Master Thesis

Social acceptance of smart meters

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Social acceptance of smart meters

By

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To my mother and father, who let me strive for the best with their incomparable encouragement and support.

Executive Summary

The introduction of intelligent meters - smart meters - to the electricity infrastructure should provide the grid intelligence the ability to cope with challenges and changes; thus, it is named smart grid (Verbong et al., 2013). We have learned that the smart grid system is a complex product system because its technologies, components and interfaces are interdependent; hence, the smart meter as its key node is a complex product (Ligtvoet et al., 2015; Suarez, 2004). However, the societal rejection of smart meters detains the introduction of smart meters in the Netherlands. Societal rejection results from a lack of consideration of social ethical values and conflicting values in society (Künneke et al., 2015). *The research objective is to determine the most important values for the social acceptance of smart meters and formulate design requirements that facilitate its social acceptance in the Netherlands*.

We have reviewed social acceptance literature, finding multiple studies (Künneke, Mehos, Hillerbrand, & Hemmes, 2015; Ligtvoet et al., 2015; Narayanan & Chen, 2012; Shin, Kim, & Hwang, 2015) stating that a complex technology such as the smart meter should be assessed from multiple perspectives. We build our concept on the social acceptance concept of Wüstenhagen et al. (2007), adapting the dimensions to socio-political, market and household acceptance, which represent the important stakeholder groups for smart meters. Literature regarding each group of stakeholders' acceptance was analyzed to derive and define their values, namely energy policy, network economics, technology management, technology acceptance, applied ethics and ethics of technology literature stream (see Appendix 1). Our multidisciplinary approach to analyze the acceptance and selection of a complex technology is a first notion and our theoretical contribution.

This framework for the social acceptance of smart meters enables utilizing experts representing and possessing insights into the group of stakeholders to evaluate the importance of the values. After a qualitative validation of the values, the best-worst method (Rezaei, 2015) was utilized to evaluate the importance of the values, which is a first notion to measure the importance of the values with this method, our methodological contribution. Three experts performed the qualitative validation of the values. The evaluation of the values with the best-worst method was conducted with ten experts for smart meters and showed privacy as the most important value for socio-political and household acceptance, as well as cost-effectiveness for market acceptance of smart meters. Due to different regulation about privacy, there was no socio-political acceptance for smart meters (Bellantuono, 2014; Cuijpers & Koops, 2013; Ligtvoet et al., 2015). Several scholars have stated that for end users of smart meters, privacy is particularly important (AlAbdulkarim et al., 2014; Cuijpers & Koops, 2013; Darby, 2012; Verbong et al., 2013). On the other hand, cost effectiveness depends on the size of the market (Erlinghagen et al. 2014), the installed base of smart meters (Van de Kaa et al. 2011), which requires the acceptance of the end users and their importance for privacy.

The value hierarchy approach enables to formulate design requirements based on values. We demonstrate how design requirements can be formulated based on the value privacy. These design requirements should foster the social acceptance of the smart meters, although it is limited due the conflict with the other important value of cost effectiveness. Hence, the design requirements should be analyzed and evaluated with the other important values by the groups of stakeholders for acceptance.

Further studies should segment the groups of stakeholder (e.g. different end user groups) to analyze their important values, which enables creating service and incentive mechanisms for a particular group of stakeholders. Moreover, other complex products and other regions should be analyzed with our multidisciplinary approach, which would enable us to generalize our approach.

Acknowledgement

I would like to express my gratitude to Dr. G. van de Kaa, my first supervisor, for guiding me in the process of conducting this research and his support and feedback during the entire project. For my questions and doubts, he often provided suggestions such that I can answer it myself. Furthermore, I would like to thank him for giving me a new spark of perspective during my research, which helped me to broaden my view of the research. He also enabled me to attend seminars that were attended by smart meter experts from the energy industry. The help of these experts and their contacts enabled me to conduct ten interviews to evaluate the findings of my research.

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List of Acronyms

BWM – Best worst method
DDPA – Dutch data protection authority
DNO – Distribution network operator
DSO – Distribution system operator
HEMS – Home energy management system
ECHR - European Convention for the Protection of Human Rights and Fundamental Freedoms Introduction

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1 Introduction

Electricity and telecommunications infrastructures are indispensable elements in the present society and any sort of malfunction can have economic and environmental consequences (Luiijf & Klaver, 2006). In this thesis, we will focus on the electricity infrastructure associated with changes and challenges, due to the energy shortage and adaption to the current energy technological developments and progresses. According to Verbong, Beemsterboer, & Sengers (2013), electrical vehicles (EV) will compose as new load to the electric grid, which is expected to double the current average electric demand and reflect a potential shift to an all-electric society. The European Commission set new directives with the 20/20/20 objective, including a 20 per cent reduction in emissions, a 20 per cent increase in renewable generation and a 20 per cent improvement in energy efficiency by 2020 (Cavoukian & Dix, 2012, p. 4). Compared to the current centralized large power plants, renewable energy sources are decentralized, vary in capacity and the generation of electricity fluctuates based upon seasonal weather (Wolsink, 2012). Furthermore the maximum capacity of the grid is only required at 5% during the peak usage time, as a result of the consumer usage pattern(Farhangi, 2010). Reducing peak usage will prevent the grid expansion and can be viewed as reduction in emissions, which is one objective of the European Directives. Hence, the successful integration of the renewable energy source to the grid requires predictability to avoid the collapse, which guarantees the reliability of the grid (Battaglini, Lilliestam, Haas, & Patt, 2009).

The integration of information and communication technology (ICT) to the electric meter introduced smart meter, hence, intelligence will be added to the electric infrastructure (grid). Adding intelligence to the grid is associated as a smart grid (Ligtvoet et al., 2015; Verbong et al., 2013). Smart metering is a technically feasible solution whereby an intelligent meter - a smart meter - is installed at a residential house. Smart meters enable real-time tracking of the electricity usage & generation that facilitating better management of the grid (demand response); furthermore, the remotely limitation of electricity usage, and interconnection to the residential network devices (demand side management). These functionalities of the smart meters should address the issues related to the electrical grid (van Gerwen, Jaarsma, & Wilhite, 2006). Additionally, smart meters should enable end users to evaluate their consumption behavior and raise their efficiency (EC, 2011). These functionalities are major components for the implementation of a smart grid system, which promise a sustainable transmission and generation capabilities for the grid (Yu & Luan, 2009). According to Verbong et al. (2013), the development path of the smart grid significantly varies from the European super grid to local loosely linked micro grids and all these pathways are technologically feasible (Verbong et al., 2013). However, they emphasized that the willingness of the end users to accept changes in their homes and daily routine will not only shape the smart grid, but it will also influence the chances of successful implementation. For this research, end users are referred to individual consumers in a household with a smart meter.

Wolsink (2012)states that all actors in power production and consumption have changes in their roles in a developed smart grid system, whereby it can be concluded that the smart grid is not only a technical solution, but also a **socio-technical system**. According to Clastres (2011, p. 5400), the notation of smart grid is defined in Europe as "electricity network that can intelligently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies". Therefore, a smart grid system requires the interplay and link between elements from the electrical grid (technical) with the social and behavior aspect of the users, because it directly determines electricity demand and decentralized supply (Worm, Langley, & Becker, 2015). Specifically, the diffusion of the smart meters is essential, because it is an important node in the smart grid system, whereby smart meters monitor the energy and information flow to balance supply, distribution, demand and storage (Wolsink, 2012).

In large, complex technological systems like the electrical grid, the technologies, components and interfaces are interdependent and linked to a large, **complex product system** (Ligtvoet et al., 2015; Suarez, 2004). The smart grid system - which should be the successor of the electrical grid - can be associated as a complex product system and smart meter belongs to it. The interdependence between the products of a complex system requires cooperative activities and the alignment of interests and criteria from the various stakeholders belong to the economic and technological domains of the complex system (Rosenkopf & Tushman, 1998). On the other hand, interests of these domains intertwine with institutional and social implications (Ligtvoet et al., 2015) and can result in conflicting scenarios. The mandatory rollout of smart meters in the Netherlands is an example of how lacking ethical principles can result in societal rejection and ultimately postponing the rollout for several years (Ligtvoet et al., 2015; Schomberg, 2011). The more complex the product system, the more stakeholders are involve, which requires aligning their opinions for the acceptance of the technology by the society (Suarez, 2004). The focus on values from a moral and political dimension of the technology will enable a comprehensive view of the smart meter and smart grid development. The problem description will address the reasons for the rejection and postponement of the smart meter rollout.

1.1 Problem description

Several distribution network operators (DNO) or grid operator and energy utilities in the Netherlands offered the smart meter installation (AlAbdulkarim & Lukszo, 2009), although there was low customer awareness and integration towards smart metering (Hoenkamp, Huitema, & De Moor-van Vugt, 2011). The goal to shift towards renewable energy sources and reduce the electrical congestion problem requires acceptance of smart meters by households (Kaufmann, Künzel, Loock, Künzel, & Loock, 2013). Even though the current electrical energy supply systems are highly institutionalized (regulations, norms, etc.), they lack the support for adjustments in a customer-production relationship (Wolsink, 2012) and hence are not focused on smart meters. On the other hand, homeowner associations (Vereniging Eigen Huis) and Dutch consumer organizations revoked against smart meters, due to concerns regarding privacy as well as possible cyber security threats (Ligtvoet et al., 2015). Van de Hoven reviews the lack of consideration for ethical aspects, especially for privacy and security values as a result for the failure of the smart metering system (van de Hoven as citied by van de Kaa, 2014, p. 24). As a result, the rollout of the smart meters in the Netherlands was postponed for several years (AlAbdulkarim & Lukszo, 2011) and the mandatory rollout was overruled to a voluntary rollout for smart meters (Darby, 2012). Reviewing the development and deployment process of the smart meters, it becomes clear that technological constellation of the smart grid and development of the smart meters is discussed between politicians and policy-makers, developers and standardization committees. Ligtvoet et al. (2015) has taken the position that technology development is driven by wide range of stakeholders. However, they state that stakeholders such as households or household organizations were not involved in deployment process, which are less significant for the technical design but essential for the acceptance of the technology. Additionally, Kaufmann et al. (2013, p. 230) argue that a mandatory rollout has several drawbacks, because energy providers will choose the cheapest smart metering solution that provides value for them, while neglecting the essential values for customer acceptance, which is necessary to achieve a 20% reduction in energy consumption. Therefore, the choice of a technology implies social and institutional provisions without the technology would not be accepted and might not achieve its intended goals (Lightvoet et al. 2015). Shin et al. (2015, p. 155) stated that "the development of standardization policies involving national technology standard-setting efforts is not a simple decision-making process, these policies have to be analyzed from various perspectives".

