when calculating Cronbach's alpha), in transparent thresholds and the missing possibility to explicitly evaluate measurement errors, the first generation of quality criteria is often labeled as only partly eligible to evaluate the reliability of a measurement tool (Bagozzi and Phillips 1982; Gerbing and Anderson 1988; Homburg and Giering 1996). Despite these downsides, their use is encouraged especially in pretests and pilot studies, as they are excellent in identifying "bad" items. Moreover, the literature recommends the combined use of first and second generation criteria as the standard procedure to evaluate measurement models (e.g., Churchill 1979; Homburg and Giering 1996). Following these recommendations, the first and second generation criteria were evaluated in the quantitative pretest of this study. The following Table 5.4 shows an overview of the different first and second generation criteria and the respective thresholds recommended by the literature.

Following Churchill (1979, p. 68), Cronbach's alpha is ".. absolutely [. . .] the first measure one calculates to assess the quality of the instrument". Cronbach's alpha is based on the assumption that reflective items should be correlated. Therefore, the higher Cronbach's alpha, the higher is the internal consistency of the instrument. Values of Cronbach's alpha next to one can be seen as problematic as they can indicate that the items are too similar. This case is normally referred to as "empirical redundancy" (Robinson et al. 1991).

Besides this most prominent reliability measure, this study assesses the reliability of the measurement scale on the construct level using the inter-item correlation.

Table 5.4 First and second generation evaluation criteria

Criterion	Threshold	Source
First generation – construct level		
Cronbach's alpha	≥0.7	Nunnally (1978, p. 245)
Inter-item correlation	≥0.3	Robinson et al. (1991, p. 13)
First generation – indicator level		
Item-to-total correlation	≥0.5	Bearden et al. (1989, p. 475)
Second generation		
Indicator reliability	≥0.4	Bagozzi and Baumgartner (1994, p. 402)
	≥0.5	Chin (1998a)
Average variance extracted	≥0.5	Fornell and Larcker (1981, p. 46)
Composite reliability	≥0.6	Bagozzi and Yi (1988, p. 82)
	≥0.7	Hulland (1999)

Source: Based on Weiber and Mühlhaus (2010)

The inter-item correlation is used to check the item set of one-dimensionality. Again, this measure is only appropriate for reflective scales.

Finally, the item-to-total correlation was calculated to check if any of the items were inconsistent with the averaged behavior of the other items. The analysis is used to purify the scale of garbage items. A small correlation would indicate that an item is not measuring the same construct as the other items and should therefore be excluded from the measurement model.

The following Table 5.5 shows the Cronbach's alpha, inter-item and item-to-total correlation of the constructs and the respective items of the measurement model used in the pilot study.[1] It indicates that the recommended thresholds are easily met in most of the cases. The outlier-items (e.g., Int3, Att3, PBC3, IPLOC3, EPLOC3, PU4) were revisited and discussed with some of the judges from the qualitative study, as well as with some employees of the market research company collecting the data for the pretest. They were then rephrased and further iterated for the final field test.

The second generation criteria include the indicator reliability, the composite reliability and the average variance extracted (AVE).

Indicator reliability reveals the proportion of an indicator's variance that can be explained by the underlying latent variable. It is defined as the square of the correlation between a latent factor and that indicator (Bagozzi and Yi 1988). Using standardized factor loadings, the indicator reliability is calculated as squared factor loadings. The commonly requested explained proportion of an indicator's variance and is ranging between 50 % (Chin 1998a) and 40 % (Bagozzi and Baumgartner 1994). Additionally, the factor loadings of the items are often directly observed (Homburg and Giering 1996). 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

[1] IBM SPSS Statistics 20 was used to calculate the first generation criteria.

Table 5.5 First generation evaluation criteria in the quantitative pretest

Construct	Indicator	Item-to-total	Cronbach's alpha	Inter-item
Intention	Int1	.673	.718	.459
	Int2	.694		
	Int3	.282		
Attitude	Att1	.833	.763	.517
	Att2	.845		
	Att3	.312		
Perceived behavioral control	PBC1	.652	.735	.409
	PBC2	.710		
	PBC3	.203		
	PBC4	.596		
Subjective norm	SN1	.814	.931	.731
	SN2	.846		
	SN3	.699		
	SN4	.846		
	SN5	.885		
Internal PLOC	IPLOC1	.699	.868	.569
	IPLOC2	.810		
	IPLOC3	.444		
	IPLOC4	.732		
	IPLOC5	.761		
External PLOC	EPLOC1	.523	.753	.427
	EPLOC2	.776		
	EPLOC3	.252		
	EPLOC4	.703		
Perceived privacy risk	PPR1	.550	.815	.387
	PPR2	.383		
	PPR3	.712		
	PPR4	.598		
	PPR5	.468		
	PPR6	.517		
	PPR7	.663		
Perceived ease of use	PEOU1	.854	.860	.606
	PEOU2	.799		
	PEOU3	.747		
	PEOU4	.458		
Perceived usefulness	PU1	.693	.752	.431
	PU2	.518		
	PU3	.638		
	PU4	.294		

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, p. 198). Furthermore, some authors request that the factor loadings of all reflective items should be statistically significant at the $p < .05$ level (Homburg and Giering 1996, p. 12). As shown in Table 5.6, most of

Table 5.6 Factor loadings and indicator reliability for all items in the quantitative pretest

Construct	Indicator	Factor loading	Indicator reliability
Intention	Int1	$.91^{**}$	.84
	Int2	$.94^{**}$	.88
	Int3	$.44^{**}$	.19
Attitude	Att1	$.96^{**}$	.93
	Att2	$.97^{**}$	.93
	Att3	$.45^{**}$	.21
Perceived behavioral control	PBC1	$.89^{**}$	.78
	PBC2	$.88^{**}$	.78
	PBC3	$.30^{*}$	.09
	PBC4	$.84^{**}$	.71
Subjective norm	SN1	$.90^{*}$	.81
	SN2	$.89^{*}$	.79
	SN3	$.77^{*}$	.60
	SN4	$.92^{*}$	.84
	SN5	$.93^{*}$	.86
Internal PLOC	IPLOC1	$.80^{**}$	.65
	IPLOC2	$.89^{**}$	.79
	IPLOC3	$.52^{**}$	.27
	IPLOC4	$.82^{**}$	.67
	IPLOC5	$.90^{**}$	.81
External PLOC	EPLOC1	$.78^{**}$	.61
	EPLOC2	$.86^{**}$	.74
	EPLOC3	$.61^{**}$	.37
	EPLOC4	$.81^{**}$	.65
Perceived privacy risk	PPR1	$.73^{**}$	.53
	PPR2	$.67^{**}$	.44
	PPR3	$.66^{**}$	.44
	PPR4	$.76^{**}$	.57
	PPR5	$.62^{**}$	.38
	PPR6	$.55^{**}$	.30
	PPR7	$.78^{**}$	.62
Perceived ease of use	PEOU1	$.95^{**}$	.90
	PEOU2	$.93^{**}$	.86
	PEOU3	$.87^{**}$	.75
	PEOU4	$.63^{**}$	.40
Perceived usefulness	PU1	$.94^{**}$	.88
	PU2	$.65^{**}$	.42
	PU3	$.94^{**}$	.88
	PU4	$.31^{*}$	.09

Significance $^{*}p < 0.05$; $^{**}p < 0.01$)

the items tested in the pilot study exceed the stated threshold criteria for the indicator reliability, the factor loadings and their respective significance level.[2]

[2] The loadings, reliabilities and significances were calculated using SmartPLS Version 2.0 (M3). The significances were calculated using the bootstrapping algorithm with 110 cases and 1,000 samples.

Table 5.7 Composite reliability and AVE for all constructs in the quantitative pretest

Construct	Composite reliability	Average variance extracted
Intention	.828	.636
Attitude	.859	.690
Perceived behavioral control	.837	.588
Subjective norm	.946	.778
Internal PLOC	.895	.638
External PLOC	.852	.593
Perceived privacy risk	.859	.469
Perceived ease of use	.912	.727
Perceived usefulness	.823	.569

Using these criteria, the same outlier-items were identified, confirming the implications posed by the first generation criteria.

Finally, the evaluation of the reliability is completed by two measures on the construct level. The AVE of a construct indicates the average ratio of the variance of the items explained by the respective construct (Hair et al. 2006, p. 777). It ranges between values of 0 and 1 and the remaining share of the variance is attributed to the measurement error. Thus, literature demands that, on average, more variance is explained by the construct than by the measurement error, resulting in a common threshold for the AVE of >.5 (Fornell and Larcker 1981, p. 46). The composite reliability matches the indicator reliability on the construct level and, similar to the AVE, refers to the amount of variance of the items that is explained by the construct, not by the measurement error. Since the composite reliability is commonly higher than the AVE the requested threshold is >0.7 (Hulland 1999). Table 5.7 shows the composite reliabilities and the AVE of the constructs. It indicates that most values are well above the recommended thresholds. Again, outlier-constructs were revisited and their specification was discussed with some of the judges.

After assessing the reliability of the measurement scale, the construct validity was evaluated measuring convergent, discriminant and nomological validity. Convergent validity is established if the measurement with two maximal different methods yields the same results. As this criterion is normally hard to achieve it is seldom calculated. Instead, results are checked for the non-existence of convergent validity (Bagozzi et al. 1991, p. 425; Campbell and Fiske 1959). The non-existence can be checked by the following three criteria: First, each item should load significantly on their respective constructs (Gefen and Straub 2005). 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). If these three criteria are met, no evidence of the non-existence of convergent validity can be found and therefore convergent validity is considered as established. As shown in Tables 5.6 and 5.7 the measurement items met these requirements in most cases and therefore seem to offer a good basis for the final field test.

Discriminant validity is defined as “the dissimilarity in a measurement tool’s measurement of different constructs” (Götz et al. 2010, p. 696). It 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 (Gefen and Straub 2005, p. 93). Table 5.8 shows the cross loadings of the items in the pilot sample. Again, the already identified outliers were confirmed as critical items. 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 (Fornell and Larcker 1981; Gefen and Straub 2005). Consequently, Table 5.9 shows that the correlations between the constructs are indeed smaller than the respective square root of the AVE.

Nomological validity is the degree to which a construct behaves as it should within a system of related constructs (Bagozzi 1980). It is established by testing if the theoretical causal relationships between the constructs are confirmed and can be evaluated in a confirmatory factor analysis (Campbell 1960). Most of the theoretical causal relationships were confirmed in the pilot study, thus indicating that nomological validity is established in this study.

In summary, the evaluation of the measurement model provides excellent results. All critical evaluation criteria were assessed and most constructs and items comfortably exceed the majority of the requested thresholds. The few critical items that were identified in this pilot test were dropped or rephrased to ensure a frictionless procedure for the final field test. This indicates a sound basis for a valid and reliable measurement scale for the final field test of this study.

5.3 Measures

The following section briefly summarizes the origin of the measurement items used in the final field test. It further specifies the number of items for each construct measured. Some of the items had to be excluded in the final model due to low item loadings in one or both of the samples. To establish the same set of items in both model estimations, those items were trimmed in both samples.

Intention to use a technology was measured using an adapted three item scale from Davis et al.’s (1989). Attitude towards the technology was measured using a four item scale based on Davis et al.’s (1989) scale. The measures for perceived usefulness and perceived ease of use were taken from Venkatesh et al. (2003) and adapted to the area of smart metering. This study used a four item scale for perceived usefulness and a three item scale for perceived ease of use.

