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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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

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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
December 2012

Professor Dr. Daniel J. Veit

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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

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