According to Wüstenhagen et al. (2007), barriers for achieving a successful implementation can be manifested as a lack of social acceptance. Societal and ethical issues can be endorsed and viewed through **public values** (Chittenden, 2011, p. 1556), which are valuable for the technological design process (Taebi, Correljé, Cuppen, Dignum, & Pesch, 2014). Therefore, smart meter technology must be assessed regarding its acceptance from social and ethical values. Wüstenhagen et al. (2007) have conceptualized the social acceptance of renewable energy technologies and determined three dimensions: market, socio-political and community acceptance. Each dimension can be associated with a group of stakeholders' perspectives of acceptance for a technology, which can be utilized to highlight the important values from stakeholders for the respective dimension.

Taebi & Kadak (2010, p. 1343) argued that "acceptance of a technology relates more to the way values are prioritized and traded off than how one single value is conceived". Therefore, the values from each dimension need to be evaluated by the stakeholders of the particular dimension to determine the importance of the values in the respective dimension of acceptance. Translating the important values to norms that are used to set standards and policies will provide design requirement and foster the acceptance as well as diffusion of the technology (Van de Kaa, 2014).

The concept of smart grid was introduced and promised to have a sustainable transmission, energy efficiency and reduction (AlAbdulkarim, Molin, Lukszol, & Fens, 2014; Ligtvoet et al., 2015). However, it conceals a shift to a more decentralized, various sized and seasonal fluctuating energy generation in contrast to the current electrical grid (Wolsink, 2012). Hence, many scholars referred to the smart grid as a socio-technical system and smart meter as its key node (Al-Abdulkarim et al., 2014; Ligtvoet et al., 2015; Von Schomberg, 2011). However, these scholars also stated the lack of social and ethical consideration in the innovation and design stages, which led to the societal rejection of smart meters in the case of the Netherlands. Ligtvoet et al. (2015) emphasized that other stakeholders such as households play a significant role in the acceptance of a technology. The acceptance of the smart grid system requires addressing its socio-ethical aspects because the smart grid system is a complex product system. Therefore the values at stake for smart meters need to be assessed, because it is the key node of the smart grid system. The focus of the research is to address social and ethical issues for the acceptance of smart meters by identifying the *values at stake for the social acceptance of smart meters*, as well as *categorizing* and *prioritizing* them according to the dimensions of acceptance.

1.2 Research objective

To address societal rejection of smart meter in the Netherlands, the social acceptance of smart meters will be conceptualized into different groups of stakeholders' perspectives for the acceptance of technology (Wüstenhagen et al., 2007). Social rejection is a result of conflicting values in society regarding the technology (Künneke et al., 2015). Values of a different technical, economic, social and moral nature play a role in the design and production of technical goods and services (Kroes & Poel, 2015, p. 152). Each group of stakeholders' values for acceptance will be analyzed regarding the salient values for smart meters. Additionally, the analysis will point out the stakeholders relevant for each dimension, which will enable evaluating the importance of the values of smart meters. The prioritization between the values in each dimension will illustrate the key values for market acceptance, as well as key values for socio-political, market and community acceptance. Incorporating the key values to technological (e.g. standard) and institutional (policies, norms etc.) design will foster the acceptance of smart meters and ultimately facilitate the diffusion of smart meter technology. The approach to include stakeholders values for the acceptance of a technology into the technological and institutional design has been utilized for offshore wind-energy systems, nuclear power and shale gas technology (Dignum, Correljé, Cuppen, Pesch, & Taebi, 2015; Künneke et al., 2015; Behnam Taebi & Kadak, 2010).

The aim of the research is to analyze the importance of the eminent values in each dimension of acceptance of smart meters. The identified stakeholder groups representing a dimension of acceptance will be interviewed utilizing the best-worst method (BWM), which enables establishing weights of the values in each dimension. Hence, the importance of the values in the respective dimension can be depicted. The findings of the research will enable making trade-offs between the values to create norms and design requirements for smart meter technology. A value hierarchy (van de Poel, 2013) will be proposed with norms and design requirements from the key values for the social acceptance of smart meters. *The research objective is to determine the most important values for the social acceptance of smart meters and formulate design requirements that facilitate its social acceptance.*

1.3 Research Questions

The research objective enables formulating the research question for the Master Thesis. As has been discussed, the social acceptance of smart meters (the key nodes of the smart grid) can be conceptualized to market acceptance, socio-political and community acceptance. The important values for the social acceptance of the smart meters - identified by the different dimensions - will be assigned to the conceptualization and compared. The main research question will address the research objective of ascertaining the importance of the values and formulating design requirements for the social acceptance of smart meters.

Main-RQ: "*Which values are important for the social acceptance of smart meters and design requirements to facilitate its social acceptance in the Netherlands?*"

To resolve this research question, a set of sub-research questions have been formulated, which will provide insights and build the answer for the main research question.

The first step is to assess the conceptualization for the social acceptance of smart meters. Information will be gathered regarding smart meters and their innovation processes, as well as the smart grid development with a specific focus on the value-sensitive design, which comprises social and moral values of the end users.

Sub-RQ1: "*How can acceptance of smart meters be conceptualized?*"

The result will depict the framework for the social acceptance of smart meters based upon Wüstenhangen et al.'s (2007) conceptualization, where each dimension for acceptance is assessed regarding the smart meter technology and smart grid. This dimension represents a perspective of a group of stakeholders and hence their important values should be identified.

The second step will focus on deriving the relevant values of each dimension for smart meter technology's acceptance, as well as the relevant stakeholder for each dimension. The set of values will be broadly and intersubejctivly formulated for a group of stakeholders; by intersubjectively formulates values different individuals and stakeholders could relate to these values, regardless of their subjective value systems (Taebi & Kadak, 2010, p. 3). Information will be gathered regarding the different economic, socio-political and standardization perspectives, as well as ethics of technology regarding social and moral values (value-sensitive design), which includes the identification of the key stakeholders and human values.

Sub-RQ2: "*Which values should be considered for the social acceptance of smart meters?*"

These findings will point out values for the social acceptance of smart meters as well as the relevant stakeholders for each dimension of acceptance. Experts will validate the set of values qualitatively to ensure that the right values have been determined.

However, values are often conflicting and to utilize these values in the technology design, innovation process and institutional design, the importance of these values must be determined. Hence, the importance of the values for the conceptualized dimensions of social acceptance need be identified, which will depict the relevance of the values at stake for smart meters.

Sub-RQ3: "*What is the importance of the values in each of the conceptualized dimensions for the social acceptance of smart meters and how can they be explained by the extant literature?*"

The results of Sub-RQ3 will enable establishing the importance of the values in each dimensions of acceptance of smart meters. The prioritization between the values in each dimension enables making trade-offs between the values in the design process, while also helping to comprehend the essential insight for the social acceptance of the smart meter technology and fostering the successful implementation of the smart grid system. Thereafter, the value hierarchy approach will be depicted as an approach to translate values to design requirements.

Sub-RQ4: "*How can the important values for the social acceptance of smart meters be translated to design requirements?* "

The outcome of Sub-RQ4 will illustrate the value hierarchy method and the steps required to formulate the design requirements for the social acceptance of smart meters. However, formulating design requirements for all the important values for social acceptance lies beyond the scope of our research.

1.4 Research Approach

The research will be conduct in three phases: desk research, including a literature review; semi-structured interviews; and a best-worst method (BWM) will be applied to establish the importance of the values for the social acceptance of smart meter technology.

Desk research

In the first phase, a literature review will be conducted to identify a list of values and create a framework for the social acceptance of smart meter technology. Literature regarding technology or standard selection, market acceptance, social acceptance, ethics of technology and value sensitive design will be utilized. The literature review will also enable highlighting the stakeholders for smart metering and a special focus will be given to evaluating their influence on the innovation and implementation process. Hence, the literature review will provide a subset of results for Sub-RQ1 and Sub-RQ2. The focus will be to assess the values and their relation to the social acceptance. The finding will establish grounds for Sub-RQ3 by highlighting the relation between values and smart meter technology acceptance.

In the second phase, the findings will enable focusing on the research for the values of smart meters' acceptance (Sub-RQ2). However, to find data and information about the relevance of the values for smart meters from the identified stakeholders of each dimension, interviews need to held to validate the relevance of the gathered values for smart meters (Sub-RQ2).

Semi-structured interviews

The findings of the desk research and literature review enable developing interviews with a pre-formulated direction. The focus of the semi-structured interview is to evaluate the desk research (set of values) and extend the set of values from the desk research. The collect data will be prepared for Sub-RQ3, which will be addressed by applying the BWM. The identified key stakeholders for smart meters are the suitable interviewees. Interviewees should have expertise about the smart grid and the events surrounding smart meters. Preferable interviewees should be strategic managers or advisors from intra-firms, energy providers and smart meter vendors, which are involved in the decision-making. However, in case of low attendance, project managers, consultants or researchers involved in the smart meter domain will be contacted for interviews. These interviews will provide essential inputs for the conceptualized dimensions for the social acceptance of smart meters.

Applying the Best-worst method (BWM)

The results from the semi-structured interview ensure the relevance of the set of values for the social acceptance of the smart meter.

BWM is an approach that evaluates criteria (values) in a pairwise comparison between the best and worst criteria of a decision (Rezaei, 2015a). It is particularly suitable if several criteria (values) play a role for a decision (dimension for acceptance). Hence, one to three experts representing the stakeholders of a particular dimension will compare set of values according to the BWM, which will enable structuring the values regarding their importance in each dimension for the social acceptance of smart meters (Sub-RQ3).

The results from the desk research and semi-structured interviews (Sub-RQ1 and Sub-RQ2) will be utilized to create the framework for the social acceptance of smart meter technology. The validation of the values will guarantee the relevance of the values. The output from the BWM will provide weights of the values, depicting the importance of the values in the particular dimension (Sub-RQ3). The smart meter social acceptance framework will enable policy makers and key stakeholders to make decisions between the values in each of the dimensions. Translating the important values to design requirements that foster social acceptance of the smart meters requires creating a value hierarchy for the important value, which needs to be a trade-off (Sub-RQ4). The structure of the research approach is illustrated in Figure 1.