For the PLOC scales, this study used the measurement instruments suggested by Ryan and Connell (1989), which have been adapted to the IT-context by Malhotra et al. (2008). These abstract measures were then combined with some

Table 5.8 Crossloadings of all items in the quantitative pretest

	Int	Att	PBC	SN	IPLOC	EPLOC	PPR	PEOU	PU
Int1	.91	.66	.49	.15	.56	.42	−.34	.44	.52
Int2	.94	.69	.48	.22	.59	.60	−.35	.34	.50
Int3	.44	.23	.04	−.06	.27	.28	−.16	.02	.29
Att1	.70	.96	.43	.15	.47	.44	−.30	.32	.40
Att2	.71	.97	.46	.18	.47	.42	−.22	.31	.44
Att3	.27	.45	.07	.07	.25	.13	−.32	.08	.36
PBC1	.41	.40	.89	−.06	.27	.26	−.14	.68	.25
PBC2	.47	.38	.88	−.17	.30	.21	−.19	.71	.40
PBC3	.09	.10	.30	−.24	.09	.05	−.23	.27	.19
PBC4	.41	.37	.84	.05	.33	.23	−.38	.52	.26
SN1	.19	.18	−.07	.90	.30	.32	−.17	−.22	.14
SN2	.10	.09	−.10	.89	.19	.28	−.15	−.22	.07
SN3	.11	.14	−.15	.77	.12	.23	−.06	−.25	.16
SN4	.19	.18	−.03	.92	.33	.41	−.18	−.10	.11
SN5	.12	.11	−.10	.93	.23	.40	−.14	−.20	.07
IPLOC1	.50	.37	.21	.25	.80	.31	−.26	.24	.49
IPLOC2	.60	.41	.35	.20	.89	.46	−.44	.39	.53
IPLOC3	.29	.28	.14	.20	.52	.19	−.14	.11	.26
IPLOC4	.40	.41	.31	.32	.82	.41	−.37	.33	.44
IPLOC5	.61	.47	.31	.20	.90	.44	−.41	.34	.58
EPLOC1	.47	.35	.28	.27	.37	.78	−.40	.13	.26
EPLOC2	.36	.25	.12	.36	.37	.86	−.35	.06	.32
EPLOC3	.47	.43	.25	.21	.34	.61	−.16	.17	.17
EPLOC4	.37	.22	.09	.34	.33	.81	−.31	.08	.24
PPR1	−.25	−.26	−.29	−.13	−.22	−.27	.73	−.21	−.28
PPR2	−.31	−.21	−.22	.04	−.28	−.22	.67	−.16	−.35
PPR3	−.31	−.29	−.23	−.19	−.42	−.37	.66	−.17	−.27
PPR4	−.21	−.20	−.11	−.12	−.35	−.30	.76	−.14	−.35
PPR5	−.20	−.12	−.11	−.17	−.23	−.17	.62	−.15	−.29
PPR6	−.21	−.21	−.23	−.13	−.16	−.23	.55	−.09	−.11
PPR7	−.21	−.13	−.10	−.12	−.32	−.33	.78	−.22	−.36
PEOU1	.39	.31	.70	−.19	.36	.15	−.26	.95	.37
PEOU2	.39	.33	.69	−.15	.38	.14	−.21	.93	.37
PEOU3	.31	.20	.59	−.19	.25	.10	−.15	.87	.28
PEOU4	.19	.18	.50	−.24	.24	.14	−.22	.63	.17
PU1	.52	.45	.35	.12	.57	.29	−.35	.39	.94
PU2	.33	.23	.16	−.15	.26	.06	−.27	.18	.65
PU3	.55	.47	.35	.23	.63	.40	−.45	.31	.94
PU4	.08	.10	.13	−.06	.02	−.03	−.12	.18	.31

self-developed items to create a better fit to the energy context, resulting in a five item measurement scale for the internal PLOC, and a three item measurement instrument for the external PLOC.

To measure perceived behavioral control, the scale by Fishbein and Ajzen (1975) was used. This scale consisted of three items. Perceived privacy risk was

Table 5.9 Inter-construct correlation matrix for all variables (square root of AVE shown on diagonals)

Constructs	1	2	3	4	5	6	7	8	9
1. Intention	**.80**								
2. Attitude	.72	**.83**							
3. Perceived behavioral control	.49	.43	**.77**						
4. Subjective norm	.17	.17	−.09	**.88**					
5. Internal PLOC	.62	.49	.34	.29	**.80**				
6. External PLOC	.56	.43	.27	.38	.47	**.77**			
7. Perceived privacy risk	−.37	−.31	−.28	−.17	−.43	−.40	**.69**		
8. Perceived ease of use	.39	.31	.74	−.21	.37	.15	−.24	**.85**	
9. Perceived usefulness	.56	.47	.36	.13	.59	.32	−.43	.36	**.75**

measured with the instruments provided by Featherman and Pavlou (2003). Again, these items had to be adapted to better fit into the context of SMT, and the measurement instrument consisted of three items. The same holds true for the measurement scale of the subjective norm. Again, this study draws on the scales of Ajzen (1985, 1991). Further the scales for social influence (Venkatesh et al. 2012b) and introjected PLOC (Ryan and Connell 1989) were used to ensure a fit with the different influences in relation to environmental values. The final scale consisted of five items.

Finally, the specific energy related variables i.e., income, household size, age, willingness to pay for energy innovations, and the monthly electricity costs were measured using the standard items and clustered scales provided by the professional polling firm. The interest in new technology and the other items were measured using a seven point Likert Scale. Further details of the items are provided in Appendix 1.

5.4 Samples

As discussed earlier, the sample consisted of survey respondents in Germany only. 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 targets of the European Union (EU) which are formulated in the Directive 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. This target is broken down on the individual member states and results in a target of 18 % share of renewable energy within the German energy mix. 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 give the opportunity to steer demand directly by providing a price signal at the demand side, and making devices and humans take rational and price sensitive consumption decisions. Hence, one of the core concepts of the introduction of smart meters is to steer the demand according to shortages in supply or transmission by a price signal at the end-consumer. Given the above, that is, the ambitious targets in the share of renewable energy in the energy mix as well as the phase out of the nuclear power, and the expected congestion in the German transmission network, Germany is a particularly interesting region for an empirical investigation of the adoption of smart meters in private households.

The goal of this study was to draw on a sample of both users (adopters) and non-users (potential adopters) of SMT. As SMT is still in its infancy in Germany, and therefore hardly known to its citizens, it was essential to shortly illustrate the technology in order to establish a common technological understanding among all participants. Using an online survey had multiple advantages: (1) the possibility to add an introduction to smart metering technology, including pictures for virtualization, (2) the possibility to control if respondents actually read through the introduction or just skipped ahead, and (3) the possibility to address a high number of citizens to get a solid database to test the model.

5.4.1 Non-user Sample Characteristics

The sample of non-users, was collected in collaboration with a professional market research company that hosts a representative panel of German citizens. The recruitment process of the company ensured the representativeness of the sample.

Consequently, the non-user sample consisted of German citizens (co-)responsible for energy decisions in their own household. Overall, 3,002 panel members all over Germany were invited via email to participate in the survey in the course of 4 weeks. To ensure that only those participants who invested enough time to read and answer all survey questions reasonably, participants with uncompleted or unreliable questionnaires (i.e., answers exhibiting certain unlikely response patterns) and questionnaires with implausibly short handling time were removed from the sample. 932 completed questionnaires were used for the further analysis resulting in a response rate of 31.05 %.[3] The percentage of missing values in the final data set is

[3] As this panel consists of German citizens who form a representative subsample of the German population and are especially recruited for this panel, the response rate is higher than that of the user sample.

ranging between 0 % and 2.5 % per variable and therefore far below the recommended thresholds of 10–20 % (Hair et al. 2006). The participants' age was ranging from 20 to 80 years (mean: 49.42 years), with 50.7 % being males and 49.3 % being female respondents.

5.4.2 User Sample Characteristics

Through the collaboration with one of the largest SMT providers in Germany, a representative sample of SMT users could be collected. The company – a major Southern-German energy provider – gave access to its customer database, from which a random sample of 10,000 households was drawn, who were invited via email to participate in an online-survey. Again, uncompleted questionnaires and questionnaires with implausibly short handling time were removed from the sample. 933 completed questionnaires were used for the further analysis resulting in a response rate of 11.67 %. The percentage of missing values in the final data set is ranging between 0 % and 4.8 % per variable. 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 percentage of male respondents in the user sample can be explained by the fact that the majority of early adopters of SMT at this energy provider were multi-person households ($M_{\text{number of occupants}} = 3.24$). This percentage is reasonable since the amount of possible energy savings and the amount of shiftable loads is correlated with energy use, which is higher for multi-person households. Addressing the person (co-)responsible for adopting SMT resulted in mostly male respondents in the survey.

5.4.3 Non Response Bias

Given the response rate and the approach applied to collect the two samples investigated, this study verified that the final samples were adequate. Thus, the final sample was checked to make sure that it did not suffer from the threat of a potential non-response bias and that qualified responses had been obtained from the participants (Rogelberg and Stanton 2007). First, no significant differences when comparing construct means for early and late respondents were observed. Furthermore, early and late respondents did not differ with respect to their mean ratings for the intention to adopt/continue using SMT. Thus, a non-response bias did not pose a problem with the data.

Second, participants' personal interest in new technologies was assessed through an item at the very end of the questionnaire: "What is your interest in new technologies?" (measured on seven-point Likert-type scales anchored by 1 = "very low" and 7 = "very high"). The mean score on this item was 5.21 (non-users) and 5.83 (users) for interest in new technologies. These results show that the participants were sufficiently knowledgeable and sufficiently involved to participate in this study.

Chapter 6
Analysis

Whereas Chap. 5 mainly described the preliminary steps of the survey, this chapter comprehensively explains the several steps analyzing the collected data. This chapter is divided into three subsections: Sect. 6.1 reports the evaluation criteria and results of the non-user sample. Section 6.2 describes the same for the user sample. In Sect. 6.3 the results of an exploratory comparison of both samples are shown.

In this study 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, p. 198). With respect to the evaluation and reporting criteria, this study follows the recommendations by Gefen et al. (2011) who recently published an updated guideline on the reporting standards for structural equation modeling.

6.1 Results of the Non-user Sample

The following section summarizes the results of the final non-user sample. Following the common recommendations in literature, the evaluation process is split into two parts (e.g., Anderson and Gerbing 1988; Chin 2010). First the evaluation of the measurement model will be outlined, followed by the evaluation of the structural model. As Chin (2010, pp. 669–670) explains: "The logic is that if you are not confident that the measures are representing the constructs of interest, there is little reason to use them to test the theoretical model in question. But if the measures are shown to be adequate, then the validity and results of the theoretical model (i.e., structural portion) is then presented."

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6.1.1 Measurement Model Evaluation

In assessing the validity of the instruments using the PLS-approach, this study relied on prior/recent research using PLS (e.g. Bhattacherjee and Premkumar 2004; Brown and Venkatesh 2005; Chin 1998a, 2001; Gefen and Straub 2005; Hulland 1999). Therefore, this study tested the reflective measures employed by checking for (1) content validity, (2) convergent validity and (3) discriminant validity.

Content validity reflects the degree to which items in an instrument reflect the content universe to which the instrument will be generalized (e.g., Cronbach and Thorndike 1971; Rogers 1995b). It is generally established trough literature reviews or expert judges/panels as already described in Sect. 5.2 (Boudreau et al. 2001).

Convergent validity is defined as the extent to which multiple attempts to measure a variable, using varying methods, are in agreement (Bagozzi and Phillips 1982). In other words, measures of constructs that theoretically should be related to each other are, in fact, observed to be related to each other. Prior research suggests that convergent validity of items can be established by satisfying the following three criteria: First, each item should load significantly on their respective constructs (Gefen and Straub 2005). As stated before, 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, p. 198). 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). Table 6.1 highlights that each of the items loaded significantly on their respective construct, and that all the items had loadings above the requested .70 mark.

Further, as Table 6.2 highlights, the composite reliabilities of all the constructs are above .70 and the AVEs of all the constructs are above the threshold value of .50. This established the convergent validity in the non-user sample in this study.

