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# Acceptance of Privacy-Sensitive Technologies: Smart Metering Case in The Netherlands

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***Abstract.*** *Over recent years there have been several initiatives around the world that aim to roll out smart metering systems, especially within North America and member states of the European Union. Smart metering systems, giving essential conditions for smart grids in the energy sector, can offer services aimed at achieving many different goals beyond the main task of metering electricity consumption of households. Despite the many advantages gained by the smart metering system, there is a number of serious issues that may lead to the system's failure or inability to reach its goals. One such obstacle which can lead to consumers' rejection of smart meters is perceived security and privacy violations of consumers' information. The social rejection of smart meters poses a significant threat to a successful rollout and operation of the system as consumers represent a cornerstone in the fulfillment of goals such as energy efficiency and savings, by their active interaction with the smart meters. To investigate consumers' perception of smart meters theories and models from the technology acceptance literature can be used for understanding consumers' behaviors, and exploring possible factors that can have a significant impact on consumers' acceptance and usage of a smart meter. In this paper, a first-stage hybrid model of a two well-known technology acceptance theories is presented. These theories are: the Unified Theory of Acceptance and Usage of Technology-UTAUT, and Innovation Diffusion Theory- IDT. The hybrid model is further extended with additional acceptance determinants derived from the smart metering case in the Dutch context. The model aims to investigate determinants that can help shed the light on consumers' perception of the system and its acceptance.*

***Keywords.*** *Information privacy, infrastructure systems, smart metering, technology acceptance.*

## 1 Introduction

Over recent years there have been several initiatives around the world that aim to roll out smart metering systems, especially within North America and member states of the European Union. Smart metering systems offer vast services aiming at achieving many different goals beyond the main task of metering electricity consumption at remote households. The motivations behind launching the system are various, and differ from one country to another. In general, there are common drivers among member states of the European Union, such as aiming to meet requirements from both the Kyoto protocol and the EU Energy Efficiency Directives: EU Directive

2006/32/EC (*Directive 2006/32/EC*, 2006) and EU Directive 2005/89/EC (*Directive 2005/32/EC*, 2005). In the Netherlands, in addition to environmental incentives such as $CO_2$ emissions reduction, energy efficiency in a liberalized electricity markets forms other key driver.

However, despite the many advantages gained by the smart metering system, there is a number of serious issues that may lead to the system's failure or inability to reach its goals. The lack of significant financial incentives, health concerns, or anxieties related to security and privacy violations of consumers' information that is generated and maintained by the system can be seen as possible obstacles The significance of these issues results from the fact that consumers represent a cornerstone in the fulfillment of goals such as energy efficiency and savings, by their active participation through their actual utilization of the system and adjusting their consumption behaviors and patterns accordingly.

A possible approach to investigate consumers' perception of smart meters is by using a wide variety of theories and models from the technology acceptance literature. Doing so, it aids in understanding consumers, what influences their opinions and behaviors, and exploring possible factors that can have a significant impact on consumers' acceptance and usage of a smart meter. From the many technology acceptance models and theories that were founded in different research areas such as information systems, psychology, and sociology, two well-known theories are used for this work; they are the Unified Theory of Acceptance and Usage of Technology- UTAUT, and Innovation Diffusion Theory- IDT. In this paper, a first-stage hybrid model of the two theories is presented, which is further extended with additional acceptance determinants derived from the smart metering case in the Dutch context. The model aims to investigate determinants that can help shed the light on consumers' perception of the system and potentially have impact on the variance of consumers' acceptance of smart meters.

The sections of this paper are presented as follows: section two discusses the concept of technology acceptance, and presents two well-known theories from existing literature; UTAUT and IDT, section three presents a number of smart meters rejection antecedents and acceptance stimulants. Section four presents the proposed smart metering acceptance model, while in section five an overview of future steps to validate the model is given. Finally, conclusions and future work are presented in section six. For an overview of the smart metering system in The Netherlands, the reader is referred to (AlAbdulkarim & Lukszo, 2009).