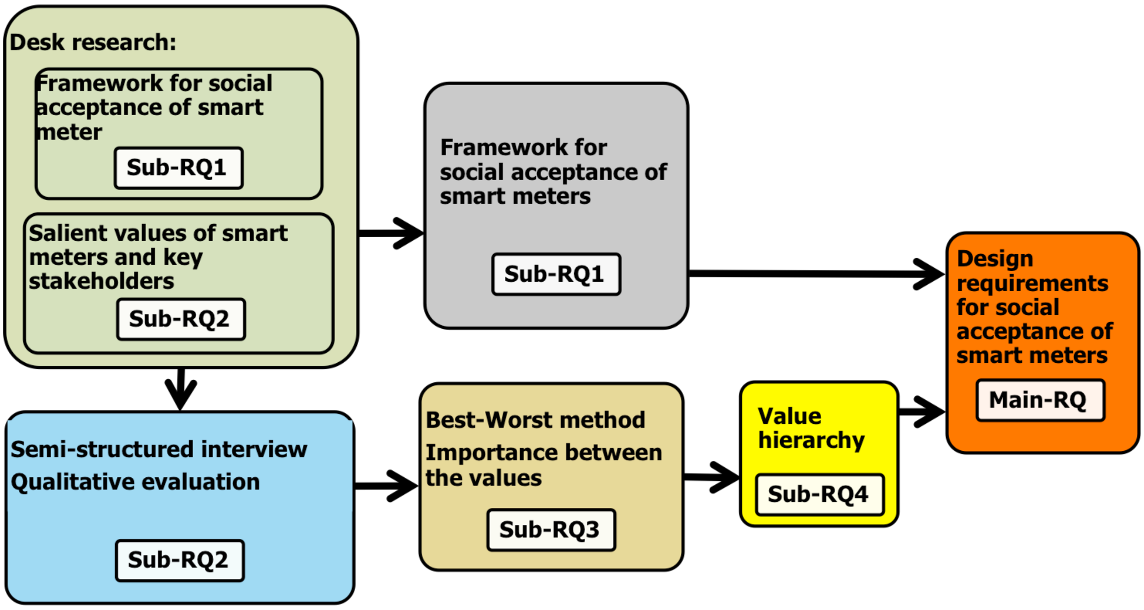

Figure 1: Research Approach

Desk research and semi-structured interviews should be conducted regarding the duration of the research. Therefore, the depth of the desk research will depend on the possibilities for the interviews. If interviewees are available for the semi-structured interviews, then the desk-research will only be conducted for an overview to formulate the semi-structured interview. In case of low responses for interview participation, the desk-research will be conduct in depth. Therefore, it is essential to determine the availability of interviewees at the outset.

1.5 Academic relevance

Attempts to investigate a technology from different perspectives for the technology selection or acceptance have mainly conceptual nature(van de Kaa, 2013; Van de Kaa, 2014). We will go a step further and analyze the acceptance or selection of a technology based on important values for each perspective. Therefore, it is suggested to include the opinions of various groups of stakeholders for smart meters, from multiple perspectives (Van de Kaa, 2014). This research aims to fill this gap by conducting empirical interviewees between several groups. Hence, the empirical contribution of our research will increase the generalizability to analyze the acceptance of complex technology from multiple perspectives, as suggested by several scholars (Brunsson, Rasche, & Seidl, 2012; Narayanan & Chen, 2012; Shin et al., 2015).

On the other hand, the research will apply the best-worst method (BWM) and depict the operations to assess the importance of the often-contradicting values (independence of assessing values) for social acceptance. As a result, the application of BWM to operationalize and assess the importance of the values will be a proof of concept for the BWM in the ethics of technology field; to date, the BWM has been utilized for decision-making with multiple factors in the supply chain field.

1.6 Limitation

The importance of the key values in each dimension for social acceptance will enable making a trade-off between the conflicting values in a dimension. However, the importance between the three dimensions for social acceptance will not be evaluated. The importance between the stakeholders varies depending on the scenario and hence reflects a limitation for the research.

The values for each dimension of social acceptance are gathered from the literature. However, values have different meanings: it can be related to the monetary definition of an object, values standing for principles and standing for themselves without applying to an object or values describing individuals' importance and the usefulness of an object (de Greef, Mohabir, van der Poel, & Neerincx, 2013). The latter is referred to as an instrumental or subjective value, which is also our perspective of values (van de Poel, 2009). This group of stakeholders with intersubjective values represents a dimension, although the dimension can be segmented to further sub-groups of stakeholders, which will increase the complexity of the evaluation and outcome. Thus, further segmentation is out of scope for our research.

The technological solution for the value will be a normative statement, suggestion and possibilities of technological (smart metering) and institutional design. Hence, we will not assess all the available smart metering solution, but rather we will point out technological and institutional implications for the particular important value. According to Ligtvoet et al. (2014), a fully quantified set of values provides guidance and enables distinguishing between options for an objective function.

The focus of the research will be limited to the Netherlands, because available experts are from the Netherlands and it is not feasible to conduct interviews in other regions due to time constraints. Additionally, values have differing importance in different culture and nations (Davis & Nathan, 2015); hence, a multi-national assessment for acceptance of a technology will not provide the implications for a particularly nation.

1.7 Thesis structure

The report of the thesis has been structured according to the research objective. In Chapter 1, the background about smart meters as well as smart grids is described. Furthermore, the problem definition for the technology is depicted. Building upon the problematic, a research objective has been developed, which enabled formulating the main research question: "*Which values are important for the social acceptance of smart meters and design requirements to facilitate its social acceptance in the Netherlands?*" This will be answered with a set of sub-research questions. Based upon the research objective and question, the research approach has been established.

In Chapter 2 first the concept of a smart meter and its functionalities in the Netherlands will be described. Moreover, the market structure of the electricity market in the Netherlands will be depict, illustrating the stakeholders involved in the smart meters, while the current legislation and policies about the smart meter will also be determined.

Furthermore, chapter 2 will address Sub-RQ1, which focuses on developing the concept based upon Wüstenhagen et al. (2007) for social acceptance and the literature streams about market acceptance and socio-political acceptance. Moreover, the value sensitive design will depict the framework and will have inputs about the values and stakeholders of each dimension of acceptance (setting ground for Sub-RQ2).

In Chapter 3, the methodology will depict the requirements for the BWM and the highlight the steps the BWM.

Chapter 4 describes the interviewees with representatives of the stakeholder group of each dimension and the resulting values from their evaluation. The importance of the values in each dimension will be analyzed by applying the BWM. Sub-RQ2 will be answered in this chapter and the ground for Sub-RQ3's answers will be set.

Chapter 5 will depict the value hierarchy approach, which enables formulating design requirements (technological and institutional) for the important values. For the design requirements, the values need to be traded off and the consequences for the trade-off will be discussed, which answers the Sub-RQ4.

In Chapter 6, we will discuss the most important values for each group of stakeholders (dimension), which will answer Sub-RQ3. Additionally, the scientific contribution and limitation of the research will be described.

In Chapter 7, the conclusion of the research will be provided by answering the main-RQ and the sub-RQs. Moreover, recommendations for further research will be suggested.

1.8 Conclusion of the Introduction

The electricity Infrastructure is an indispensable element in present society (Luiijf & Klaver, 2006), which is associated with changes and challenges due to new policies regarding energy efficiency, the reduction of energy production and sustainable energy production. The introduction of intelligent meters - smart meters - should provide the grid with intelligence to cope with challenges and changes, which is named as a smart grid (Verbong et al., 2013). We have learned that the smart grid system - the successor of the electrical grid - can be associated as a complex product system because its technologies, components and interfaces are interdependent (Ligtvoet et al., 2015; Suarez, 2004)**.** A smart meter as key node of the smart grids system is a component of the complex product system. However, societal rejection of smart meters detains the introduction of smart meters in the Netherlands. We have identified that societal rejection is a result of lacking consideration of social ethical values and conflicting values in society (Künneke et al., 2015). Hence, the important values for the social acceptance of smart meters in different group of stakeholders needs to be determined. We formulated the Main-RQ: *Which values are important for the social acceptance of smart meters and design requirements to facilitate its social acceptance in the Netherlands?*

The answer for the Main-RQ will be built upon four Sub-RQs. The Sub-RQ1 determine the concept for the social acceptance of smart meter, based upon Wüstenhagen et al.'s (2007) conceptualization. Several scholars have suggested to review the selection or acceptance of technology and its policy standardization from multiple perspectives (Brunsson et al., 2012; Ligtvoet et al., 2015; Narayanan & Chen, 2012; Shin et al., 2015). Hence, different stakeholder groups' literature streams (multiple perspectives) will be assessed to determine their important values, which will be qualitatively validated (Sub-RQ2). The BWM - a multi-criteria decision making method (Rezaei, 2015a) - will be used to evaluate the importance of the group of stakeholders' values for the social acceptance of the smart meter (Sub-RQ3). The important values will be formulated to design requirements (Sub-RQ4), which will ultimately facilitate the social acceptance of smart meters.

The thesis comprises seven chapters, with the first introducing the problem definition, research objective and research questions, in the further chapter addressing the research questions, and in the finally chapter answering the research questions and suggesting recommendations.

2 Literature Review

Information about the relevant values and the stakeholders for smart meter has been gathered from the literature review. In this chapter the first sub question Sub-RQ1 - *How can acceptance of smart meters be conceptualized?* we will address. The social acceptance literature depicts influential stakeholders as well as their essential values for each dimension of acceptance for smart meters. As mentioned in the research objective, the conceptualization of social acceptance from Wüstenhagen et al. (2007) and associated Energy Policy publication will be the key papers for the social acceptance literature stream.

Literature from Energy Policy referring to the social acceptance and smart grid as well as smart meter will be utilized to gather information about the socio-political acceptance of smart meters as well as for the end-users. The market dimension from the social acceptance will be analyzed from various perspectives, which includes literature from network economics as well as technology management.

Additionally, in this chapter the foundation will be set for Sub-RQ2: "*Which values should be considered for the social acceptance of smart meters?*" The values will be identified from each literature stream addressing the important values of a group of the stakeholder that equates to a dimension of acceptance. These values will be refined with the Value Sensitive Design (VSD) approach, which is based on applied ethics and ethics of technology literature. This literature will illustrate the characteristics and definitions of the values and implications for the derived values. Moreover, the moral and social definitions for the values are derived from this literature stream. This approach has been utilized for social acceptability of shale gas technology in the Netherlands (Dignum et al., 2015, p. 5). The information from each literature stream will be utilized to build the framework for the thesis.

However, initially a description about smart metering concept, deployment event, and electric market structure in the Netherlands will be provided. This will show the important stakeholders for the smart metering case in the Netherlands.

2.1 Smart metering case in the Netherlands

The Introduction briefly mentioned the functions of the smart meters that are major components to implement the smart grid system. In this section the concept of smart metering, its deployment, and market structure in the Netherlands will be described. Through this, the important stakeholders for the Dutch case will be highlighted.

2.1.1 Smart metering concept in the Netherlands

Smart meters are installed in a household to measure remotely the electricity and gas consumption. Electricity smart meters together with gas, heat, and water meters can be interconnected into a large network offering a potential value to implement energy savings and other energy-related services. Compared to the traditional meters the smart meter can offer services, such as remote activation/deactivation of the energy connections and two-way communication between the smart meter and the service provider.