Discriminant validity is defined as "the dissimilarity in a measurement tool's measurement of different constructs" (Götz et al. 2010, p. 696). It indicates that measures of constructs that theoretically should not be related to each other are, in fact, not related to each other. Gefen and Straub (2005, p. 93) 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 (see Appendix 3). 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 (Fornell and Larcker 1981; Gefen and Straub 2005). Table 6.3 further 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

Table 6.1 Item mean, standard deviation, loadings and mean loadings for the non-user sample

Item	Mean	Standard deviation	Item loading	Mean loading[a]
Int1	4.95	1.84	.92	.92
Int2	4.54	1.91	.95	.95
Int3	4.44	1.89	.95	.95
Att1	5.53	1.66	.95	.95
Att2	5.46	1.68	.94	.94
Att3	5.92	1.64	.80	.80
Att4	5.39	1.76	.94	.94
PBC1	4.91	1.80	.86	.86
PBC2	4.28	1.76	.88	.88
PBC4	4.32	2.05	.74	.74
SN1	2.40	1.68	.73	.72
SN2	2.23	1.53	.84	.84
SN3	2.46	1.67	.76	.75
SN4	2.55	1.60	.87	.86
SN5	2.37	1.58	.87	.86
IPLOC1	5.28	1.80	.82	.82
IPLOC2	4.69	1.93	.88	.88
IPLOC3	4.30	1.88	.76	.75
IPLOC4	4.03	1.95	.79	.79
IPLOC5	4.85	1.88	.88	.88
EPLOC1	4.01	1.93	.79	.79
EPLOC2	3.82	1.96	.75	.75
EPLOC5	5.75	1.72	.84	.84
PPR1	4.49	1.97	.79	.78
PPR2	4.30	2.03	.84	.84
PPR7	4.78	1.88	.72	.71
PEOU1	5.00	1.57	.89	.89
PEOU2	4.88	1.60	.87	.87
PEOU4	4.44	1.68	.87	.87
PU1	5.71	1.55	.93	.93
PU2	5.24	1.66	.90	.90
PU3	5.57	1.58	.92	.92
PU4	5.72	1.52	.91	.91
Income	4.27	1.39	1	1
Household size	2.40	1.13	1	1
Age	4.15	1.23	1	1
Electricity costs	3.87	1.36	1	1
Interest tech.	5.21	1.21	1	1
Willingness	3.44	1.00	1	1

[a]Mean item loadings were calculated using the bootstrap algorithm with 200 subsamples; all mean loadings are significant at $p < .01$

diagonal, with the off-diagonal cells reflecting the correlation between that construct and other constructs). This confirmed the relative discriminant validity of the instrument of this study in the non-user sample.

Table 6.2 Composite reliability and average variance extracted in the non-user sample (composite reliabilities and AVEs for the socio-demographic variables are not reported as they equal one for single-item constructs)

Construct	Composite reliability	Average variance extracted
Intention	.960	.889
Attitude	.951	.829
Perceived behavioral control	.869	.691
Subjective norm	.907	.662
Internal PLOC	.915	.684
External PLOC	.838	.633
Perceived privacy risk	.823	.609
Perceived ease of use	.910	.771
Perceived usefulness	.954	.839

In summary the evaluation of the measurement model based on the non-user sample provides excellent results. All critical evaluation criteria are met for the non-user sample and all constructs and items exceed the requested criteria. This indicated that the measurement scale fits and provides a sound basis for the evaluation of the structural model.

6.1.2 Structural Model Evaluation

In the next phase of the analysis, the significance and strength of the hypothesized relationships were examined. To calculate the statistical significance, the bootstrapping routine of SmartPLS was used. The number of bootstrapping samples was 5,000 as recommended by Hair et al. (2011).

Overall, the model was able to explain about 65.2 % of the variance of individuals' intention to adopt SMT and is therefore comfortably exceeding the prescribed threshold (40 %) for the explained variance R^2 of dependent variables as recommended by Homburg und Baumgartner (1995, p. 364). Further, the identified relations explain 58 % of the variance of attitude, 47 % of the variance of perceived usefulness, 17 % of the variance of perceived ease of use and 7 % of perceived behavioral control's variance extracted.

Regarding the significance of the hypothesized relationships, 18 of the 23 hypothesized effects have been found to be significant. In the following the results of the structural model evaluation are described:

First, hypothesis 1 suggested that individuals' attitudes toward SMT would have a positive influence on the individuals' intention to adopt the technology. This prediction was supported ($\beta = .380$, $p < .01$). Further, hypothesis 2, which suggested that subjective norm would have a positive influence on the individual's intention to adopt that technology, was also supported. This predicted influence was weak but significant ($\beta = .048$, $p < .05$). Hypothesis 3 suggested that the perceived behavioral control would have a positive influence on the individuals' intention to

Table 6.3 Inter-construct correlation matrix for the non-user sample (square root of AVE shown on diagonals)

Constructs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Intention	**.94**														
2. Attitude	.73	**.91**													
3. Perceived behavioral control	.31	.21	**.83**												
4. Subjective norm	.25	.16	.08	**.81**											
5. Internal PLOC	.73	.70	.25	.32	**.83**										
6. External PLOC	.61	.63	.13	.31	.68	**.80**									
7. Perceived privacy risk	−.34	−.34	−.20	−.18	−.36	−.27	**.78**								
8. Perceived ease of use	.41	.37	.63	.10	.41	.29	−.18	**.88**							
9. Perceived usefulness	.62	.64	.26	.15	.65	.57	−.24	.39	**.92**						
10. Income	.06	.02	.10	−.07	.02	−.04	−.03	.08	.05	**1**					
11. Household size	.04	.02	.00	−.03	.02	−.02	.05	−.01	.04	.36	**1**				
12. Age	−.04	.01	−.05	.08	.03	.09	−.09	−.09	−.08	.04	−.28	**1**			
13. Electricity costs (monthly)	−.01	.00	.01	−.03	.00	.02	.00	−.02	.00	.26	.37	.09	**1**		
14. Interest in new tech.	.18	.11	.34	−.01	.14	.07	−.07	.34	.10	.07	.01	.00	.04	**1**	
15. Willingness to pay for E.I.	.08	.03	.03	.07	.11	.09	−.08	.05	.05	.23	.09	.05	.11	.13	**1**

adopt SMT. This prediction was supported ($\beta = .093$, $p < .01$). Consistent with hypothesis 4, results indicated that that consumers' perceived usefulness would have a positive influence on the individual's attitude toward SMT ($\beta = .264$, $p < .01$). Further, the effect of perceived ease of use on the individuals' attitudes toward SMT was positive as proposed by hypothesis 5 ($\beta = .063$, $p < .05$). Also, hypothesis 6 suggesting that perceived ease of use would have a positive effect in perceived usefulness was supported ($\beta = .144$, $p < .01$).

Drawing on the SDT and OIT, hypothesis 7a predicted that the internal PLOC would have a positive influence on the perceived ease of use. Results supported this prediction ($\beta = .403$, $p < .01$). Further, regarding the effect of external PLOC on perceived ease of use hypothesis 7b predicted that this influence would be positive as well. This was not supported ($\beta = .015$, $p > .10$). Thus, while hypothesis 7a is supported, hypothesis 7b has to be rejected. Hypothesis 8a predicted a positive effect of the internal PLOC on perceived usefulness. This prediction was supported ($\beta = .422$, $p < .01$). Also, hypothesis 8b, which regards the effect of external PLOC on perceived usefulness was supported. The predicted positive relationship was confirmed out of the data used in this study ($\beta = .240$, $p < .01$).

Concerning the role of users' PLOC in relation to the TPB constructs, hypothesis 9a predicted that the internal PLOC would have a positive influence on individuals' attitudes toward SMT. Results supported this prediction ($\beta = .346$, $p < .01$). Further, hypothesis 9b predicted that the internal PLOC would have a positive influence on the perceived behavioral control. This too was supported ($\beta = .308$, $p < .01$). Hypothesis 9c predicted a positive effect of the internal PLOC on the individuals' intention to adopt SMT. This prediction was supported as well ($\beta = .329$, $p < .01$). Concerning the effects of external PLOC on the TPB constructs, hypothesis 10a, which predicted that the external PLOC would have a positive influence on the individuals' attitudes toward SMT was supported ($\beta = .228$, $p < .01$). Hypothesis 10b, which predicted a positive influence of external PLOC on perceived behavioral control was not supported. Instead of the hypothesized positive effect, external PLOC had a marginally significant negative effect on individuals' attitudes ($\beta = -.082$, $p < .10$). Finally, as suggested by hypothesis 10c, results showed a positive effect of external PLOC on the individuals' intention to adopt SMT ($\beta = .112$, $p < .01$).

Concerning privacy and the socio-demographic variables, hypothesis 11 predicted that perceived privacy risk would have a negative effect on the individuals' intention to adopt SMT. This was not supported ($\beta = -.035$, $p > .10$). Regarding the set of socio-demographic variables, income had a weak effect on the individuals' intention to adopt SMT ($\beta = .046$, $p < .05$), supporting hypothesis 12a. Hypothesis 12b predicted a positive relationship between the household size and the individuals' intention to adopt SMT. This was not supported ($\beta = .009$, $p > .10$). Hypothesis 12c stated that the individual's age would negatively affect the intention to adopt SMT. This was supported ($\beta = -.062$, $p < .01$). Further, hypothesis 12d predicted a positive effect of average monthly electricity costs on the individuals' intention to adopt SMT. This was not supported ($\beta = -.022$, $p > .10$). Consistent with hypothesis 12e, results indicated that the

Table 6.4 Results of model estimation in the non-user sample

#	Path	Path coefficient	Significance (two-tailed)
H1	Consumers' attitudes → Consumers' intentions	.380	$p < .01$
H2	Subjective norm → Consumers' intentions	.048	$p < .05$
H3	Perceived behavioral control → Consumers' intentions	.093	$p < .01$
H4	Perceived usefulness → Consumers' attitudes	.264	$p < .01$
H5	Perceived ease of use → Consumers' attitudes	.063	$p < .05$
H6	Perceived ease of use → Perceived usefulness	.144	$p < .01$
H7a	Internal PLOC → Perceived ease of use	.403	$p < .01$
H7b	External PLOC → Perceived ease of use	.015	$p > .10$
H8a	Internal PLOC → Perceived usefulness	.422	$p < .01$
H8b	External PLOC → Perceived usefulness	.240	$p < .01$
H9a	Internal PLOC → Consumers' attitudes	.346	$p < .01$
H9b	Internal PLOC → Perceived behavioral control	.308	$p < .01$
H9c	Internal PLOC → Consumers' intentions	.329	$p < .01$
H10a	External PLOC → Consumers' attitudes	.228	$p < .01$
H10b	External PLOC → Perceived behavioral control	−.082	$p < .10$
H10c	External PLOC → Consumers' intentions	.112	$p < .01$
H11	Perceived privacy risk → Consumers' intentions	−.035	$p > .10$
H12a	Income → Consumers' intentions	.046	$p < .05$
H12b	Household size → Consumers' intentions	.009	$p > .10$
H12c	Age → Consumers' intentions	−.062	$p < .01$
H12d	Electricity costs → Consumers' intentions	−.022	$p > .10$
H12e	Interest in new technologies → Consumers' intentions	.050	$p < .05$
H12f	Willingness to pay for E.I. → Consumers' intentions	.000	$p > .10$

interest in new technologies would have a positive impact on the individuals' intention to adopt SMT ($\beta = .050$, $p < .05$). Finally, hypothesis 12f had to be rejected. There was no significant relationship between the willingness to pay for energy innovations and the individuals' intention to adopt SMT ($\beta = .000$, $p > .10$).

Results of the path analysis, including the path coefficients, and path significances for each endogenous variable are summarized in Table 6.4.

Based on the variance explained R^2 of the dependent variable, another characteristic of the different paths can be evaluated. The effect size f^2 measures the influence of an independent variable on the dependent variable and is computed as depicted in Fig. 6.1:

Therefore to calculate the effect size, the variance explained of the dependent variable is determined once using the original model and once using a modified model depending on which effect size is calculated. Table 6.5 offers an overview of the effect sizes of the main constructs used in this study. Results indicate that attitude has the strongest influence on the intention to adopt SMT followed by

Fig. 6.1 Effect size formula

$$\text{Effect size: } f^2 = \frac{R^2_{incl} - R^2_{excl}}{1 - R^2_{incl}}$$

Table 6.5 Effect size of independent variables on the dependent variable in the non-user sample

Construct (with direct influence on intentions)	Relation	Effect size (f^2)
Attitude	Attitude → Intention	.186
Subjective norm	Subjective norm → Intention	.005
Perceived behavioral control	Perceived behavioral control → Intention	.019
Internal PLOC	Internal PLOC → Intention	.114
External PLOC	External PLOC → Intention	.016
Perceived privacy risk	Perceived privacy risk → Intention	.002

internal PLOC, perceived behavioral control and external PLOC. The weak influence by subjective norm and the non-significant path of privacy risk, are well below the .02 threshold, confirming the previous findings for these constructs (Chin 1998b, p. 317). Further, following the reporting recommendations of Gefen et al. (2011), the effect size f^2 of the saturated model compared with the theoretical model was calculated (Chin et al. 2003; Cohen 1988). The analysis indicated no change in the significance of the hypothesized paths, and the calculation of the effect size being below .02 ($f^2 = .015$) confirmed no substantial effects through the added paths (perceived ease of use → intention, perceived usefulness → intention) (Chin 1998b, p. 317).

Another evaluation criterion is the Stone-Geisser criterion (Geisser 1975; Stone 1974). It is used to assess the predictive relevance of a structural model and is calculated using the formula illustrated in Fig. 6.2 (Chin 1998b, p. 317).