## 2 Technology acceptance theories and models

### 2.1 Technology acceptance

Individuals' acceptance of technology is defined by Dillon as "the demonstrable willingness within a user group to employ [a certain] information technology for the tasks it is designed to support" (Dillon & Morris, 1996). In general, technology acceptance relates to psychological traits of individuals that can lead to their voluntary adoption and usage of a newly introduced technology. Potential technology adopters can either be users within organizations or consumers within a society, both of which are contexts covered by different bodies of literature. The rise of interest in technology acceptance research was an innate consequence to the rapid development of information technologies. The efforts carried out in this body of literature are focused on formulating theories that are tailored for different fields of applications such as e-commerce or e-government systems. Each theory is unique by investigating acceptance from a certain perspective via a number of factors derived from its respective field of study. The aim is to explore how these factors could impact consumers' willingness to adopt a technology. The findings of such research go beyond gaining an insight into consumers' opinion, as it aids in forming policy recommendations related to design and implementation processes. This can be achieved by translating the results of such models into actionable steps or plans that can be carried out by change actors, legislators, policy makers or system designers and developers (Dillon, 2001). For this work, two prominent technology acceptance theories were chosen as a foundation for a smart metering technology acceptance model, to investigate the matter within the Dutch context. The next sections present the theoretic foundation of the proposed model.

### 2.2 The Unified Theory of Acceptance and Usage of Technology- UTAUT

The unified theory of acceptance and use of technology- UTAUT was formulated by Venkatesh et al. in 2003 (Venkatesh et al., 2003) in the IT field, to study individual's acceptance and usage of new information technologies introduced within organizations. Over the decades technology acceptance research efforts have resulted in a wide spectrum of diverse theories and models, each offering a different view of individuals' acceptance and usage of technology. This, according to Venkatesh et al. forces researchers to either "pick and choose" acceptance determinants across the different models, or choose a "favored model" and discard other models along with their variant contributions. The significance of the UTAUT is that it is a synthesis of a set of technology acceptance theories and models that offers a unified view of user acceptance and usage of technology (Venkatesh et al., 2003). The theory is based on a compilation of eight prominent technology acceptance theories and models; each consists of a different set of technology acceptance determinants, and originates from different research area such as: information systems, sociology, and psychology. The theories comprising the UTAUT model are: Theory of Reasoned Action- TRA, Technology Acceptance Model- TAM, Motivational Model- MM, Theory of Planned Behavior- TPB, Combined TAM and TPB (C-TAM-TPB), Model of PC Utilization- MPCU, Diffusion of Innovation– DOI, and Social Cognitive Theory – SCT. The acceptance determinants adopted from the UTAUT theory into the proposed research model are explained below along with their respective hypotheses underlying the proposed model. For a full description of the UTAUT model, the reader is referred to (Venkatesh et al., 2003).

**Performance Expectancy.** Is "the degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh et al., 2003).

***$H_0$*****:** *Performance expectancy has a positive influence on smart meter acceptance*

**Effort Expectancy.** Is a technology acceptance determinant that is "defined as the degree of ease associated with the use of the system" (Venkatesh et al., 2003).

***$H_0$*****:** *Effort expectancy has a negative influence on smart meter acceptance*

**Social Influence**. Is the "degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh et al., 2003).

***$H_0$*****:** *Social influence has a positive influence on smart meter acceptance*

### 2.3 Innovation Diffusion Theory- IDT

The innovation diffusion theory – IDT was developed by Rogers (Rogers, 1995) in the area of sociology. It is one of the principle theories on innovation diffusion tackling acceptance of innovation within societies at a global level and was later both adopted and extended by research efforts from various disciplines (Dillon & Morris, 1996). Rogers defines diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1995). Roger further describes diffusion as some sort of a social change that is defined as the "process by which alteration occurs in the structure and function of a social system" (Rogers, 1995). In general, Rogers IDT theory attempts to explain the process of dissemination of new innovations within societies via an innovation-decision process model, and concepts such as innovation adoption rate, and a number of variables affecting the adoption rate. Rogers argues that the innovation adoption rate is influenced by five variables: perceived innovation attributes, types of innovation-decision, communication channels, nature of the social system, and the extent of change agents' promotion efforts. Among the five, the perceived attributes of innovation forms an important element as it explains between 49% to 87% of the variance in the adoption rate is explained by these five attributes (Rogers, 1995). Consequently, the innovation attributes were adopted by researchers from different disciplines in combination with other acceptance determinants originating from their respective field of study. In the proposed research model, Relative Advantage and Complexity were eliminated as they overlap with Effort Expectancy and Performance Expectancy determinants from the UTAUT model. The definitions of the five innovation attributes and the hypotheses underlying the three adopted variables are given in Table 1. For an in-depth description of IDT theory, the reader is referred to (Rogers, 1995).