The Dutch Normalization Institute NEN formulated the following requirements (NTA 8130) for the smart meter in the Netherlands (Alabdulkarim, 2013, p. 73):

- Generate remotely meter readings on a periodic base, which contains energy usage and if applicable the supplied energy.
- Provide end-users with real-time energy usage to create energy saving awareness and services (demand side management).
- Enable remote activation / deactivation or limitation of electricity
- Enable flexible tariffs and prepaid electricity offers
- Monitor the distribution network and fraud detection
- Measure power quality remotely

An added value for the end users is that they can get information from the smart meter about their billing situation. According to Alabdulkarim (2013, p. 76) under the conventional meters consumers were charge based on approximate estmations balanced out at the end of the year. Smart meters can provide more accurate billing, depending on periodic meter reading. A second feature from smart meters for end users is the real-time tracking of the electricity consumption in the household. Additionally the smart meters facilitate switching between energy supplier, since the smart meter enable the transmission of the meter reading anytime. Figure 2 illustrate the concept of smart metering in a household in the Netherland.

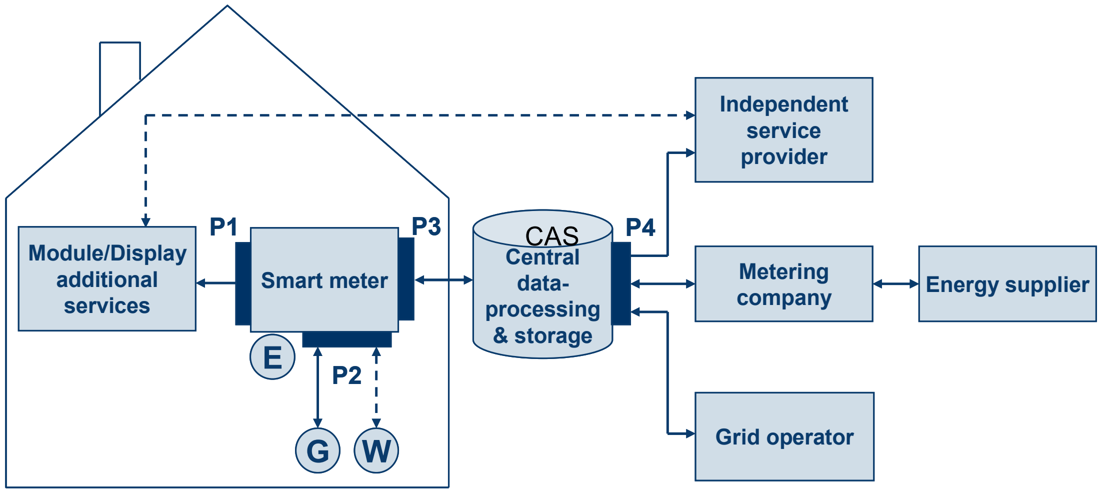

Figure 2: The concept of the smart metering from a household based on Gerwen et al. (2010, p. 42)

E/G/W in figure 2 represent electricity, gas and water respectively. P1 to P4 in figure 2 are communication ports also defined in NTA 8130 (AlAbdulkarim & Lukszo, 2009; Vasconcelos, 2008):

- P1: Read only port, external devices in the household can connect via this port to access meter readings
- P2: Through this port the smart meter can be linked to grid operators metering devices (up to four)
- P3: A two communication to connect the smart meter through intermediate nodes to the central access server (CAS)
- P4: This port is not located on the smart meter, instead on CAS, where the distribution network operator, suppliers and independent service providers (appointed by the end-users) have access to the meter readings

The change from mandatory to voluntary rollout offers two options for the end users to limit the functionalities regarding the meter reading from the smart meter (see Table 1). Moreover household owners can also deny smart meter. The reason for the change will be discuss in the next paragraph.

Table 1: Limited function according the different options for smart meters based on (Gerwen et al., 2010, p. 43)

Function	Administrative-off	Standard reading	Detailed reading
Frequent reading (quarterly/ hourly) and flexible tariffs	✖	✖	✔
Measure power quality remotely	✖	✔	✔
Monitor the distribution network and fraud detection	✖	✔	✔
Bi-monthly reading and at changing the supplier or house	✖	✔	✔
Remote de-/activation or limitation	✖	✔	✔
Meter data locally available (P1)	✔	✔	✔
Metrological control the meter	✔	✔	✔

Metrological control of the meter is characterized the control and maintenance of the meter e.g. its status (battery, alarms, error messages), firmware updates etc. Depending on the option chosen, the end-users transmission of the meter reading (energy usage) is limited, which limits the DNOs to improve their grid-management and energy supplier to offer additional services.

2.1.2 Incentive and system rollout of smart meters

The European Union have set several directives (2005/89/EC, 2006/32/EC, 2009/72/EC) to increase the end-users energy efficiency, saving and active role in the electricity supply market; furthermore, reliability and safeguard of the electricity infrastructure needs be guaranteed, but still facilitate the liberalization of the electricity market (AlAbdulkarim & Lukszo, 2009). Smart metering was indicated as a key to achieving these goals and European states were responsible for the rollout to achieve 80% deployment by 2020(Gerwen et al., 2010, p. 21).

The European directives for smart meters were implemented by each state according to their incentives and goals. For the Netherlands, the main incentives were to improve the liberalization of the electricity market (competitiveness, transparency), eliminate further electricity production expansion, improve energy efficiency (protect environment), and improve the management of the grid (fraud detection, locate power cuts and improved demand & supply planning). The rollout and deployment strategies were based on these incentives.

The evaluation of a rollout strategy for smart meter started in 2004 with several reviews of the cost-benefit analysis. In 2007 a smart metering technical standard (NTA 8130) was released by the Dutch Standardization Institute (NEN – Nederlands Normalisatie Instituut) (AlAbdulkarim & Lukszo, 2009). Additionally, a legislative proposal was formulated for the mandatory rollout of smart meters in 2008, since a voluntary rollout were estimated by grid operators, energy suppliers and producers to have only a 30% adoption rate.

Due to privacy concerns, the Dutch consumer organization and homeowner associations were against the mandatory the rollout and demanded a voluntary rollout where end users could to decline the smart meter(Cuijpers & Koops, 2013; Ligtvoet et al., 2015). Dutch upper house of Parliaments required the Ministry of Economic Affairs to change the rollout proposal and allow voluntary rollout; as a result the voluntary rollout with several options for the end-users (see Table 1 above) was formulated (Alabdulkarim, 2013, p. 65). The revaluation of the cost-benefit analysis indicated that only at 80% acceptance rate by the end-users with standard reading (Table 1) could bring in a positive business case (Gerwen et al., 2010, p. 50). In 2010 the Dutch upper house of Parliament approved the consumer's the right of voluntary adoption of the smart meter (Alabdulkarim, 2013, p. 66).

2.1.3 Market structure for smart meters in the Netherlands

Traditionally, the policy goals for the Dutch electricity market have been reliability, affordability and environmental sustainability(De Vries, Correljé, & Knops, 2010, p. 5). To increase competitiveness and create more choices for the end-users, the Dutch residential electricity market was opened up for liberalization in 2004 (AlAbdulkarim & Lukszo, 2009). Through this, the incumbent energy companies' (Alliander, Enexis) distribution network was unbundled and owned by the local government authorities in the Netherlands (De Vries et al., 2010). DNOs (distribution network operators) are therefore a regulated entity in the Dutch electricity market. The smart metering system, which belongs to the electricity infrastructure, resides mainly in the regulated domain because the operation and management of the grid is the task of the DNOs (AlAbdulkarim & Lukszo, 2009). The metering reading however belongs to the energy suppliers and end-users, thus in the liberalized market. Figure 3 depicts the division of different smart meter elements in regulated and liberalized markets.

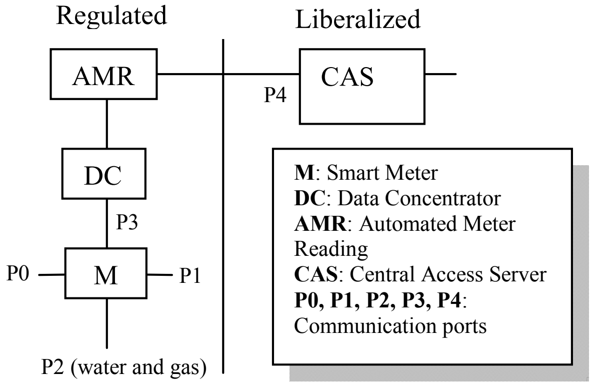

Figure 3: Smart metering components within the market structure from AlAbdulkarim & Lukszo (2009, p. 2)

Data concentrators (DC in Figure 3) manage the meter readings from the households (substation) and link the collected data to the CAS (AlAbdulkarim & Lukszo, 2009). Liberalized market stakeholders only have access to the CAS, whereas DC is managed by the DNOs.

In this section, the main actors in the smart metering case of the Netherlands have been described. From the deployment and policy points, the actors involved are the Ministry of Economic of Affairs, the Dutch standardization institute, and the Dutch parliament (upper chamber and second chamber). However, their policies and strategies were initiated in order to achieve compliance with the European Directives from the European Commission.

The Dutch consumer organization and homeowner associations are stakeholders with the interest for the end-users requirements from the smart meters.

The Dutch electricity market structure comprises regulated and liberalized stakeholders. The DNOs are regulated stakeholders, which are responsible for the operations and management of the distribution network. The energy suppliers (retailers) and also energy service providers (e.g. HEMS) are stakeholders belonging to the liberalized market section.

The following section will explain about Infrastructure technology and society, since smart meter is an infrastructure technology that needs to be accepted by the society.

2.2 Society and Infrastructure technology

The introduction and adoption of a new infrastructure technology requires social acceptance due to the perceived risks of a new technology (Sauter & Watson, 2007). Telecommunication and electrical infrastructures are evaluated as being the most critical in case of malfunctioning (Luiijf & Klaver, 2006). According to Sauter and Watson (2007, p. 2772), the term social acceptance consists of ***social***, which refers to society and its different groups (consumers, producers, etc.) and ***acceptance*** that varies from between passive consent to active involvement. They state that infrastructure technologies such as the entire electricity grid only require a passive acceptance by the local population. Ligtvoet et al. (2015, p. 173) state that the public may still be able to judge the technology of their energy supply, but they remain uninvolved (passive consent). Smart meters on the other hand are mostly visible to the people in the household, thus getting their attention (Ligtvoet et al., 2015). The technology acceptance model (TAM) is a commonly used model to investigate acceptance, but it emphasizes technology adoption from an organizational context (Curtius, Künzel, & Loock, 2012, p. 65). However for the acceptance of an infrastructural technology requires evaluating the values of the different stakeholder involved with the technology. Attitudes regarding a technology can be generally divided into public and private attitude; public position regarding an infrastructure technology represents moral values of the population; private attitudes on the other hand represent personal needs (Ek, 2005). Wüstenhagen et al. (2007) segregate social acceptance into different dimensions rather just public acceptance. Wolsink (2013, p. 1785) states that social acceptance should not be misconceived as public acceptance, which only focuses on the public view, but for the successful implementation of new infrastructure technology the acceptance from individual key stakeholders, which is determined as social acceptance, is crucial. Carlman (1984), one of the first to access social acceptance, defined different type of acceptance and determined that social acceptance is beyond public acceptance.