The predictive relevance is then calculated by omitting some data points from the sample and comparing the predicted values out of the model with the real ones (Chin 1998b). The omission distance D describes the distance between the respective data points. In the literature the omission distance is commonly recommended to be 7 but should not be a divisor of the case size to avoid deleting the same items in every case. During the first iteration, the first omitted data point is the data for indicator 1 in case one in the sample, followed by the 1 + D data point, followed by the 2xD + 1 data point and so on until the end of the data set is reached. Based on the estimates of the structural model, these omitted data points are then predicted and compared to the true data points. Out of the sum of the squared differences between the true and predicted data points, the predictive error E_1 is calculated. Further, O_1 is calculated from the squared differences between the predicted and the mean values of the remaining data set. This procedure is the repeated starting at the second data point in the sample, i.e. the second indicator in the first case. After the D iteration the process stops as each data point has once been deleted. Positive values of Q^2 indicate a good predictive relevance of the structural model. Values equal 0 or below indicate that a simple mean prediction would lead to better results

$$\text{Stone-Geisser test criterion: } Q^2 = 1 - \frac{\sum_D E_D}{\sum_D O_D}$$

Fig. 6.2 Stone-Geisser test criterion formula

than the structural model-based prediction. It is important to note that this criterion is only meaningful for reflective data sets (Herrmann et al. 2006, p. 58).

The Q^2 value for the non-user sample in this study was calculated following the recommendations of Chin (1998b, p. 318), using the SmartPLS blindfolding procedure with an omitting distance of 7. The results showed a Stone-Geisser criterion of 0.57 and therefore being well above the threshold of 0 and hence confirming the validity of the structural model (Chin 1998b; Fornell and Bookstein 1982, p. 449).

Finally, the recommended procedural and statistical remedies by Podsakoff et al. (2003) to minimize and control for common method bias were applied in this study. 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 general factor apparent in the unrotated factor solution indicating that common method variance was not a problem. The results showed a .302 variance explained and is therefore well below the recommended .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.

In summary, these results yield confidence for the model's validity and provide clear support for most of the established hypotheses with exception for hypotheses 7b, 11, 12b, 12d and 12f being not significant in the non-user sample. The negative effect of EPLOC on perceived behavioral control was contrary to the suggested effect of hypothesis 10b. Amongst others, these findings will be further discussed in Chap. 7.

6.2 Results of the User Sample

The following section summarizes the evaluation of the user sample. Again, first the measurement and then the structural model is evaluated.

6.2.1 Measurement Model Evaluation

Again building on prior/recent research using PLS (e.g. Bhattacherjee and Premkumar 2004; Brown and Venkatesh 2005; Chin 1998a, 2001; Gefen and Straub 2005; Hulland 1999), this study tested the reflective measures employed by checking for (1) content validity, (2) convergent validity and (3) discriminant validity in the user sample.

As shown in Sect. 5.2, content validity was established through the literature review and expert judges/panels (Boudreau et al. 2001).

To evaluate convergent validity in the user sample, the data was again checked for the following three criteria: First, each item should load significantly on their 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, p. 198). 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). Table 6.6 highlights that all items loaded significantly on their respective construct and that most of the items had loadings of .70 or higher. To ensure comparability between both, the user and the non-user sample, the same set of items was employed for both model evaluations resulting in some items with loadings below .70 in the user sample. This resulted in very low loadings for the external PLOC construct.

Further, as Table 6.7 highlights, the composite reliabilities of most of the constructs are over .70 and the AVEs of most of the constructs are over the threshold value of .50. Again external PLOC has to be mentioned as outlier-construct in this sample due to the low loadings of the EPLOC1 and EPLOC2 item. Still, this established the convergent validity in the user sample in this study.

Again this study followed the approach of Gefen and Straub (2005), who 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 (see Appendix 4). 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 (Fornell and Larcker 1981; Gefen and Straub 2005). Table 6.8 further 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 the instrument of this study in the user sample.

In summary the evaluation of the measurement model based on the user sample provides excellent results as well. All critical evaluation criteria are met for the user sample and all constructs and items exceed the requested criteria. This indicated that the measurement scale fits and provides a sound basis for the evaluation of the structural model.

Table 6.6 Item mean, standard deviation, loadings and mean loadings for the user sample

Item	Mean	Standard deviation	Item loading	Mean loading[a]
Int1	5.54	1.57	.87	.87
Int2	4.81	1.75	.91	.91
Int3	4.57	1.81	.88	.88
Att1	5.97	1.47	.93	.93
Att2	5.94	1.48	.93	.93
Att3	6.25	1.50	.59	.58
Att4	5.93	1.55	.94	.94
PBC1	5.15	1.70	.91	.91
PBC2	4.66	1.62	.90	.90
PBC4	4.63	1.72	.80	.80
SN1	2.08	1.53	.84	.75
SN2	2.01	1.56	.70	.61
SN3	2.31	1.71	.81	.72
SN4	1.85	1.33	.79	.70
SN5	1.77	1.26	.83	.73
IPLOC1	5.31	1.71	.68	.68
IPLOC2	5.56	1.64	.86	.86
IPLOC3	4.62	1.80	.65	.65
IPLOC4	4.91	1.78	.79	.79
IPLOC5	5.32	1.59	.86	.85
EPLOC1	3.69	1.93	.56	.56
EPLOC2	2.05	1.38	.23	.23
EPLOC5	5.10	1.89	.96	.96
PPR1	3.46	1.95	.59	.56
PPR2	3.43	1.95	.60	.57
PPR7	3.84	1.54	.91	.91
PEOU1	5.03	1.65	.91	.91
PEOU2	5.00	1.56	.90	.90
PEOU4	4.95	1.66	.91	.91
PU1	6.01	1.33	.91	.90
PU2	5.30	1.61	.84	.84
PU3	5.78	1.44	.91	.91
PU4	5.94	1.40	.87	.87
Income	5.04	1.13	1	1
Household size	3.06	1.22	1	1
Age	4.64	0.97	1	1
Electricity costs	4.60	1.16	1	1
Interest tech.	5.83	1.14	1	1
Willingness	3.84	1.02	1	1

[a]Mean item loadings were calculated using the bootstrap algorithm with 200 subsamples; all mean loadings are significant at $p < .01$

Table 6.7 Composite reliability and average variance extracted in the user sample (composite reliabilities and AVEs for the socio-demographic variables are not reported as they equal one for single-item constructs)

Construct	Composite reliability	Average variance extracted
Intention	.919	.791
Attitude	.918	.742
Perceived behavioral control	.904	.760
Subjective norm	.895	.631
Internal PLOC	.880	.597
External PLOC	.643	.432
Perceived privacy risk	.751	.513
Perceived ease of use	.933	.822
Perceived usefulness	.935	.782

6.2.2 Structural Model Evaluation

Again, the next phase of the analysis consisted of evaluating the significance and strength of the hypothesized relationships. In accordance with the non-user data, to calculate the statistical significance, the bootstrapping routine of SmartPLS was used. The number of bootstrapping samples was 5,000 as recommended by Hair et al. (2011).

Overall, the model was able to explain about 46.8 % of the variance of individuals' intention to adopt SMT and is therefore exceeding the prescribed threshold (40 %) for the explained variance R^2 of dependent variables as recommended by Homburg und Baumgartner (1995, p. 364). As often seen in research comparing non-user and user samples, the variance explained was lower than the one in the non-user case (see Brown et al. 2012 for an overview). Moreover, the model could explain 32 % of the variance extracted of attitude, 43 % of perceived usefulness, 18 % of perceived ease of use and 14 % of perceived behavioral control.

Regarding the significance of the hypothesized relationships, 14 of the 23 hypothesized effects have been found to be significant. In the following the results of the structural model evaluation are described:

First, hypothesis 1 suggested that individuals' attitudes toward SMT would have a positive influence on the individuals' intention to adopt the technology. This prediction was supported ($\beta = .326$, $p < .01$). Further, hypothesis 2, which suggested that subjective norm would have a positive influence on the individual's intention to adopt that technology, was not supported. This predicted influence was not significant ($\beta = .021$, $p > .10$). Hypothesis 3 suggested that the perceived behavioral control would have a positive influence on the individuals' intention to adopt SMT. This prediction was supported ($\beta = .202$, $p < .01$). Consistent with hypothesis 4, results indicated that that consumers' perceived usefulness would have a positive influence on the individual's attitude toward SMT ($\beta = .233$, $p < .01$). Further, the effect of perceived ease of use on the individuals' attitudes

Table 6.8 Inter-construct correlation matrix for the user sample (square root of AVE shown on diagonals)

Constructs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Intention	**.89**														
2. Attitude	.56	**.86**													
3. Perceived behavioral control	.42	.32	**.87**												
4. Subjective norm	.05	−.09	−.03	**.79**											
5. Internal PLOC	.56	.51	.37	.16	**.77**										
6. External PLOC	.34	.25	.13	.22	.41	**.66**									
7. Perceived privacy risk	−.18	−.22	−.19	−.07	−.27	−.19	**.72**								
8. Perceived ease of use	.52	.35	.71	−.05	.43	.17	−.16	**.91**							
9. Perceived usefulness	.54	.48	.44	.01	.59	.34	−.27	.49	**.88**						
10. Income	.01	.08	.08	−.15	−.03	−.10	.04	.09	−.01	**1**					
11. Household size	−.12	−.08	−.03	−.03	−.09	−.15	.05	−.03	−.08	.19	**1**				
12. Age	−.03	−.01	−.04	.12	.01	.08	−.03	−.11	−.05	−.11	−.35	**1**			
13. Electricity costs (monthly)	−.06	.01	−.03	−.06	−.03	−.02	−.01	−.08	−.07	.17	.27	−.02	**1**		
14. Interest in new tech.	.17	.14	.32	.07	.25	.02	−.04	.27	.13	.12	−.07	.07	.08	**1**	
15. Willingness to pay for E.I.	.13	.12	.12	.04	.16	.06	−.03	.10	.12	.14	.01	.04	.03	.15	**1**

toward SMT was positive as proposed by hypothesis 5 ($\beta = .094$, $p < .05$). Also, hypothesis 6 suggesting that perceived ease of use would have a positive effect in perceived usefulness was supported ($\beta = .300$, $p < .01$)

Drawing on the SDT and OIT, hypothesis 7a predicted that the internal PLOC would have a positive influence on the perceived ease of use. Results supported this prediction ($\beta = .428$, $p < .01$). Further, regarding the effect of external PLOC on perceived ease of use hypothesis 7b predicted that this influence would be positive as well. This was not supported ($\beta = -.004$, $p > .10$). Thus, while hypothesis 7a is supported, hypothesis 7b has to be rejected. Hypothesis 8a predicted a positive effect of the internal PLOC on perceived usefulness. This prediction was supported ($\beta = .406$, $p < .01$). Also, hypothesis 8b, which regards the effect of external PLOC on perceived usefulness was supported. The predicted positive relationship was confirmed out of the data used in this study ($\beta = .128$, $p < .01$).

Concerning the role of users' PLOC in relation to the TPB constructs, hypothesis 9a predicted that the internal PLOC would have a positive influence on individuals' attitudes toward SMT. Results supported this prediction ($\beta = .328$, $p < .01$). Further, hypothesis 9b predicted that the internal PLOC would have a positive influence on the perceived behavioral control. This too was supported ($\beta = .388$, $p < .01$). Hypothesis 9c predicted a positive effect of the internal PLOC on the individuals' intention to adopt SMT. This prediction was supported as well ($\beta = .274$, $p < .01$). Concerning the effects of external PLOC on the TPB constructs, hypothesis 10a, which predicted that the external PLOC would have a positive influence on the individuals' attitudes toward SMT was not supported ($\beta = .022$, $p > .10$). Hypothesis 10b, which predicted a positive influence of external PLOC on perceived behavioral control was not supported. Instead of the hypothesized positive effect, external PLOC had non-significant negative effect on individuals' attitudes ($\beta = -.032$, $p < .10$). Finally, as suggested by hypothesis 10c, results showed a positive effect of external PLOC on the individuals' intention to adopt SMT ($\beta = .120$, $p < .01$).