**Table 1.** Definitions of innovation attributes and hypotheses underlying proposed model.

| Attribute | Definition and Hypotheses |
|---|---|
| Relative Advantage | The degree to which an innovation is perceived as being better than the idea it supersedes (Rogers, 1995) |
| Complexity | The degree to which an innovation is perceived as relatively difficult to understand and use (Rogers, 1995) |
| Observability | The degree to which the results of an innovation are visible to others (Rogers, 1995)<br>***$H_0$**: Observability has a positive influence on smart meter acceptance* |
| Compatibility | The degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters (Rogers, 1995)<br>***$H_0$**: Compatibility has a positive influence on smart meter acceptance* |
| Trialability | The degree to which an innovation may be experimented with on a limited basis (Rogers, 1995)<br>***$H_0$**: Trialability has a positive influence on smart meter acceptance* |

## 3 Smart Meters Acceptance Determinants

In addition to the acceptance determinants adopted for the UTAUT and IDT theories, the proposed research model incorporates determinants that are related to ICT-based, privacy-sensitive systems. These determinants are explained further below.

### 3.1 Smart Meters Rejection Antecedents

**Perceived Financial Costs.** Is the financial obligation enforced by service providers on consumers in return for the new technology, and which were not present prior to the introduction of the new technology. Consumers around the world reported different cost-related reasons for their lack of enthusiasm for adopting smart meters other than having to pay for the meter installation. For example, one consumer reported that the electricity bill of an uninhabited home had an increase of more than the double of previous electricity bills after the installation of a smart meter (Betz, 2010).

***$H_0$:** Perceived financial costs have a negative influence on smart meter acceptance*

**Perceived Loss of Control.** Is consumers' concerns regarding electricity grid operators' ability to remotely disconnect services of an electricity consumer at any time without consumers' permission or prior notification. Upon using new technologies, consumers seek assurance of remaining in control of both the technology and whatever consequences that may occur as a result of its usage. This becomes more so in the case of ICT-based technologies that involve interacting with remote systems, by sending private information via means of digital networks. This can create hesitation within consumers to use such technologies without some guarantees for the safety of their information and a sense of control over the usage of the technology (Gupta & Xu, 2010; Xu, 2007).

***$H_0$*****:** *Perceived loss of control has a negative influence on smart meter acceptance*

**Perceived Health Risks.** Is consumers' concerns in relation to the adverse effects of the presence of a the technology in their premises, or its usage on the health of household members. The deployment of wireless smart metering infrastructures in many parts of the world have been met with strong resistance. For example, e-mail campaigns in Maine, USA have been launched against the roll-out of smart metering systems, in addition to suspending system roll-out partly due to health-related concerns (Barringer, 2011).