2.3 Social acceptance

Many scholars discuss social acceptance in terms of conflicting interests among stakeholders groups after the technology has been developed and during its deployment (Künneke et al., 2015). According to Wüstenhagen, Wolsink, and Bürer (2007, p. 2684) social acceptance of a technology can be divided into three dimensions: socio-political acceptance, community acceptance and market acceptance. The dimensions will facilitate policy makers and stakeholders supporting the smart meter technology to formulate strategies and design policy, norms and regulations according to the important values for the acceptance of smart meters.

The objective of social acceptance addresses the different groups of stakeholders' acceptability of the relevant values of smart meters to ensure a long-term support of these within in the smart grid context. Policy makers need to prioritize between values' acceptability in the market in their policies as well as to prioritize between smart meter values' acceptability in the household (Wüstenhagen et al. 2007). These values are also essential for the stakeholders from the market acceptance dimension and need to be integrated into their design for smart metering system, which will foster a high rate of adoption for smart meters. The social acceptance of smart meters can be reached by addressing the values of each dimension of acceptance or group of stakeholders.

2.3.1 Socio-political acceptance

Socio-political acceptance is the broadest general level of social acceptance and focuses on policies for the technology made by the policy makers and its acceptance as well as trust by the key stakeholders (end-users, market actors) (Wüstenhagen et al., 2007). In case of complex infrastructure like the electrical grid, all stakeholders' values are essential for socio-political acceptance (institutionalization), which in turn will facilitate the adoption and diffusion of the technology (Link & Tassey, 1986). Designing appropriate policies not only includes technological criteria, but also insight about preferences and demands of the end users (Chou & Gusti Ayu Novi Yutami, 2014).

Policies, norms, regulations or institutional changes are required if the new technology will lead to a fundamental shift in thinking, designing and operation of the system (Wolsink, 2013b). For instance, the shift to decentralization and varying the power production capacity of the smart grid system is a fundamental shift from the current electrical grid. Additionally, the smart grid objective to shift the load from the peak period, requires the introduction of Demand Side management (DSM). DSM combines smart meters and smart appliances (washing and drying machine or EV's) and allows demand to match with the available supply (Verbong et al. 2013). The objective and goals are initiated and based on the values from policies and directives.

The electricity market in the Netherlands is based on the values of reliability, affordability and environmental sustainability (see section 2.1.3) (De Vries et al., 2010). However these values can conflict with the European Directives, hence need to be trade-off and to reach compliance with the directives. The policy standardization in Europe is hierarchical and influenced by the European Directives and standards (Bellantuono, 2014, p. 263). Hierarchical standardization is developed in a committee, where a network of actors discusses the content of this policy (van de Kaa & de Bruijn, 2015). In this committee, directives and policies are constructed through constant alignment of interests and depending on power constellation between the different member states (Backhouse, Hsu, & Silva, 2006). Especially in the energy policy sector, the standard setting is based on this approach, where European directives serve as a regulatory framework for the 'local' governments to create policies, regulations and standards for their energy market(Vasconcelos, 2008).

European Directives for smart meters have a mandatory nature, since the directives demanded to deployment of the smart meters by 2020 (see in 2.1.2). Therefore standards developed by local government have been created in the same standard-setting process. These new policies (institutionalization) for the implementation of smart meters could be impeded by the behaviors of the actors that are used to the existing institutions (Wolsink, 2012). One reason is that the standard-setting process for smart meters in the Netherlands lack the involvement from end-users and end-user organizations (Ligtvoet et al., 2015). Therefore the new technologies will change practices, resulting in promoting or undermining certain values (Taebi et al., 2014, p. 119).

Energy Policy papers address the policy implication for energy supply from economic, social planning and environmental aspects, covering from global, regional, nation to even local topics(Elsevier, 2015). In this thesis, the Energy Policy literature has been assessed regarding socio-political stakeholders for smart meter (European commission, Netherlands: ministry of economic affairs, Dutch parliament, Dutch standardization institute) and policy, norms and regulations for the smart meters technology. Through this, the following values were derived (see Appendix 1 for definition of the values and relation to the socio-political stakeholders):

Privacy is undermined for smart metering, because grid operators can theoretically access the meter anytime (Horne, Darras, Bean, Srivastava, & Frickel, 2014) compared to manual meters, where they can only access it in the presence of the end-user. Policy makers need to design institutions, which should enable end-users to cope with the undermined value of privacy. Failing to do so is the case of the Netherlands, where the policy for a mandatory rollout of the smart meters was changed to a of voluntary rollout, due to privacy concerns (Ligtvoet et al. 2015; Darby, 2012).

Compatibility - Comparing the institutionalization of the cellular technology with the smart grid development (Peretz, 2011), Peretz (2011, p. 24) states that a uniform, national standard and ubiquitous **compatibility** will provide a significant edge for the adoption rate of the Smart grid. The smart meter is the key step to introduce the smart grid system.

Trust – the level of trust for the policies and regulation should be evaluated,. As stated by Verbong and Geels (2010) the strictness of the policies (level of carbon tax or emission norms) plays a role in the transformation of the electrical grid.

Cost-effectiveness - Verbong and Geels (2010, p. 1220) suggest the market-based policy-setting process have the goals regarding cost-efficiency (incentive-mechanism for utilities as well as end-users). Therefore the policy for smart meter should have a cost-effective nature for firms as well as for end-users (Wüstenhagen et al., 2007).

Reliability – policy goals for the electricity infrastructure should be to have a reliable system, because of different electrical power production sources, which are decentralized and fluctuates to seasonal weather (Verbong and Geels, 2010; Wolsink, 2012).

Environmental sustainability – in the Netherlands environmental incentives are key drivers in the electricity market, which also resulted in the mandatory roll-out of smart meters (AlAbdulkarim and Lukszo, 2011). One of the primary goals for the policy makers is to address the environmental issue (Verbong and Geels, 2010).

Autonomy – local control, **degree of control** or **autonomy** are important for households (Verbong and Geels, 2010; Sauter and Watson, 2007; Verbong et al. 2012). Therefore policies will be increasingly designed to enhance the autonomy of (local) groups of end-users (Wolsink, 2013, p.10).

Fairness (procedural justice) – Investment on both sides of the electricity meter should be treated equally (Sauter and Watson, 2007, 2778) and should have influence on the decision-making of the policies for smart meters. This is comparable to the case in the Netherlands, where customer organizations demanded the removal of the remote switch from the smart meters (Ligtvoet et al. 2015).

Institutionalization is required for new technologies, such as the smart meter, to foster and enhance market acceptance as well as the acceptance from the households for the successful implementation and diffusion of the technology (Wüstenhagen et al. 2007). Actors involved in the decision-making of the policies and regulations (institutionalization) in the Netherlands consist of the national government, agencies as well as the European commission, who provide principles and direction and is the regulatory framework in Europe. However, government agencies are influenced by organizations such as homeowner association, utilities or even standardization bodies (Ligtvoegt et al. 2015; Wolsink 2013), but their important values are derived in the other dimensions.

2.3.2 Household acceptance

Wüstenhagen et al. (2007, p. 1805) describe the acceptance regarding renewable energy technologies, where community acceptance has been found crucial for the siting decision of renewable project. In the case of smart meter technology, siting decisions are not applicable. However, they also stated that community or local acceptance of all types of infrastructure technologies, of which the smart meter is a type, is steeped in local conflict. The conflict for community acceptance described by Wüstenhagen et al. (2007) can be associated between public interest in smart grid versus private interests of the house owners in the context of smart meters. Sauter and Watson (2007, p.2772) stated that households' acceptance requires both positive public and private attitude to achieving market up-take. They reviewed the social acceptance regarding micro-grid deployment, small-scale domestic level power generation from individual households. Hereby they have distinguished acceptance regarding private attitude and investment (providing the site for renewable energy technologies, similar to Wüstenhagen et al. 2007 community acceptance), but also the change of energy consumption behavior of individual households. As previously mentioned siting and investment aspects are less significant for smart meter deployment.

According to Kaufmann et al. (2012, p. 229), households' economic benefits from cost savings from a reduced energy usage), is seen as an important benefit from smart meters. This requires households to change their energy consumption behavior. They also emphasize that the energy awareness as well as utilization of the smart meter (energy consumption feedback) are essential for the energy usage of the households. Therefore, Sauter and Watson's (2007, p. 2777) conclusion implies that in the case of smart meters, an 'active' acceptance or engagement from the household is required rather than a passive acceptance relevant for traditional large energy infrastructure technologies (e.g. nuclear power plant). Hence, for the household not only the values for passive consent, but also values for the active involvement of the end-users will be determined.

Considering the difference between the renewable technologies Wüstenhagen et al. (2007) evaluated for social acceptance and smart meter technology, the dimension community acceptance will be renamed as **household acceptance**; smart meters require 'active' acceptance from individual households rather than the approval of a community. Innovators (named by Rogers 1995, the first group to purchase a new product in its "introduction" phase), intrigued adopters with knowledge of energy problems and with financial capacity, have willingness for active involvement with the smart meter. Nevertheless, there is a lack of interest from the end-users (Verbong et al, 2013). Sauter and Watson (2007) on the other hand, have stated that end-users that moved into a micro generation houses, have raised their energy awareness if there is continuous information flow about how smart meters works. Thus, it is essential to provide the household with the information regarding energy consumption, awareness and the benefits from smart meters.

Existing literature presents different arguments for the end-users willingness to change. There are environmental reasons (feedback of energy consumption increases awareness), financial incentives (real time or flexible pricing) or punishment (higher cost for end-users refusing to adopt) (Hargreaves, Nye, & Burgess, 2010; Verbong et al., 2013). On the other hand, these scholars describe the inability of financial incentives inability to have a sustainable change in the behavior for the end-users consumption. Several barriers have been determined together with requirements for the acceptance of smart meters in the household. These values were determined from the literature regarding social and moral values as well as functional values for end-users of smart meters. (See Appendix 1 for definition of the values and relation to the household stakeholders):

Privacy - Verbong et al. (2013, p.120) state that privacy is considered an issue that the can block the successful introduction of smart grid and demand side management (DSM). Darby (2012, p. 103) states that end-users were concerned that their data will be shared with third parties, but did accept that their data will be useful for the government and energy supplier to predict the energy demand.