Concerning privacy and the socio-demographic variables, hypothesis 11 predicted that perceived privacy risk would have a negative effect on the individuals' intention to adopt SMT. This was not supported ($\beta = -.030$, $p > .10$). Regarding the set of socio-demographic variables, income had a weak non-significant effect on the individuals' intention to adopt SMT ($\beta = .002$, $p > .10$), rejecting hypothesis 12a. Hypothesis 12b predicted a positive relationship between the household size and the individuals' intention to adopt SMT. The data showed a weak negative effect, rejecting this hypothesis as well ($\beta = -.061$, $p < .05$). Hypothesis 12c stated that the individual's age would negatively affect the intention to adopt SMT. This was supported ($\beta = -.060$, $p < .05$). Further, hypothesis 12d predicted a positive effect of average monthly electricity costs on the individuals' intention to adopt SMT. This was not supported ($\beta = -.032$, $p > .10$). Rejecting hypothesis 12e, results did not indicate any significant effect of the interest in new technologies on the individuals' intention to adopt SMT ($\beta = -.012$, $p > .10$). Finally, hypothesis 12f had to be rejected. There was no

Table 6.9 Results of model estimation in the user sample

#	Path	Path coefficient	Significance (two-tailed)
H1	Consumers' attitudes → Consumers' intentions	.326	$p < .01$
H2	Subjective norm → Consumers' intentions	.021	$p > .10$
H3	Perceived behavioral control → Consumers' intentions	.202	$p < .01$
H4	Perceived usefulness → Consumers' attitudes	.233	$p < .01$
H5	Perceived ease of use → Consumers' attitudes	.094	$p < .05$
H6	Perceived ease of use → Perceived usefulness	.300	$p < .01$
H7a	Internal PLOC → Perceived ease of use	.428	$p < .01$
H7b	External PLOC → Perceived ease of use	−.004	$p > .10$
H8a	Internal PLOC → Perceived usefulness	.406	$p < .01$
H8b	External PLOC → Perceived usefulness	.128	$p < .01$
H9a	Internal PLOC → Consumers' attitudes	.328	$p < .01$
H9b	Internal PLOC → Perceived behavioral control	.388	$p < .01$
H9c	Internal PLOC → Consumers' intentions	.274	$p < .01$
H10a	External PLOC → Consumers' attitudes	.022	$p > .10$
H10b	External PLOC → Perceived behavioral control	−.032	$p > .10$
H10c	External PLOC → Consumers' intentions	.115	$p < .01$
H11	Perceived privacy risk → Consumers' intentions	.030	$p > .10$
H12a	Income → Consumers' intentions	.002	$p > .10$
H12b	Household size → Consumers' intentions	−.061	$p < .05$
H12c	Age → Consumers' intentions	−.056	$p < .05$
H12d	Electricity costs → Consumers' intentions	−.032	$p > .10$
H12e	Interest in new technologies → Consumers' intentions	−.016	$p > .10$
H12f	Willingness to pay for E.I. → Consumers' intentions	.023	$p > .10$

significant relationship between the willingness to pay for energy innovations and the individuals' intention to adopt SMT ($\beta = .023$, $p > .10$).

Results of the path analysis, including the path coefficients, and path significances for each endogenous variable are summarized in Table 6.9.

As in the non-user sample, the following Table 6.10 offers an overview of the effect sizes of the main constructs used in this study. Results indicate that attitude has the strongest influence on the intention to adopt SMT followed by internal PLOC, perceived behavioral control and external PLOC. Again, the non-significant paths by subjective norm and privacy risk are well below the .02 threshold, confirming the previous findings for these constructs (Chin 1998b, p. 317). Further, following the reporting recommendations of Gefen et al. (2011), the effect size f^2 of the saturated model compared with the theoretical model was calculated (Chin et al. 2003; Cohen 1988). The analysis indicated no change in the significance of the hypothesized paths, and the calculation of the effect size being between .02 and .15 ($f^2 = .078$) confirmed only weak effects through the added paths (perceived ease of use → intention, perceived usefulness → intention) (Chin 1998b, p. 317).

Table 6.10 Effect size of independent variables on the dependent variable in the user sample

Construct (with direct influence on intentions)	Relation	Effect size (f^2)
Attitude	Attitude → Intention	.138
Subjective norm	Subjective norm → Intention	.001
Perceived behavioral control	Perceived behavioral control → Intention	.054
Internal PLOC	Internal PLOC → Intention	.078
External PLOC	External PLOC → Intention	.018
Perceived privacy risk	Perceived privacy risk → Intention	.001

Further, the predictive relevance Q^2 was calculated for the user sample, using the SmartPLS blindfolding procedure with an omitting distance of 7. The results showed a Stone-Geisser criterion of 0.36 and therefore being well above the threshold of 0 and hence confirming the validity of the structural model for the user sample as well (Chin 1998b; Fornell and Bookstein 1982, p. 449).

Finally, the recommended procedural and statistical remedies by Podsakoff et al. (2003) to minimize and control common method bias were applied in this study. 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 general factor apparent in the unrotated factor solution indicating that common method variance was not a problem. The results showed a .249 variance explained and is therefore well below the recommended .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.

In summary, these results yield confidence for the model's validity and provide clear support for most of the established hypotheses with exception for hypotheses 2, 7b, 10a, 10b, 11, 12a, 12d, 12e and 12f being not significant in the user sample.

6.3 Exploratory Comparison of the User and Non-user Sample

After analyzing the two samples, an exploratory test of whether significant differences emerge when assessing the intention to adopt or continue using SMT of non-users versus users was conducted. To test whether the parameter estimates obtained for the samples significantly differed, this study employed the *t*- test suggested by Chin (2004). The formula is depicted in the following Fig. 6.3.

The path coefficients are taken out of the model estimation, whereas the standard errors (S.E.) for the compared paths are calculated in the bootstrapping procedure. The different sample sizes are indicated by m and n.

In general, the results significantly differ for seven of 23 hypothesized relationships. First, perceived ease of use is a stronger determinant of perceived

$$\text{t-value calculation: } t = \frac{Path_{Sample\ 1} - Path_{Sample\ 2}}{\left[\sqrt{\frac{(m-1)^2}{(m+n-2)} \times S.E._{Sample\ 1}^2 + \frac{(n-1)^2}{(m+n-2)} \times S.E._{Sample\ 2}^2}\right] \times \left[\sqrt{\frac{1}{m} + \frac{1}{n}}\right]}$$

Fig. 6.3 T-value calculation between two samples

Table 6.11 Results of the exploratory model comparison

#	Path	t-value	Significance (two-tailed)
H1	Consumers' attitudes → Consumers' intentions	.936	p > .10
H2	Subjective norm → Consumers' intentions	.665	p > .10
H3	**Perceived behavioral control → Consumers' intentions**	**2.642**	**p < .01**
H4	Perceived usefulness → Consumers' attitudes	.535	p > .10
H5	Perceived ease of use → Consumers' attitudes	.643	p > .10
H6	**Perceived ease of use → Perceived usefulness**	**3.164**	**p < .01**
H7a	Internal PLOC → Perceived ease of use	.451	p > .10
H7b	External PLOC → Perceived ease of use	.339	p > .10
H8a	Internal PLOC → Perceived usefulness	.331	p > .10
H8b	**External PLOC → Perceived usefulness**	**2.423**	**p < .05**
H9a	Internal PLOC → Consumers' attitudes	.297	p > .10
H9b	Internal PLOC → Perceived behavioral control	1.402	p > .10
H9c	Internal PLOC → Consumers' intentions	.970	p > .10
H10a	**External PLOC → Consumers' attitudes**	**4.043**	**p < .01**
H10b	External PLOC → Perceived behavioral control	.854	p > .10
H10c	External PLOC → Consumers' intentions	.063	p < .01
H11	**Perceived privacy risk → Consumers' intentions**	**1.920**	**p < .10**
H12a	Income → Consumers' intentions	1.310	p > .10
H12b	**Household size → Consumers' intentions**	**2.061**	**p < .05**
H12c	Age → Consumers' intentions	.161	p > .10
H12d	Electricity costs → Consumers' intentions	.314	p > .10
H12e	**Interest in new technologies → Consumers' intentions**	**1.876**	**p < .10**
H12f	Willingness to pay for E.I. → Consumers' intentions	.667	p > .10

usefulness for users than for non-users ($\beta_{users} = .30$, $\beta_{non\text{-}users} = .14$; $t = 3.16$, $p < .01$). Although not significant, the same holds for the direct effect on consumers' attitudes ($\beta_{users} = .09$, $\beta_{non\text{-}users} = .06$; $t = 0.64$, $p > .10$). Second, external PLOC is a more important driver of perceived usefulness for non-users than for users ($\beta_{users} = .13$, $\beta_{non\text{-}users} = .24$; $t = 2.42$, $p < .05$). The same holds true for the effect of external PLOC on consumers' attitudes ($\beta_{users} = .02$, $\beta_{non\text{-}users} = .23$; $t = 4.04$, $p < .01$). Thus, extrinsic motivation is less important for actual users than for potential adopters. Interestingly internal PLOC seems to have the same importance for both groups, the potential adopters and the actual users. Although not significant in neither sample, the influence of privacy risk seems to be significantly different in both samples ($\beta_{users} = .03$, $\beta_{non\text{-}users} = -.04$; $t = 1.92$, $p < .10$). This marginal effect is most probably mainly influenced by the change in the direction of the effect. Further, perceived behavioral control is a more important determinant of the consumer's intentions for users than for non-users ($\beta_{users} = .20$, $\beta_{non\text{-}users} = .09$; $t = 2.64$, $p < .01$). Finally, there could be found significant differences in two of the socio-demographic variables tested in the model. Household size had only a marginally significant effect in the user case. This is confirmed by the significant difference found in the comparison of both cases ($\beta_{users} = -.06$, $\beta_{non\text{-}users} = .01$; $t = 2.06$, $p < .05$). However, technological interest was only found to be significant for the potential adopters. Again this effect was confirmed by a significant difference in the comparison of both samples ($\beta_{users} = -.02$, $\beta_{non\text{-}users} = .05$; $t = 1.88$, $p < .10$).

The following Table 6.11 summarizes the results of the model estimation indicating the t-values and the significance of the differences. Significant differences between both samples ($p < .10$) are highlighted.

In summary the model comparison showed, that only a few significant differences could be found between the two examined groups. Interestingly the effect of extrinsic incentives seems to vanish for the users' group. Especially this effect could be heavily influenced by the specification of the measurement model. Further, the findings concerning the effects of perceived ease of use and perceived behavioral control could reflect that operability and facilitating conditions are hard to grasp while not yet using a technology. Finally, the differences in the socio-demographic variables could also help to identify how potential adopters can be found and how to motivate them to continue using the technology.

Chapter 7
Discussion and Interpretation

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.

Although studies show that the overall economic impact of SMT should be positive (e.g. Department of Energy and Climate Change UK 2011; Faruqui et al. 2010), a smart meter opposition has been formed, and the adoption of SMTs have faced resistance. Customers are driven by concerns such as mistrust of utilities, misinformation about dynamic rates introduced with SMT, and a variety of privacy and health concerns. It is remarkable that in the case of SMT, most energy suppliers introduced the devices without engaging in programs to inform their customers. As Nancy Brockway, a leading voice in consumer advocacy puts it: "You can't force them down consumers' throats and then be surprised that consumers don't want to swallow" (c.f. Fox-Penner 2010).

Practitioners and researchers (e.g. Watson et al. 2010) stress the need to understand consumers' adoption decisions in the field of energy informatics. Service research has highlighted the crucial role of transformative services not only for sustainable production and consumption (Ostrom et al. 2010) but also as an enabler of a "society-driven innovation" with policies "using service innovation to address societal challenges and as a catalyst of societal and economic change" (European Commission 2009, p. 70) as well. The case of SMT shows that the adoption of Green-IS can be an essential part to limit the negative consequences of the rapid global growth of (residential) energy demand. The goal of this thesis was to develop and test a comprehensive model of consumers' attitudes toward and intentions to adopt SMT. This study models consumers' intentions to adopt or continue using SMT, notably by drawing on the theory of planned behavior (Ajzen 1991) and self-determination theory (see Deci and Ryan 2002; Ryan and Deci 2000a). It offers new

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insights into the adoption behavior of SMT by examining how motivational states and incentives, perceived behavioral control, perceived privacy risk, and SMT-related considerations such as interest in new technologies and average monthly electricity bills affect intentions to adopt or continue using SMT.