***$H_0$*****:** *Perceived health risks has a negative influence on smart meters acceptance*

**Perceived Information Security and Privacy Risks.** Defined as worries on consumers' part that their personal information that is managed by the new technology is not sufficiently protected, which can result in the unlawful disclosure of information to unauthorized parties or intruders. It is one of the most prominent causes for consumers' rejection of smart meters due to their concern of violation of confidentiality of their private information generated and maintained by the ICT infrastructure of the system. Such concerns result from fears of insufficient information security practices applied by the grid operators -as system owners- or violation of information privacy by unlawful disclosure of this information to an unauthorized third party. These concerns have led to several campaigns in California, USA and The Netherlands protesting against the Big Brother effect. An example campaign is StopSmartMetersNow ("StopsmartmetersNow.com,"), which calls for stopping the deployment of the system. In a similar manner, The Netherlands witnessed a similar movement that raised slogans against the allegedly ill-intentions of using consumers' private information. A bill for mandatory system roll-out was rejected in Dutch Senate in April 2009 due to a report conducted by the University of Tilburg and commissioned by the consumer organization in The Netherlands (Cuijpers & Koops, 2008). The report stated that from a legal standpoint the smart meters pose a legal dilemma since the frequent readings of the meter are considered a breach of article 8 –right to respect for private and family life- from the Convention for the Protection of Human Rights and Fundamental Freedoms (*Convention for the Protection of Human Rights and Fundamental Freedoms as amended by Protocol No. 11*; Garcia & Jacobs, 2010).

***$H_0$*****:** *: Perceived information security and privacy risks has a negative influence on smart meter acceptance*

### 3.2 Smart Meters Acceptance Stimulants

**Effective Feedback.** Is providing consumers with a meaningful form of electricity consumption feedback that can motivate them to take an active role in demand response. Effective forms of feedback include: real-time pricing, attractive easy to use meter display, sound alerts, receiving SMS or using hand-held devices applications to monitor consumption.

***$H_0$*: *Effective feedback has a positive influence on smart meter acceptance***

**Data Architecture.** Refers to the data storage architecture of the system; centralized (residing in the Central Access Server (AlAbdulkarim & Lukszo, 2009)) vs. distributed (residing in meter at consumers' homes). For this work it is assumed that a distributed data storage across the system units is favored by consumers over a centralized approach.

***$H_0$*: *A distributed data architecture has a positive influence on smart meter acceptance***

**Technology Awareness.** The extent to which consumers know about smart meters.

***$H_0$*: *A high level of technology awareness has a positive influence on smart meter acceptance***

**Perceived Organization Image.** The extent of consumers' knowledge of the organization that govern a technology, i.e. electricity grid operators for smart metering systems.

***$H_0$*: *A high level of knowledge has a positive influence on smart meter acceptance***

**Mass Media.** The frequency or extent to which smart meters are mentioned in different media channels such as newspapers, radio and the internet.

***$H_{0a}$*: *Frequent press coverage of smart meters has a positive influence on smart meter acceptance***

***$H_{0b}$*: *Frequent press coverage of smart meters leads to increased technology awareness***

***$H_{0c}$*: *Frequent press coverage of smart meters leads to increased knowledge of an organization***

## 4. Proposed Hybrid Smart Metering Acceptance Model

Integrating different technology acceptance models to investigate users' acceptance of certain information technology system is not uncommon. The aim of these attempts usually is to combine the different points of strength of each model to devise a hybrid technology acceptance model that is high in its predictive power. In this work a blend of the UTAUT model and IDT theory is applied in the context of the smart metering as an ICT-reliant infrastructure system. The two theories are combined into a hybrid model to investigate the deployment and diffusion of the smart metering system from consumers' point of view, by exploring factors that can stimulate consumers to adopt a smart meter and use it. The hybrid model –shown in Fig 1- is further extended with the acceptance determinants listed in section three of this article. The proposed research model is presented in the next section with a description of the observed consumer behavior of interest for this study.

### 4.1 Observed Behavior

An important component of any technology acceptance theory is the observed behavior of interest. That is the behavior exhibited by a consumer in response to the technology being diffused. For many of these theories the main focus is to study the influence of the acceptance determinants in the model on a certain observed consumer behavior, such as their intention to adopt a technology, their intention to use or their satisfaction with such technology. For this work, the influence of the afore-presented acceptance determinants on consumers' behavioral intention to accept and use a smart meter is investigated. Definitions of these two constructs are given below.

**Smart Meters Acceptance.** Is consumers' positive perception of a smart meter by acquiring it or agreeing to the operational presence of a smart meter in consumers' premises.

***$H_0$*****:** *A high level of acceptance has a positive influence on smart meter usage*

**Smart Meter Usage.** The actual usage of a smart meter by the consumers to monitor their electricity consumption and adjust their consumption behavior.