Autonomy – Verbong et al (2013, p. 122) state that barriers relate to **freedom** regarding what data to communicate and **degree of control** over e.g. smart appliances (smart washing machine), which also relates to the complexity of the system.

Usability – The smart meter and system around it (smart appliance or home energy management system) should reduce its complexity, meaning the system needs to be easy to use for the end-users (Verbong et al. 2013).

Compatibility - Kaufmann et al (2013) have evaluated the requirements of the smart meter end-users and determined that technology-minded end-users want to connect smart meters to their smart device, meaning that the smart meter should be compatible to connect to other apparatus.

Security – Failure in protecting the security of the end-users information will lead to resistance from the household and can lead to inability to involve end-users actively for demand side management (AlAbdulkarim & Lukszo, 2011, p. 287).

Cost-effectiveness – Many scholars state that financial incentives should attract customers to demand side management (DSM) by emphasizing on price-based demand response (Sauter and Watson, 2007; Wolsink, 2012; Kaufmann et al. 2013).

Environmental sustainability – The second most commonly expressed motivation for smart meters and smart energy monitors is environmental sustainability (Hargreaves et al. 2010, p. 6114). According to Verbong et al. (2013, p. 120) one argument has been that end-users are willing to change their behavior for environmental reasons.

Fairness (distributed justice) – Kaufmann et al. (2013, p. 229) state, *"consumers should receive appropriate benefits from any cost reductions achieved by the Energy supply industry resulting from smart metering"*.

Trust – Huijts et al. (2012, p. 528) state that *"when people know little about a technology, acceptance mostly depend on trust in actors that are responsible for the technology… "*

Wolsink (2013, p. 1805) states that **trust** and **fairness** are important for the acceptance between investors (energy utility firms and government) and the community. These also relate to the household acceptance, where trust and fairness is required to provide the investors with data and control of smart appliances. Therefore informing the end-users about the usage of the data to build trust and a fair usage of it can solve the barriers regarding privacy.

In the Netherlands, concerns about the privacy issues with smart meters were discussed and highlighted by the customer organizations and homeowner associations (Ligtvoegt et al., 2015); end-users were unaware or did not actively influence the government. Therefore, the important stakeholders regarding household acceptance are customer organizations and homeowner associations, rather than individual households.

Market acceptance focuses on diffusion and adoption of the technology and comprise communication and negotiation between customers, government, investors and intra-firms (large electric utilities, power technology manufacture etc.) (Wüstenhagen et al. 2007). The literature stream about format selection from economical perspectives will address the market acceptance dimension.

2.3.3 Market acceptance

The process of adoption and diffusion of an innovation by a consumer, through the communication process between individual adopters and their environment, can be interpreted as market acceptance (Wüstenhagen et al. 2007, p. 2685). Lee (1995, p. 6) states that after achieving market acceptance for a significant amount of time for providing a service or product it can be characterized as a dominant design.

Many scholars have investigated the emergence of a technology, the transition process between innovation and economic success, from multiple perspectives (Lee, O'Neal, Pruett, & Thomas, 1995; Suarez, 2004; Van de Kaa, Van den Ende, De Vries, & Van Heck, 2011). Suarez (2004) used the term technology dominance, or a dominant design, by analyzing the technology development between standard (VHS vs. Betamax) or Mobile Internet standard development (GSM and CDMA), where a single architecture becomes widely accepted as the industry standard(TEGARDEN, HATFIELD, & ECHOLS, 1999). De Vries (2007) on other hand, calls it "standard selection" from the standardization process of a technology.

Van de Kaa et al. (2011) combines various perspectives about the emergence of a technology and selects the term *format selection* or *format dominance*. These terms and definitions resulted from different perspectives; e.g. the evolutionary economist associates the selection of a format as a natural process (Arthur, 1989), because existing technology will be obsolete due to radical new technologies which create new markets and applications(Bower & Christensen, 1996). Industrial economists on the other hand reviewed the emergence of a new innovation from the technological lifecycle model (Utterback & Abernathy, 1975) and determined a new perspective, network economics, where also non-technical forces like market characteristics influence and determine the dominance(Katz & Shapiro, 1985; Lee et al., 1995). In contrast, Institutional economists have pointed out that a firm can facilitate selection of their format or technology by strategic decisions and communication. Combining the institutional and network economics perspectives, scholars indicate the importance of market and technology characteristics for the market acceptance by customers and the industry.

The technology characteristics determine the type of product, e.g. a simple product such as a kettle only requires a quality standard, whereas for complex systems (e.g. communication system or smart grid see in section 1) compatibility standards are essential to guarantee the interconnection between the components of the system. Schilling (1998, p.271) states that complex technologies have a tendency for increasing returns, because more usage will result in more enhancement of the system, which attract more users. Telecommunication technology can be defined as a complex system, because scholars describe network technologies as complex due to the interdependencies between the components and actors of the network (Majumdar & Venkataraman, 1998). Additionally network technologies have network externalities, which are the installed base (number of users) and availability of complementary goods. The network externalities have network effects, because a new user will bring benefits to the installed base (direct effect) and more complementary goods for the network will attract more users (indirect or cross-side effect) or more users will attract more complementary goods producers (indirect cross-side effect) (Suarez, 2004; Tiwana, 2014).

The smart meters are a complex technology that is based on communication technology and the electrical grid, and therefore can be characterized as a network technology or network component of the smart grid network. However, smart meters do not have direct network effects, but indirect network effect; a larger installed base does not attract new users, but more complementary goods for smart meters (e.g. smart home application) will attract more users, meaning there is cross-side effect of the network (Tiwana, 2014). Therefore suppliers, as well as users, want their device to communicate with each other, which requires compatibility between the devices (Besen & Farrell, 1994). Compatibility is essential for the diffusion of a technology, or else there will be a low demand, since vendors will disagree on a standard. This increases uncertainty for the end-users and ultimately delays the adoption or even prevent it, as was the case for AM-stereo technology (Besen & Farrell, 1994; Peretz, 2011). Standardization for compatibility between the standards will provide incentives for dominance of the technology (Schilling, 1998). This can be related to the conclusion of Link & Tassey (1986), that some technologies require standardization to create the critical mass for the diffusion of the technology. De Vries (2001) states that systematic standardization includes the continuous matching of a stable infrastructure, where the interface specification is kept unchanged for a long period of time, but components that changes shifts human behavior.

Van de Kaa et al. (2011) have evaluated all the perspectives and strategy implications and have created an overview of factors, which facilitate the adoption and diffusion of a technology and its markets acceptance. The factors are divided into five categories from the different economic perspectives. Erlinghagen et al., (2014) have compared the smart meter communication standards depending on technical and non-technical criteria to how Lee (1995) distinguished between technical and non-technical forces that influence the economic success of an innovation. Additionally they based their non-technical criteria on van de Kaa et al (2011) factors and used it to compare the smart meter standards. Moreover, the factors have been applied to analyze the technology battle in the wireless home network domain, a network technology (van de Kaa, de Vries, & van den Ende, 2015) and also to PC connection standards (USB and FireWire) or digital audio standards (MPEG-2 Audio vs. AC-3) (van de Kaa & de Vries, 2015). Furthermore, van de Kaa et al. (2011) factors for winning format battle has be utilized to analyze the highly regulated and monitored Chinese standardization (van de Kaa, Greeven, & van Puijenbroek, 2013), which is expediently, because the energy industry in the Netherlands also is highly institutionalized. Therefore the groups of factors from van de Kaa et al. (2011) were applied to the characteristics of the smart meter technology and the smart grid system values for market acceptance. Additionally, the evaluation highlighted the important stakeholders for market acceptance. If the relationship of the factor and market dominance has a negative direction (van de Kaa et al. 2011, p. 1403) it was excluded from the evaluation, because the objective is to find values that are important for market acceptance.

These factors have been applied to a methodology (AHP similar to BWM) to derive importance of the factors (van de Kaa, van Heck, de Vries, & Rezaei, 2014), which enables the selection of a technology, for instance, the technology selection among Photovoltaic technology designs (van de Kaa, Rezaei, Kamp, & de Winter, 2014). In other case the importance of these factors were derived for the selection of a build automation systems (van de Kaa, de Vries, & Rezaei, 2014). These factors are therefore suitable to derive the importance of them for the smart meter technology. The factors also account for stakeholders associated with market acceptance of smart meters that are the Energy suppliers, DNOs, manufactures of smart meters (format supporters), incumbent energy companies (big fish) and HEMS-suppliers (complementary good suppliers). These stakeholders' values' have be derived using the factors (See Appendix 1 for definition of the values relation to market stakeholders).

Quality is the overall value for technology superiority from van de Kaa et al. (2011, p. 1404). However, quality needs to be fragmented into efficiency (performance) and reliability of the smart meter, because according to Erlinghagen et al. (2015, p. 1255) smart meter standard G3 sacrificed data rate and latency (performance) to achieve more robustness. Quality needs to be categorized because the fragments of quality for smart meter are in contrast to each other.

Efficiency can be related to data rates/latency and range (distance) of a smart meter, which are two technical criteria to compare the smart meter communication standards (Erlinghagen et al., 2014).

Reliability on the other hand relates to robustness (technical criteria of Erlinghagen et al.) and correctness of the smart meter data.

Compatibility – relates to the fit between interrelated entities and the functioning together (H. J. de Vries & Egyedi, 2007) and differentiates between horizontal and equivalent objects to exchange data; backward compatibility to older types, and interoperability between equivalent objects and interrelated entities by Erlinghagen et al. (2014).

Availability of complementary goods - is associated with complementary goods for smart meters (e.g. smart appliances, HEM-systems), which creates demand-side economies of scale and will increase demand for the smart meters. Moreover, complementary goods are associated with **network externalities** and in case of smart meters have an indirect (cross-side) network effect of attracting more end-users, which will attract more complementary goods vendors.

Flexibility – relates to adapting the product's format to customer requirement, more specifically facilitating and fostering the adoption of the technology. For WiFi-standard, a network technology, this was an essential factor to reach the dominance in the market (van den Ende, van de Kaa, den Uijl, & de Vries, 2012).

Openness - associated with **appropriability strategy**, firms' actions to protect it from imitation by the competition and has negative direction regarding market dominance. On contrary, open licensing policy will increase the installed base. Erlinghagen et al. (2014, p. 1254) state that openness of a standard will enable many suppliers to offer the same standard and foster acceptance by the end-users for smart meters due to **lower uncertainty and risk**.

Ownership — Erlinghagen et al. (2014, p.1254) refer to the ownership of the communication network for smart meters, which can be either outsourced or is owned by some utilities to guarantee the smart meter networks reliability. In the context of reliability and ownership, the concern regarding responsibility of the network operation is an important issue (Verbong et al. 2013), whereby the question arises about the accountability of the smart meter in case of malfunction. Additionally the factor of scarce assets (van de Kaa et al. 2011, p. 1403) relates to ownership of the communication network, because firms acquire the communication network or frequency band to exclude competitor, hence can create competitive advantage.