As part of this thesis, an analysis was conducted in the energy sector and focused on smart metering technology and its services. SMT as an IT artifact is the key technology for enabling energy suppliers to move from a goods-oriented business model to a service-oriented approach and to manage the fundamental shift to "green energy supply." The model was tested with survey data from 933 users of SMT and 932 non-users in Germany. In general, this thesis found strong empirical support for the employed model. In particular, results show that endogenous motivational states have important direct and indirect effects on non-users' adoption intentions and users' continuance intentions. In the following these results are further outlined and interpreted. As this study is one of the first to conduct empirical research in the area of SMT adoption and use, the interpretations are only posing first possible explanations.

The results indicate that motivational influences, especially the internal PLOC had a strong effect on users' and non-users' intentions. Opposed to the extrinsic–intrinsic dichotomy that often treated extrinsic motivation in terms of external rewards, and in contrast, considered intrinsic motivation as being innate, the continuum of motivation allows focusing on the volitional basis of internal PLOC. In this case, although not innate (intrinsic), some (identified) social values such as environmentalism seem to be internalized, and consequently acted forcefully as intrinsic motivation. This finding reflects the growing importance of environmental aspects in today's societies and was mentioned by the members of the discussion groups in the informal conversations as well. One of the marketers mentioned that "Customers often ask if they can see how much CO_2 they are saving when using a smart meter" (Interviewee MA5). Further, customers interested in their smart meters often were interested in green energy tariffs (Interviewee MA2). Besides these two factors customers seemed to be interested in "the financial aspects of our smart meter and the associated tariffs. They wanted to know whether they could save money according to their current electricity bills" (as Interviewee MA2 mentioned). This study's results confirmed this perception as the external PLOC was found to have a significant impact on non-users' and users' intentions, too. But compared to the internal PLOC, the effect is much weaker especially in the user sample. This shows 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). As already briefly mentioned, the weaker effects of external PLOC in this study could result from different specifications of the construct, which includes two items with very low loadings in the user case. But results for other specifications of external PLOC strengthen the first interpretation that indeed external PLOC seems to play a minor role in the user case.

Interestingly the effect of perceived privacy risk was found to be weak and not significant. Especially regarding moratoriums and lawsuits as well as consumer protection groups and the media's echo perceived privacy risk would have been expected to be a strong influencing factor. When discussing the model with the experts of the energy supplier, they indicated that their customers had asked as well for "privacy and security issues arising with the use of the new meter. We think that this could be an important factor regarding the acceptance of the technology" (Interviewee MA1). 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 service research and may result from users' perceptions regarding the sensitivity of information disclosed (Mothersbaugh et al. 2012). Other examples such as Apple's iPhone data scandal confirm this perception (Cheng 2011). It is quite often the case that small groups that feel ignored by major companies start organizing into an opposition surrounding privacy issues, in an effort to catch the media's attention. Further, the same could count for the perceptions of the experts of the energy supplier as their statements did not rely on any database.

Consistent with the decomposed theory of planned behavior, perceived behavioral control was found to be significant. This implies that the more the consumers feel in control over adopting SMT the higher are their intentions to do so. The influence of perceived behavioral control was much stronger in the user sample. This could imply that potential users simply cannot imagine living with SMT. As soon as they start experiencing the new technology and its services these perceptions change. Subjective norms however were only significant in the non-user sample and had only very weak effects. Also, perceived ease of use affects perceived usefulness and both were found to be significant as predictors of attitude towards SMT in both samples. The effect of perceived ease of use is significantly stronger for the user group. Again, it seems as if present non-users can hardly imagine the actual usability of SMT. Finally, attitude was found to be a significant and strong predictor of users' intention to adopt SMT.

The socio-demographic variables showed a quite heterogeneous picture in both samples. Whereas income was found to be a significant predictor of individuals' intentions to adopt the new technology in the non-user sample, it was insignificant in the user sample. These findings are especially interesting as income has been the strongest predictor in the recent study of Poortinga et al. (2004). Interestingly, household size was only to be found significant in the user sample. These findings are interesting in the light of the studies of Gatersleben et al. (2002) and Poortinga et al. (2004) that found household size to be a strong and significant predictor of home energy use. One of the reasons for this lack of results of household size could be the newness of the technology itself. While it is assumed that use of SMT will likely impact (and reduce) energy costs in larger households, potential adopters of this technology (who are yet to witness its positive effect on energy savings) are unlikely to depend on this criteria to make adoption decisions. This interpretation is supported as household size plays a more critical role in continued usage, where consumers have had a chance to witness the energy savings from this technology.

Still future research needs to be conducted to understand this anomalous result. Further, this study found no influence of the average monthly electricity costs on users' and non-users' intentions. One of the reasons for this finding could be that in Germany, electricity costs are billed only once a year so that they are not really in the minds of the consumers. Furthermore, the savings with SMT are after all only marginal. Another interesting result was the effect of age. Although, Poortinga et al. (2004) didn't find age to be of significant impact it has a significant impact in both employed samples in this study. This is most probably due to the fact that SMT will impact energy consumption behaviors and while younger people are more interested and willing to change their habits, older people normally do not. However, the willingness to pay for energy innovations did not have a significant effect in this study. This could be explained by the effect that although the SMT consists of many services and products, the prevailing belief is that the smart meter itself, as well as the use of the online platform will be at no additional costs compared to the old mechanical meters. Finally, the interest in new technology had a minor but significant effect on the intention to adopt SMT while no significant effect could be measured in the user case. Overall none of the socio-demographic variables was found to be a very strong predictor of user's intention to adopt or use SMT.

7.1 Theoretical Contribution

Understanding how endogenous motivations influence user intentions, beliefs, and behaviors is important for both theoretical and practical reasons. This thesis contributes to both IS and service research in four major ways.

First, it contributes to energy informatics and transformative service research, which to the best of the author's knowledge have so far been conceptual in nature (Ostrom et al. 2010; Watson et al. 2010). A key characteristic of transformative technologies and services is to deliver services in a sustainable manner – that is, preserving health, society, and the environment. This study's results show that consumers' intrinsic motivations – that is, through feelings of volition – tend to be more important for the adoption of transformative services than internalized external pressures and social norms. Prior work has shown that social norms can be an important determinant of pro-environmental behavior (Goldstein et al. 2008). However, the results imply that messages that are too assertive or "pushy" are problematic, notably when consumers lack initial inclination to that behavior (Kronrod et al. 2011). More specifically, these results show that the *type* of motivation is more important than the amount. In contrast to the extrinsic–intrinsic dichotomy that treats extrinsic motivation in terms of external rewards and intrinsic motivation as being self-inherent, this study shows that although not intrinsic, the internalization of social values such as environmentalism can influence behavior as powerfully as intrinsic motivation. In the employed samples, internal PLOC was found to be a stronger indirect and direct predictor of adoption than external PLOC. This finding is in line with prior research on the effects of external rewards on the adoption of e-learning systems (Malhotra et al. 2008) as well as work on relational marketing outcomes (Dholakia 2006; Melancon et al. 2011).

Second, this study shows that the SDT and TPB provide complementary explanations regarding the motivational process that underlies volitional behaviors. Although the TPB and SDT are each well studied, this investigation is the first to integrate these theories to understand the adoption of transformative technologies and services by consumers. The findings show that motivations at the contextual level (internal and external PLOC) are influential antecedents of the TPB's belief-based constructs at the situational level (see Vallerand 1997). More specifically, internal PLOC is a strong predictor of attitude and perceived behavioral control for both non-users and users of SMT. This result further underscores the pivotal role of internalized values and perceived autonomy in predicting behavioral intentions (see also Cadwallader et al. 2010; Hagger et al. 2006). External PLOC, however, only significantly affects the TPB's belief-based constructs for non-users. This finding may indicate that for evaluative judgments on the favorability and control of a target behavior, non-users depend more on external regulations like external rewards or referrals. The negative (non-user sample) and insignificant (user sample) effect of external PLOC on perceived behavioral control was unexpected. Seemingly, the more non-users perceive external regulations as coercive and controlled, the lower their perceived control over internal and external factors that limit the adoption of SMT. An explanation for this finding may be that non-users expect extrinsically motivated behaviors to require more competence and effort to control inhibiting factors.

Third, the findings support the basic relationships proposed by classical models on technology acceptance (Davis et al. 1989; Fishbein and Ajzen 1975). However, these findings have to be interpreted in light of the underlying motivational effects of internal and external PLOC. In particular, this study's results show substantial effects of consumers' internal PLOC on perceived usefulness and ease of use of SMT. This finding 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). In addition, when people identify with values associated with a specific behavior, they regard it as more useful (Malhotra et al. 2008). Finally, the results reflect the ongoing discussion about the predictive power of the technology acceptance model (TAM) in the IS literature (Benbasat and Barki 2007): Ba et al. (2001) note that, although well designed and useful, a system will not necessarily lead to a successful outcome. These results show that the underlying motivational structures are more important for the adoption of transformative technologies than the traditional TAM constructs.

Fourth, this study contributes to energy informatics research by investigating the effect of socio-demographic variables on intentions in this area. Socio-demographic variables have been found to be strong drivers of energy consumption behavior in the home- and transport-energy field (e.g., Gatersleben et al. 2002; Poortinga et al. 2004). Although, these results show only minor impacts, it allows for theorization of cluster based research and helps to broaden the horizon on SMT adoption.

7.2 Practical Contribution

This study's results imply that to increase the adoption of transformative technologies, namely SMT, companies and policy makers generally need to ensure that consumers do not feel limited in their choices and way of living. The success of innovative transformative technologies and services depends on moving consumers' perceived locus of causality from external to internal regulation. In this respect, marketers should seek to establish congruence between the values inherent to transformative technologies and services and those of their target group. This prerequisite implies that, rather than stressing assertive social norms to reach a larger clientele, marketers have to emphasize transformative technologies' and services' inherent individual and collective benefits that address widely accepted values und norms.

This study also provides practical implications for the energy context. 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 reframe their business models towards more service-orientation. Infusing services in their business models poses severe challenges to energy suppliers. On the one hand, consumers' engagement regarding energy is still low. On the other hand, energy suppliers still lack important capabilities to manage interactions with their customers. A technology which can act as a "game changer" is the SMT.

The key question is how to leverage the technology and encourage passive energy consumers to use SMT. This study demonstrates the substantial direct and indirect positive effect of internal PLOC. Users feeling volitional about adopting SMT are more likely to adopt it. Thus, providers of SMT first have to establish an understanding about which extrinsic and intrinsic motivations are important to their target groups. The provided set of socio-demographic variables can help to better specify these groups. Next, they have to carefully align their marketing activities. For instance, to market its SMT, a German energy supplier targets innovative consumers with the promotional slogan "One step ahead" to position itself as a leader in innovation. However, marketers have to consider that "visionary" early users are stronger driven by distinct values than the more "pragmatic" group of non-users. As this study shows, external PLOC is important for inexperienced users. Hence, reaching the mainstream customer requires providing meaningful extrinsic motivations, which have to be complementary to intrinsic motivations and to users' feelings of autonomy and volition. Thus, 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 adoption of the technology. On the other hand external factors as recommendations and financial incentives are a distinct determinant in users' adoption decisions. This is especially important for the services offered with SMT, as the deployment of the technology alone (i.e. the smart meter) is (or will become) legally mandatory in many countries arousing perceptions of coercion. Further, a factor not considered in this study could be new business models allowing home automation and raising the level of comfort for the customers. The identified socio-demographic factors can help the energy providers identify customer clusters that they can target in the earlier phase of their SMT-rollout or to whom they can offer additional services. These socio-demographic factors are especially valuable as many of them are automatically surveyed by the energy provider. This offers the unique opportunity for the energy providers to foster customer loyalty by engaging these identified "adopters" into smart home packages, opening the way back into their permanent perception as a service provider. Although the study's findings suggest that perceived privacy risk only has an indirect effect on adoption intentions, it is important to take privacy issues seriously and to highlight privacy-enhancing measures in advertising campaigns to overcome a possible negative media echo.

7.3 Limitations and Further Research

Besides its contributions, this study has limitations that should be addressed by future research. First, this study investigated only one country, namely Germany. Future research should thus account for cultural and regional differences to validate these results. Second, the cross-sectional design of the data limits the findings in at least two ways (Rindfleisch et al. 2008), which are that user perceptions of SMT may change significantly over time, for example because of changing societal values or contemporary incidents. Second, the posited causal relationships can only be inferred. Thus, longitudinal research on consumers' adoption intentions of transformative technologies and services as SMT should be conducted. Third, this study focused on a specific category of transformative technologies that has special characteristics. Especially the fact that the installation of SMT might become mandatory in most Western countries may limit the generalizability of the findings regarding user perception of volition, autonomy, or external pressure. Finally, the model could be extended through an investigation of moderators on the effects of external and internal PLOC to answer the questions of when and how the effects of these psychological states differ.