## 5. Model Verification

In order to test the hypothesized relationships between the acceptance determinants in the model and the observed behavior, i.e. acceptance and intended usage, a questionnaire was developed, which consists of a number of items used to measure the acceptance determinants in the model. The questionnaire is intended to be administered among household electricity consumers in The Netherlands. The dataset to be acquired is intended to be analyzed using Structural Equation Modeling -SEM. understanding of consumers' behavior and opinion is a crucial step in system design and development processes, rather than carrying on these steps in isolation from consumers, which can result in systems that are potentially low in acceptability.

## 6. Conclusions and Future Work

In this paper the concept of smart metering technology acceptance and its importance was discussed, mentioning the negative consequences of consumers' rejection, and giving an overview of the most well-known technology acceptance models and theories throughout the literature. Finally, a first stage smart metering technology acceptance model was presented. The model is a combination of two widely-used theories: UTAUT and IDT, and further extended with acceptance determinants that

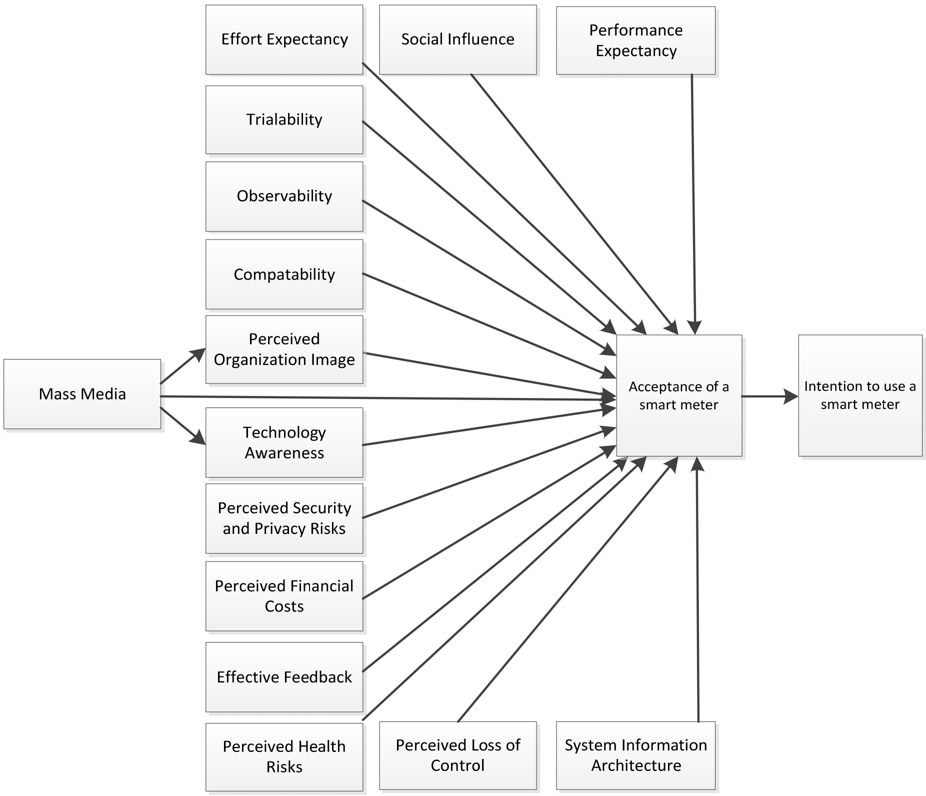


**Fig. 1** The proposed smart meter acceptance model

were derived from the smart metering system in the Dutch context. The next steps of this research are administering a questionnaire aimed at measuring each of the acceptance determinants in the model, and testing the hypothesized relationships between these determinants and the acceptance and intended usage of a smart meter. The results of the analysis are intended to be translated into recommendations in the form of actionable steps to be carried out by change agents, i.e. legislators, policy makers, and system designers and developers, to influence current policies and system design and implementation processes. These alterations take the consumers perspective into consideration rather than designing, developing and deploying a system in isolation of understanding consumers, their nature, and what affects their opinions and behaviors.

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