Cost effectiveness - According to Erlinghagen (et al. 2014, p.1259), the cost for smart meters depends on the **size of the market** (current and expected installed base), because economies of scale will decrease the overall cost of production for smart meters, meaning a large utility can significantly influence the price of a smart meter type. Hence a large utility can be associated with Van de Kaa et al (2011, p. 1405) factor of *big fish*, which "can exercise a lot of influence by either promoting a format or by exercising buying power that is so great that this will tip the balance for the format to become dominant in the market". Another factor concerning cost is the type of replacement strategy for a smart meter, a comprehensive one (large scale or mandatory) or a selective one (voluntary or only specific type of end-users) Erlinghagen et al. (2014). Each strategy can be cost-effective depending on the communication technology (LAN for comprehensive and wireless for selective). This is comparable with the format support strategy from van de Kaa et al. (2011), **distribution strategy,** utilities ability to follow a certain replacement strategy; as well as the format supporter characteristics financial strength, because **financial strength** is essential to endure periods of low earnings from the investments (e.g. low priced smart meters). Even **operation supremacy** can be related to cost effectiveness, because vendors or hardware manufacture of smart meter, who have superior production capacity need economies of scale to create to create competitive advantage over their competitor.

Commitment — is a format support strategy factor from van de Kaa et al. (2011, p. 1405), which relates to the level of attention and support of a firm regarding a format or standard in case there are several standards available. Several standards leads to more uncertainty, where firms invest in multiple formats, however a firm's commitment to one standard has a positive direction for market dominance. In case of smart meters, there are several standards available, which increase the uncertainty in the market, and therefore the commitment of a firm to a standard is essential.

Publicity — the importance of marketing communication or publicity about the smart meters and its benefits for the end-users has been emphasized by several studies and scholars (Sauter & Watson, 2007; Darby, 2010; Kaufman et al. 2012; Verbong et al. 2013) and is essential to create the customers expectations, which has a positive effect on the market share (Van de Kaa et al. 2011, p. 1404).

Popularity (product rather than firm) — is value for market acceptance addressed by van de Kaa et al. (2011) and Erlinghagen et al. (2014) as bandwagon effect and also current installed base. Erlinghagen et al. (2014, p. 1254) state, "A large installed base typically creates bandwagon effects leading new users to choose the standard with the highest prospects of becoming dominant". Popularity is chosen to be on the product rather on the firm, because the product that has a large installed base is popular and will have bandwagon effect.

Trust - Wüstenhagen et al. (2007, p. 2687) and Wolsink (2013, p. 1805) emphasize that trust is important between customers and utilities. Firms and utilities with a good reputation and credibility will be able to attain end-user's and other stakeholders' (suppliers, regulators etc.) trust for their product and service around smart meters. Hence trust is also essential for end-users, which have their concern regarding their privacy or degree of control of their appliances (see household support).

Experience — firms and utilities, which have experience of the electricity market, smart meter technology and smart grid will be able to gain more market share and adjust to developments in the energy market. Investing in core capabilities and absorptive capacity around the smart meter technology will enable firms and utilities to adapt to changes in the market environment of smart meters and prevent them from being locked-out of the market (van de Kaa et al. 2011).

Moreover, van de Kaa et al. (2011) have gathered the important actors for the market dominance of a technology, which have been grouped under 'other stakeholders'. These actors and the format supporters (smart meter vendors, utilities) are the key stakeholders to evaluate the technical and non-technical values for the market acceptance of smart meter. Few of the actors from the 'other stakeholders' group were mentioned in the definition of the values for market acceptance. Current installed base and expected installed base, can be related to current market size and expected market size (Erlinghagen et al. 2014), which can be associated with the current end-users of smart meters and end-users using the previous generation of technology (pervious installed base van de Kaa et al. 2011, p. 1405), but have the possibility to upgrade (expected installed base). However in the dimension of household acceptance the values of the end-users have been evaluated and are not going to be included in the market acceptance. The same applies to regulators, which are evaluated in the socio-political acceptance for smart meters. The effectiveness of the format development process can be related to a standardization organization or committee's effectiveness with the process of determining and deciding on standard criteria (van de Kaa et al. 2011). Therefore standardization bodies and committees actors are key stakeholders, which consists of DNOs, energy supplier and vendors of smart meters and need to evaluate the values for market acceptance. As mentioned before, large utilities or incumbent energy companies (large installed base) can influence the price of the smart meter (Erlinghagen et al. 2014), hence can be associated with the big fish,*" a player … that can exercise a lot of influence by exercising buying power that is so great that this will tip the balance for the format to become dominant in the market*" (van de Kaa et al. 2011, p. 1405). Suppliers of complementary goods have a positive effect on market dominance for a technology, as well as on the diversity of network of stakeholders (suppliers) providing complementary goods (van de Kaa et al., 2011, p. 1405). Hence suppliers of HEM-products (controller, sensors, etc.), smart appliance and smart grid services and products are important stakeholders, who need to evaluate the values for market acceptance of smart meters.

2.4 Value Sensitive Design (VSD)

The process of creating value from a technical artifact, system or service consists of various steps, from design and development to production, sales and after-sales. Different stakeholders are involved in this process with different views on what kind of value is being created: the design engineer emphasizes on the technical values, managers on the monetary values meaning cooperate profit, end users may appreciate the value satisfying their needs and reaching their goals, and governments look at the public and social values (Kroes & Poel, 2015). Thus, division of social acceptance for smart meter technology into dimensions is necessary for considering different stakeholder's views of values. Moreover, design not only includes functional requirements but also moral values and designers and their design will be held accountable in case of failure in form of societal rejection, as was the case of smart meter roll-out in the Netherlands (Hoven, Vermaas, & Poel, 2015; Schomberg, 2011). Van de Poel (2009, p. 979) argues that a technology is not value-neutral. Moreover, in the design process of a new technology, an intended value from the designer is incorporated, which emphasizes or undermines certain values (Taebi et al., 2014). The increased awareness of values in the design raised the desire to control and influence the values in the design process (Manders-Huits, 2011). According to Van den Hoven et al. (2015, p. 3) this matter will be addressed in Design for Values and will contribute to the success, acceptance, and acceptability of innovations and as such will also have economic benefits.

According to Dietz et al. (2005, p. 329)the word *Values* comes from the Latin *valere*–to be strong, to be worthy, but in our everyday language it is used in three senses: what something is worth, opinions about that worth, and moral principle. Friedman et al. (2013, p. 57) defined 'value' as "*what a person or group of people consider important in life*" and that values should not be conflated with facts, because facts do not logically entail value. Friedman et al. (2008) were the first to create a comprehensive approach to address human values to technological design called the Value Sensitive Design (VSD) (Van de Hoven et al. 2015). They created a list with 13 human values with ethical importance, which could be implemented in the design (Friedman et al. 2013, p. 57) based on a tripartite methodology. They methodology comprises conceptual investigation - identifying the stakeholders affected by the technology including people using the technology (direct stakeholders) and people influenced without using the technology (indirect stakeholders); identification and definition of values implicated by the use of the technology, meaning by defining it in the context; empirical investigation - where the stakeholders will be examined about their understanding and experience in relation to the implicated values by the technology. It can be quantitative and/or qualitative methods used in social science research, including observations, interviews, surveys, experimental manipulations, collection of relevant documents, and measurements of user behavior and human physiology. The methods should focus on how the stakeholder apprehend individual value or how the value can be prioritized; technical investigations includes designing a new technology to support particular values or analyzing how particular features of the existing technologies support certain values in a context of use (Davis & Nathan, 2015; Friedman et al., 2013).

Even though VSD is well established in the information and communication technology domain, specifically in human computer interaction (HCI) field, practices and developments for different values and application domains are sometimes a bit disconnected (Van de Hoven et al. 2015). The Handbook of Ethics, Values, and Technological Design (2015) contains research based on Friedman et al. (2013) value sensitive design, which analyzes the method, outlined some shortcoming of the approach and suggested improvements. The handbook was utilized for the literature stream of Value sensitive design. The factors and challenges for social acceptance were redefined from values and description of values from the Handbook (2015) and sources cited in the handbook.

2.4.1 Critiques of VSD

As mentioned, the approach for VSD is based on a tripartite methodology and the methods are rather iterative and integrative and meant to inform each other rather than engage separately (Davis and Nathan, 2015). Even though VSD features the 13 values for design, scholars criticize VSD position on universality of the set of values and they argue that the value differ depending on culture and in the context of the technology (Borning & Muller, 2012; Manders-Huits, 2011). Therefore, Borning and Muller (2012 p. 1127) suggested that VSD should not recommend any position based on the universality or relativism of values, but rather leave VSD researchers and practitioners free to take and support their own positions on the value in the context of particular projects. They can either shift from a philosophical to an empirical basis. The value derived from the group of stakeholders can be related to an empirical base. However, this process should avoid naturalistic fallacy ('is' is not equal to 'ought') by qualifying prescriptive statements or utilizing the list of values from Friedman et al. (2013) in the context of the technology but avoid the list to have a distinctive claim on the resources in the design process. The definition of values, which were used for value sensitive design have be utilized to formulate the prescriptive statement for the values in the context of smart meters.

Many scholars claim that VSD fails to provide a method to identify stakeholders and does not include stakeholders' values to the design process (Davis & Nathan, 2015; Manders-Huits, 2011). Therefore identified stakeholders from each dimension for acceptance of smart meters will be utilized to evaluate the importance of the values at stake. The literature streams about social acceptance of smart meters have depicted the important stakeholders from different views as well important values and factors for smart meters acceptance. Through this, the shortcomings of the VSD have been remedied. Borning and Muller's (2012) suggestion to utilize the list of values from Friedman et al. (2013) will be also carried out. The values from the list will be compared to the derived values and factors from the literature stream of social acceptance and if necessary, adapted. Additionally the identified stakeholder will be asked to from their view the most important value for smart meters, because Dantec et al. (2009)and Iverson et al. (2010)suggest that values should emerge from the work with the stakeholders rather than by the research alone from the conceptual investigation. In the reviews of Borning and Muller (2012) and Davis and Nathan (2015) they have taken the stand that heuristic development of the value will reduce the risk to overlook areas of concerns. Borning and Muller (2012) suggest to be cautious and to add the context and point of view (e.g. culture) to the heuristic.