Chapter 8
Conclusion

The objective of this work was to investigate, which determinants influence the adoption and usage behavior of smart metering technology. More precisely, this thesis ascertained a set of adoption, motivation and pro-environmental behavior related variables that influence consumers' intentions to adopt or continue using smart metering technology. For this purpose this thesis employed a quantitative research approach, comprising an extensive literature review and a quantitative empirical study. To get further insights into the differences between users and potential adopters of smart metering technology, the quantitative study consisted of two investigated samples one being a user and one being a non-user sample. From the epistemological perspective, in all research phases an empirical positivistic point of view was taken, assuming observable, fixed relationships to explain consumers' intentions.

As of yet there is no established energy informatics literature stream, the literature review consisted of an extensive review of adjacent fields with relevance for the thesis including technology adoption and continuance literature, motivation literature describing reasons for task engagement, literature on pro-environmental behavior and risk related literature dealing with reasons that hinder the adoption and use of technologies and services. Based on the literature review and informal interviews within a large Southern German energy supplier, the conceptual theoretical model was formulated by attentively augmenting and sophisticating classical adoption theories and the motivational framework with complementary theoretical constructs emerging from further research fields.

In order to test this theoretical model a large-scale quantitative study was conducted surveying German citizens. This quantitative study was split into two observations. First, in cooperation with a professional market research company, a representative sample of 932 current non-users of SMT was drawn. Second, a random sample of 933 current users of SMT was drawn out of the customers of a large Southern German energy supplier. Before the data was collected, as recommended for rigorous research, an intensive scale development pre-study was conducted. This guaranteed the reliability and validity of the measurement tool employed in this study. This preliminary study comprised a qualitative pre-test

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consisting of overall 16 interviews and four rounds of iterations and refinement of the items and a quantitative pre-test consisting of a small pre-study with 20 survey participants and a pilot test with 110 survey participants. The strong results out of this measurement scale development allow for strong confidence in the measurement tool. The two samples for the final field test were then successfully evaluated based on the recommended criteria and appropriate methods.

The evaluation of the data revealed several important direct determinants of consumers' intentions to adopt or use smart metering technology: consumers' attitudes, internal perceived locus of causality, external locus of causality, and perceived behavioral control. The model was able to explain a large portion of the variance extracted of consumers' intentions and revealed a set of socio-demographic factors influencing the adoption and use of smart metering technology.

This research project is to the knowledge of the author the first to have conducted large scale empirical tests with actual users of smart metering technology and the first using a large representative sample of potential adopters of smart metering technology. In summary, this research offers valuable insights into the field of energy informatics. It helped to test classic adoption research models in this new area. Further, a key goal of adoption research is to identify and understand how managerially controllable antecedents influence consumers' adoption intentions. This study provides important insights on the role of endogenous motivations in forming consumers' intentions about adopting transformative technologies. By disentangling extrinsic and intrinsic motivations this research provides new evidence on how sustainable technology adoption is influenced by different endogenous psychological states. It can serve as a starting point for further research on the role of users' endogenous motivations on green technology adoption.

Finally, one still has to keep in mind that green IS research is only in its beginning. Further, this research focuses on a very narrow field on green technology, namely smart metering technology. Therefore, although these findings can offer valuable information and guidance, they pose only a first set of results and interpretations. Further studies should reevaluate these findings in different settings and further refine them.

Ending this thesis with the words of John Holdren, senior advisor to President Barack Obama on science and technology issues and former president of the American Association for the Advancement of Science: "More specifically, I would urge every scientist and engineer with an interest in the intersection of science and technology (S&T) with sustainable well-being … to read more and think more about relevant fields outside your normal area of specialization, as well as about the interconnections of your specialty to these other domains and to the practical problems of improving the human condition; …; and indeed to "tithe" 10 % of your professional time and effort to working in these and other ways to increase the benefits of S&T for the human condition and to decrease the liabilities. If so much as a substantial fraction of the world's scientists and engineers resolved to do this much, the acceleration of progress toward sustainable well-being for all of Earth's inhabitants would surprise us all" (Holdren 2008, p. 433).

Appendix

Appendix 1: Final Questionnaire of the Quantitative Field Test

Construct (source)	Items
Consumers' 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 of using SMT
Adoption intention (Davis et al. 1989)	I can imagine using SMT regularly in my household
	I plan to use SMT in the future
	I intend to use SMT in everyday life
Continuance intention (Bhattacherjee 2001)	I intend to continue using SMT in the future
	I plan to continue to use SMT frequently
	I will always try to use SMT in my daily life
Perceived ease of use (Davis et al. 1989)	Learning to operate SMT would be easy for me
	I would find it easy to use SMT to do what I want to do
	It would take me some time to become skillful at using SMT[a]
	I would find it easy to use SMT
Perceived usefulness (Davis et al. 1989)	Using SMT would help me to better survey my energy consumption
	Using SMT would make it easier for me to lower my energy consumption
	Using SMT would be useful to regulate my energy consumption more efficiently
	Using SMT would help me to faster survey my energy consumption
Internal PLOC (Ryan and Connell 1989)	I use the system . . .
	. . . because I want to help protect the environment
	. . . because I personally like using SMT
	. . . because I think it is personally important to myself
	. . . because I want to learn how to use SMT
	. . . because I enjoy using SMT

(continued)

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Construct (source)	Items
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[a]
	. . . because the European Union recommends using SMT[a]
	. . . because I can avoid price peaks in peak load times
Subjective norm (Ajzen 1991; Venkatesh 2012a; Ryan and Connell 1989)	I would use SMT because I would feel bad if I would not
	People who are important to me think that I should use SMT
	I would use SMT because it is trendy to be green
	People who influence my behavior think that I should use SMT
	People whose opinions that I value prefer that I use SMT
Perceived behavioral control (Ajzen 1991; Taylor and Todd 1995a)	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 would be inconvenient for me to use SMT[a]
	I have control over using SMT
Perceived privacy risk (Featherman and Pavlou 2003)	Using SMT could lead to a loss of control over my personal data
	Using SMT could lead to a loss of my privacy, because my energy consumption data could be used without my knowledge
	My personal data would not be used for other purposes[a]
	My personal data that is gathered due to the usage of SMT would not be sold to third party providers[a]
	I am not worried about the data security of SMT[a]
	Internet hackers might take control of my payment and consumption data if I would use SMT[a]
	The databases that are used to save my consumption data are protected against unauthorized access

[a]Items dropped as they had low factor loadings on respective constructs

Appendix 2: Set of Socio-demographic and Control Variables

Variable	Item	Scaling
Age	In welchem Jahr sind sie geboren?	Text field for numbers
Gender	Sind Sie...	(1) weiblich (2) männlich
Living situation	Wohnen Sie an Ihrem Hauptsitz...	(1) in einer Mietwohnung (2) im gemieteten Ein-/Zweifamilienhaus/Reihenhaus (3) in Ihrer Eigentumswohnung (4) im eigenen Haus (5) sonstiges (6) keine Angabe
Household size	Wie viele Personen leben ständig in Ihrem Haushalt, Sie selbst eingeschlossen? Denken Sie dabei bitte auch an alle im Haushalt lebenden Kinder	(1) 1 Person (also nur Sie selbst) (2) 2 Personen (3) 3 Personen (4) 4 Personen (5) 5 Personen (6) 6 Personen (7) 7 Personen (8) 8 Personen (9) 9 Personen (10) 10 Personen und mehr (11) keine Angabe
Professional Carrer	Zu welcher der folgenden Gruppen gehören Sie?	(1) Schüler (2) in einer beruflichen Ausbildung/Lehre (3) Student (4) Selbständig/freiberuflich tätig (5) Angestellte(r)/Arbeiter(in) (6) Beamter, Beamtin, Richter (in), Berufsoldat(in) (7) Geringfügig beschäftigt/Mini-Job (8) Arbeitslos/"Ein-Euro-Job"(bei Bezug von Arbeitslosengeld 2) (9) Hausfrau, Hausmann/Elternzeit/Mutterschutz (10) Rentner(in), Pensionär (in), im Vorruhestand (11) Nichts davon (12) Keine Angabe

(continued)

Variable	Item	Scaling
Education	Welchen höchsten Schul- bzw. Hochschulabschluss haben Sie?	(1) ohne Haupt-/ Volksschulabschluss (2) Haupt-/ Volksschulabschluss (3) Realschulabschluss (Mittlere Reife) (4) Abschluss der Polytechnischen Oberschule (8./10. Klasse) (5) Fachhochschulreife (6) allgemeine oder fachgebundene Hochschulreife/Abitur (7) Fach-/Hochschulstudium (8) anderer Schulabschluss (9) keine Angabe
Interest in new technologies	Inwieweit interessieren Sie sich im Allgemeinen für technische Neuerungen?	7-point Likert Scale anchored by 1 – interessiere mich überhaupt nicht für technische Neuerungen 7 – interessiere mich außerordentlich für technische Neuerungen
Willingness to pay for energy innovations	Wie viel Euro pro Jahr würden Sie für technische Neuerungen ausgeben, mit denen sich der Energieverbrauch im Haushalt senken lässt?	(1) 0 Euro – dafür habe ich kein Geld (2) 1 bis 25 Euro im Jahr (3) 26 bis 50 Euro im Jahr (4) 51 bis 100 Euro im Jahr (5) 101 bis 200 Euro im Jahr (6) 201 bis 500 Euro im Jahr (7) 501 bis 1,000 Euro im Jahr (8) 1,001 bis 2,500 Euro im Jahr (9) 2,501 bis 5,000 Euro im Jahr (10) mehr als 5,000 Euro im Jahr (11) weiß nicht (12) keine Angabe
Monthly electricity costs	Wie hoch ist Ihre monatliche Abschlagszahlung für Strom in etwa? Sofern Sie alle zwei Monate bezahlen, rechnen Sie den Betrag bitte auf einen Monat um	(1) Unter 10 € (2) Zwischen 11 und 20 € (3) Zwischen 21 und 30 € (4) Zwischen 31 und 40 € (5) Zwischen 41 und 50 € (6) Zwischen 51 und 60 € (7) Zwischen 61 und 70 € (8) Zwischen 71 und 80 €

(continued)

Variable	Item	Scaling
		(9) Zwischen 81 und 90 € (10) Zwischen 91 und 100 € (11) Zwischen 101 und 110 € (12) Zwischen 111 und 120 € (13) Zwischen 121 und 130 € (14) Zwischen 131 und 140 € (15) Zwischen 141 und 150 € (16) Über 150 € (17) keine Angabe
Yearly electricity usage	Wie viel Strom verbraucht Ihr Haushalt pro Jahr? Schauen Sie dazu bitte auf Ihrer letzten Stromrechnung (Jahresabrechnung) nach. Der Stromverbrauch wird in kWh (Kilowattstunden) angegeben.	(1) Unter 500 kWh/Jahr (2) 501 bis 1,000 kWh/Jahr (3) 1,001 bis 1,500 kWh/Jahr
	Sofern der Verbrauchszeitraum auf der letzten Rechnung kürzer oder länger als ein Jahr ist, rechnen Sie bitte den Verbrauch auf ein Jahr um	(4) 1,501 bis 2,000 kWh/Jahr (5) 2,001 bis 3,000 kWh/Jahr (6) 3,001 bis 4,000 kWh/Jahr (7) 4,001 bis 5,000 kWh/Jahr (8) 5,001 bis 6,000 kWh/Jahr (9) 6,001 bis 7,000 kWh/Jahr (10) 7,001 bis 8,000 kWh/Jahr (11) 8,001 bis 9,000 kWh/Jahr (12) 9,001 bis 10,000 kWh/Jahr (13) über 10,000 kWh/Jahr (14) keine Angabe
Persons at home	Für den Stromverbrauch kommt es ja auch darauf an, wie viele Personen sich jeweils zu Hause aufhalten. Wie ist das bei Ihnen	am Vormittag zwischen 9 und 13 Uhr? niemand eine Person zwei Personen
	Wie viele Personen halten sich an einem normalen Wochentag zu Hause auf…	drei Personen vier Personen fünf Personen mehr als fünf Personen keine Angabe am Nachmittag zwischen 13 und 18 Uhr? am Abend zwischen 18 und 20 Uhr?
Switching the electricity supplier	Seit 1998 kann man in Deutschland seinen Stromversorger frei wählen. Wie ist das bei Ihnen: Wie oft haben Sie seit 1998 Ihren Stromanbieter gewechselt?	(1) noch gar nicht (2) einmal (3) zweimal (4) dreimal (5) viermal (6) fünfmal (7) mehr als fünfmal (8) keine Angabe

(continued)

Variable	Item	Scaling
Net income	Wie hoch ist das monatliche Nettoeinkommen Ihres Haushaltes insgesamt? Gemeint ist damit die Summe, die sich ergibt aus Lohn, Gehalt, Einkommen aus selbständiger Tätigkeit, Rente oder Pension, jeweils nach Abzug der Steuern und Sozialversicherungsbeiträge. Rechnen Sie bitte auch die Einkünfte aus öffentlichen Beihilfen, Einkommen aus Vermietung, Verpachtung, Wohngeld, Kindergeld und sonstige Einkünfte hinzu	(1) unter 500 EUR (2) 500 bis unter 1,000 EUR (3) 1,000 bis unter 1,500 EUR (4) 1,500 bis unter 2,000 EUR (5) 2,000 bis unter 2,500 EUR (6) 2,500 bis unter 3,000 EUR (7) 3,000 bis unter 3,500 EUR (8) 3,500 bis unter 4,000 EUR (9) 4,000 bis unter 4,500 EUR (10) 4,500 und mehr (11) keine Angabe
State	Automatically allocated by zipcode	

Appendix 3: Cross-Loadings for All Items in the Non-user Sample

Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Int1	**.92**	.75	.28	.22	.70	.60	−.32	.39	.62	.03	.03	−.05	−.01	.17	.07
Int2	**.95**	.65	.30	.25	.68	.56	−.32	.39	.57	.08	.04	−.03	.00	.19	.09
Int3	**.95**	.65	.28	.25	.68	.56	−.31	.38	.57	.06	.04	−.02	−.01	.16	.07
Att1	.67	**.95**	.18	.14	.64	.59	−.31	.32	.58	.02	.01	.01	−.01	.07	.06
Att2	.67	**.94**	.23	.16	.66	.60	−.30	.36	.61	.02	.02	.02	.00	.12	.03
Att3	.56	**.80**	.11	.07	.56	.50	−.29	.30	.53	.01	.02	.02	.00	.08	−.03
Att4	.73	**.94**	.24	.19	.68	.61	−.33	.38	.62	.01	.01	−.01	.00	.13	.03
PBC1	.24	.16	**.86**	.01	.17	.09	−.08	.59	.23	.09	.07	−.15	−.02	.31	.00
PBC2	.29	.20	**.88**	.10	.25	.14	−.20	.59	.24	.08	−.01	−.01	.00	.36	.05
PBC4	.22	.17	**.74**	.07	.19	.09	−.20	.37	.18	.06	−.05	.03	.05	.16	.01
SN1	.20	.13	.03	**.73**	.26	.21	−.13	.07	.13	−.01	−.03	.11	−.01	−.02	.09
SN2	.19	.10	.07	**.84**	.22	.23	−.15	.09	.08	−.06	−.05	.11	.00	.01	.04
SN3	.16	.10	.04	**.76**	.25	.26	−.11	.06	.08	−.06	.01	.05	−.02	.00	.06
SN4	.24	.17	.06	**.87**	.30	.28	−.15	.08	.18	−.10	−.03	.04	−.03	−.05	.02
SN5	.22	.13	.10	**.87**	.27	.26	−.18	.11	.11	−.06	−.03	.04	−.04	.02	.07
IPLOC1	.59	.61	.14	.24	**.82**	.65	−.24	.29	.59	.03	.02	.02	.00	.03	.10
IPLOC2	.70	.65	.27	.24	**.88**	.56	−.35	.43	.57	.02	.02	.00	.00	.20	.09
IPLOC3	.48	.46	.11	.27	**.76**	.54	−.25	.25	.43	−.05	−.04	.07	.00	.08	.05
IPLOC4	.53	.47	.26	.32	**.79**	.43	−.30	.36	.42	.03	.03	.01	−.01	.16	.08
IPLOC5	.67	.66	.24	.27	**.88**	.62	−.33	.36	.62	.06	.03	.04	.02	.12	.12
EPLOC1	.38	.39	.06	.34	.47	**.79**	−.24	.18	.34	−.10	−.09	.14	.00	.02	.08
EPLOC2	.39	.34	.09	.36	.44	**.75**	−.16	.15	.35	−.06	−.05	.05	.00	.01	.09
EPLOC5	.61	.67	.13	.13	.66	**.84**	−.24	.31	.59	.02	.04	.04	.03	.11	.07
PPR1	−.21	−.23	−.15	−.06	−.21	−.13	**.79**	−.14	−.09	−.05	.03	−.07	−.01	−.06	−.05
PPR2	−.27	−.28	−.13	−.09	−.28	−.20	**.84**	−.13	−.18	−.06	.06	−.11	−.02	−.05	−.09
PPR7	−.30	−.27	−.17	−.23	−.33	−.28	**.72**	−.15	−.27	.02	.04	−.04	.03	−.05	−.05
PEOU1	.35	.32	.58	.04	.33	.22	−.15	**.89**	.34	.08	.00	−.11	−.03	.31	.02
PEOU2	.35	.32	.51	.07	.36	.25	−.12	**.87**	.36	.07	.00	−.07	−.01	.30	.03
PEOU4	.38	.34	.57	.15	.39	.29	−.20	**.87**	.33	.06	−.03	−.06	−.01	.30	.08

(continued)

Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PU1	.57	.59	.26	.10	.58	.51	−.21	.37	**.93**	.04	.04	−.10	−.02	.11	.03
PU2	.57	.56	.22	.19	.60	.53	−.26	.34	**.90**	.03	.03	−.04	.02	.07	.07
PU3	.61	.63	.21	.16	.63	.56	−.23	.33	**.92**	.04	.05	−.06	.03	.08	.06
PU4	.54	.57	.28	.09	.55	.49	−.19	.38	**.91**	.06	.04	−.07	−.03	.12	.02
Income	.06	.02	.10	−.07	.02	−.04	−.03	.08	.05	**1**	.36	.04	.26	.07	.23
HouseSize	.04	.02	.00	−.03	.02	−.02	.05	−.01	.04	.36	**1**	−.28	.37	.01	.09
Age	−.04	.01	−.05	.08	.03	.09	−.09	−.09	−.08	.04	−.28	**1**	.09	.00	.05
ECosts	−.01	.00	.01	−.03	.00	.02	.00	−.02	.00	.26	.37	.09	**1**	.04	.11
InterestTech	.18	.11	.34	−.01	.14	.07	−.07	.34	.10	.07	.01	.00	.04	**1**	.13
Willingness	.08	.03	.03	.07	.11	.09	−.08	.05	.05	.23	.09	.05	.11	.13	**1**

Appendix 4: Cross-Loadings for All Items in the User Sample

Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Int1	**.87**	.62	.36	−.01	.55	.30	−.20	.44	.52	.04	−.07	−.08	−.05	.11	.12
Int2	**.91**	.45	.39	.05	.49	.31	−.15	.50	.47	−.01	−.13	−.02	−.06	.17	.14
Int3	**.88**	.39	.36	.10	.44	.29	−.13	.44	.42	.00	−.13	.02	−.06	.17	.09
Att1	.51	**.93**	.27	−.06	.48	.25	−.21	.32	.44	.07	−.08	.00	−.01	.13	.11
Att2	.53	**.93**	.30	−.06	.48	.24	−.20	.34	.45	.06	−.07	.00	.02	.14	.10
Att3	.30	**.59**	.17	−.17	.27	.08	−.12	.17	.28	.05	−.05	.00	.01	.03	.06
Att4	.55	**.94**	.33	−.07	.51	.25	−.22	.36	.46	.10	−.08	−.02	.02	.16	.13
PBC1	.37	.31	**.91**	−.06	.34	.10	−.16	.70	.41	.07	.01	−.08	−.01	.29	.13
PBC2	.43	.30	**.90**	−.01	.36	.11	−.17	.66	.41	.07	−.04	.00	−.03	.30	.11
PBC4	.27	.21	**.80**	.01	.27	.12	−.17	.48	.32	.07	−.05	−.01	−.03	.23	.07
SN1	.05	−.05	−.01	**.84**	.16	.21	−.09	.00	.04	−.10	.00	.08	−.04	.07	.04
SN2	.00	−.08	.00	**.70**	.11	.21	−.10	−.05	.00	−.15	−.06	.15	−.07	.04	.02
SN3	.04	−.07	−.03	**.81**	.15	.15	−.04	−.06	.01	−.11	−.01	.07	−.06	.02	.05
SN4	.02	−.11	−.01	**.79**	.10	.18	−.06	−.05	−.02	−.15	−.06	.13	−.05	.08	.03
SN5	.03	−.12	−.03	**.83**	.08	.15	−.02	−.06	−.04	−.14	−.04	.12	−.05	.08	.01
IPLOC1	.36	.31	.14	.27	**.68**	.38	−.20	.20	.38	−.06	−.05	.05	−.06	.04	.16
IPLOC2	.54	.48	.40	.01	**.86**	.27	−.23	.47	.55	−.01	−.09	−.03	−.03	.27	.13
IPLOC3	.27	.24	.16	.21	**.65**	.32	−.17	.15	.33	−.08	−.05	.00	−.01	.12	.07
IPLOC4	.44	.39	.35	.12	**.79**	.27	−.19	.36	.44	−.02	−.06	−.04	−.01	.26	.08
IPLOC5	.50	.49	.30	.12	**.86**	.38	−.24	.35	.50	.00	−.08	.06	−.01	.20	.16
EPLOC1	.14	.06	.03	.29	.22	**.56**	−.15	.00	.15	−.08	−.11	.10	−.02	−.05	.02
EPLOC2	.07	−.07	−.03	**.49**	.09	.23	−.05	−.02	−.03	−.09	−.06	.10	.02	.04	.02
EPLOC5	.34	.27	.13	.16	.39	**.96**	−.16	.19	.34	−.09	−.14	.06	−.01	.04	.06
PPR1	−.06	−.13	−.06	.04	−.08	−.04	**.59**	−.01	−.05	.06	.05	−.05	.00	.03	.00
PPR2	−.06	−.13	−.08	.01	−.13	−.05	**.60**	−.04	−.07	.02	.03	−.02	.03	.00	.00
PPR7	−.19	−.21	−.20	−.11	−.28	−.21	**.91**	−.19	−.30	.03	.04	−.02	−.02	−.06	−.03
PEOU1	.44	.30	.65	−.06	.35	.12	−.11	**.91**	.42	.10	−.02	−.15	−.07	.25	.08
PEOU2	.49	.34	.66	−.04	.38	.16	−.12	**.90**	.46	.10	−.02	−.07	−.05	.27	.08
PEOU4	.47	.32	.63	−.03	.42	.17	−.20	**.91**	.46	.04	−.04	−.08	−.09	.20	.10

(continued)

Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PU1	.46	.45	.41	−.02	.54	.29	−.26	.46	**.91**	.01	−.06	−.06	−.04	.15	.12
PU2	.46	.35	.34	.08	.48	.34	−.23	.39	**.84**	−.03	−.09	−.02	−.11	.07	.12
PU3	.51	.48	.39	.03	.55	.34	−.26	.44	**.91**	−.01	−.08	−.03	−.05	.12	.09
PU4	.48	.40	.41	−.06	.49	.25	−.19	.45	**.87**	.00	−.05	−.05	−.04	.14	.08
Income	.01	.08	.08	−.15	−.03	−.10	.04	.09	−.01	**1**	.19	−.11	.17	.12	.14
HouseSize	−.12	−.08	−.03	−.03	−.09	−.15	.05	−.03	−.08	.19	**1**	−.35	.27	−.07	.01
Age	−.03	−.01	−.04	.12	.01	.08	−.03	−.11	−.05	−.11	−.35	**1**	−.02	.07	.04
ECosts	−.06	.01	−.03	−.06	−.03	−.02	−.01	−.08	−.07	.17	.27	−.02	**1**	.08	.03
InterestTech	.17	.14	.32	.07	.25	.02	−.04	.27	.13	.12	−.07	.07	.08	**1**	.15
Willingness	.13	.12	.12	.04	.16	.06	−.03	.10	.12	.14	.01	.04	.03	.15	**1**

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