The thesis research meets the critiques of VSD by gather information regarding the stakeholders and values from the social acceptance literature, which were compared and redefined with the list of values from Friedman et al. (2013) and other value sensitive design papers. As a result, the critiques of VSD are resolved and a comprehensive framework for the social acceptance is created. Additionally, experts will validate the values from the framework for the social acceptance of smart meters and additional values resulting from the validation of the experts will be included to the framework, which is suggested by Dantec et al. (2009).

2.5 Framework for the social acceptance of smart meters

The literature review has depicted that infrastructure technologies like smart meters - which originated from communication and electrical infrastructure - are critical technologies for the society (Luijf and Klaver, 2006). However, such technologies do not enjoy adequate social acceptance due to their perceived risk (Sauter & Watson, 2007). Sauter and Watson (2007, p. 2772) state that social acceptance comprises ***social*** -referring to the society and its different groups of stakeholders (consumers, producers, etc.) - and ***acceptance***, which varies from passive consent to active involvement. Carlman (1984, p. 33) was one of the first to study social acceptance of such technologies, stating that social acceptance can be defined as public, political and regulatory acceptance. Many scholars have investigated social acceptance and often discuss it in terms of conflicting interests of various stakeholder groups after the technologies have been developed and deployed (Künneke et al., 2015, p. 118). Wüstenhagen et al. (2007) have conceptualized social acceptance for renewable energy technologies - including infrastructure technologies - as comprising three dimensions: socio-political acceptance, market acceptance and community acceptance, which represents the different groups of stakeholders' acceptance.

The division of social acceptance into different dimensions is similar to the different views for the design process of the technological artifact, where value is perceived differently among different stakeholder groups involved in the process to create value for the artifact (Kroes & Poel, 2015). The research around values from different stakeholders is investigated in the value sensitive design (VSD) approach by Friedman et al. (2008), reflecting "a systematic attempt to include value of ethical importance in design" (Van de Kaa, 2013, p. 62).

To achieve the objective of providing the most important values for the social acceptance of smart meters in the context of the smart grid system, we analyze the values in the dimensions for social acceptance. Therefore, we build our framework based upon the Wüstenhagen et al. (2007) conceptualization for social acceptance and the VSD approach by Friedman et al. (2008).

2.5.1 Socio-political acceptance

Socio-political acceptance is essential if the new technology ensues a fundamental shift in the design and operation of the system, which requires new policies, norms, regulations and institutional changes (Wolsink, 2013b) regarding the governance of the smart meters. Unhampered operation of decentralized, fluctuating power production with demand side management is the objective of smart meter technology (Verbong et al., 2013, p. 120), marking a fundamental shift from the existing large, centralized power plants (van de Kaa, 2013). The required new technologies will be impeded by the current consumption patterns and behavior of the end users. Hence, new technologies will promote or undermine certain values (Taebi et al., 2014, p. 119). Friedman and Kahn (2003, p. 1179) suggest that reoccurring view in many studies is that technological systems are not value neutral but invariably favor the interests of people with economic and political power. Especially in Europe, the regulatory framework is hierarchical, which requires national policies to incorporate European directives. Therefore, the key stakeholders for institutionalization (policies, norms, technical code, etc.) must evaluate the important values at stake for the socio-political acceptance of the smart meter (see Appendix 1). The key stakeholders for socio-political acceptance are national governments and agencies as well as the European commission and agencies (Ligtvoet et al., 2015). Their important values will be derived from the energy policy literature.

2.5.2 Household acceptance

Wüstenhagen et al. (2007) have identified community acceptance as being crucial for siting decisions regarding renewable projects, whereas smart meters require acceptance in the individual households. Ligtvoet et al. (2015) emphasize that stakeholders such as households play a significant role in the acceptance of a technology that is essential for the market uptake (Van de Kaa, 2013). Van de Kaa (2014, p.27) states that technology acceptability can be increased by meeting the functional as well as social and moral values of the end users. We choose the term household acceptance for the social acceptance dimension of the end users of smart meter technology because the decision to accept and use a smart meter depends on a household rather than a community or an individual person, even though acceptance ranges from passive consent to active involvement (Sauter and Watson, 2007). In the context of smart grids, the objective of smart meter technology is to achieve active involvement of the end users, e.g. for the demand side management (Verbong et al. 2013, p.120). Sauter and Watson (2007, p. 2777) state that "homeowners need to accept these technological innovations within their household" and "technologies need more 'active' social acceptance when compared to traditional large infrastructure facilities." Therefore, we have derived values for end users' passive and active acceptance. For household acceptance other than end users, customer organizations and homeowner associations are influential stakeholders and need be included in this dimension (Ligtvoet et al., 2015).

2.5.3 Market acceptance

Market acceptance the "process of market adoption" (Wüstenhagen et al., 2007, p. 2685) of smart meters relating to customer values, which is the economic driver for smart meters and holds interest to investors and firms involved in developing the smart grid system (Curtius et al. 2012). However, smart meter an infrastructure technology is identified as a network technology, like the telecommunication technology (Majumdar & Venkataraman, 1998), which has network characteristics described in the network economic literature (Katz & Shapiro, 1985; Lee, 1995; Suarez, 2004). Moreover, the smart meter has been characterized as a complex product (Ligtvoet et al., 2015), which requires strategies from the technology management literature. The most extensive collection of factors for the dominance of a technology from network economics and technology management is assemble van de Kaa et al. (2011), which will be used to depict the values for market acceptance of smart meters. These are important values for DNOs, energy suppliers, HEMS suppliers and vendors of smart meters (see 2.3.3), because market acceptance is conceptualized as their dimension of acceptance.

Figure 4 illustrates the conceptualization of the three dimensions of the framework for the social acceptance of smart meters with the important stakeholders of each dimension.

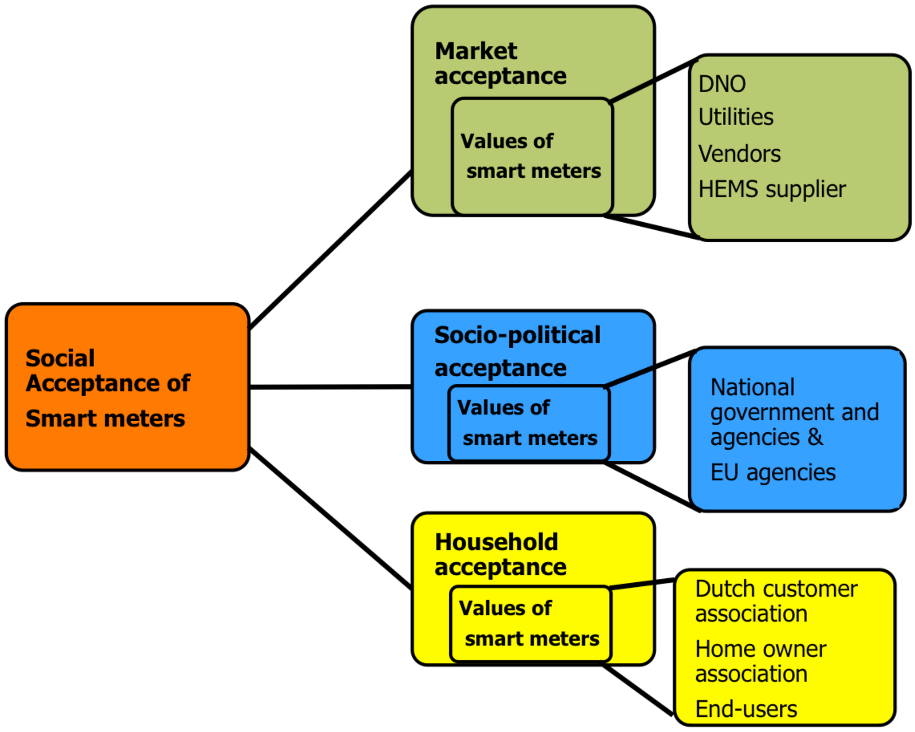

Figure 4: Framework for the social acceptance of smart meters

The values for the acceptance for smart meters have been derived from each dimension (group of stakeholders). However, these values need to be conceptualized by value sensitive design approach, which includes social and moral aspects of the end users.

2.5.4 Values for the social acceptance of smart meters

Customer or end users values for smart meters are not uniformly applicable to all three dimensions of social acceptance, because while some customer values are related to the economic objectives for firms and investors (Curtius et al., 2012) or usability from the designer's perspective (Friedman & Kahn, Jr., 2003, p. 1180), there are also customer values required for the acceptance and support by end users (functional value, as well as moral and ethical values; Ligtvoet et al. 2015), which will also be utilized for institutionalization and governance to facilitate acceptance by the society.

We have determined the values and the important stakeholders in the dimensions of social acceptance for smart meters, comparing and adapting them to the list of values for smart meters from Ligtvoet et al. (2015, 171, table 8. 2), which are based upon the 'original' values for VSD from Friedman et al. (2008) and values from the Handbook of Ethics, Values, and Technological Design. In the Appendix 1, the evaluation of each value can be seen, with the exact literature source and a comparison to VSD's values. Table 2 illustrates the values for each dimension.

Table 2: Values of each dimension for the social acceptance of smart meter (see Appendix 1)

Socio-political acceptance	Household acceptance	Market acceptance
Privacy	Security	Efficiency
Environmental sustainability	Compatibility	Reliability
Compatibility	Usability	Compatibility
Cost-effectiveness	Cost-effectiveness	Availability of complementary goods
Trust	Privacy	Flexibility
Reliability	Trust	Procedural justice
Autonomy	Distributed justice	Ownership
Procedural justice	Autonomy	Cost-effectiveness
	Environmental sustainability	Commitment
		Publicity
		Popularity
		Trust

The set of values in each dimension needs to be evaluated to ascertain their importance for that particular dimension. Depending on the importance of the values, they need to be translated to norms and incorporated into institutionalizations as well as into the firm's strategy to foster the adoption of smart meters. The concept to incorporating moral and ethical values in the innovation process is called responsible innovation (Taebi et al., 2014).

2.6 Conclusion of Literature review

In this chapter, we have reviewed the literature to answer the Sub-RQ1 - *How can acceptance of smart meters be conceptualized?* First, a description of Dutch case for smart metering enabled us to identify the important stakeholders. Second, the literature of social acceptance for infrastructure technology has be reviewed, showing that perceived risks require the acceptance by social groups (of stakeholders). The conceptualization of social acceptance (Wüstenhagen, 2007) to divide the social acceptance into dimensions representing groups of stakeholder has been adapted for smart meters. One dimension comprises socio-political acceptance, representing the institutional actors (Dutch Parliaments and national agencies as well as European agencies), whose values are important for the standard setting of the policies, regulations and directives for smart meters. One dimension comprises market acceptance representing the market actors from the energy sector and involved in the standardization committee for smart meters. One dimension comprises household acceptance, which addresses the acceptance from the end users. Dutch consumer organizations and homeowner associations are also represented in this dimension, which acts in favor of the end users (customers) of smart meters. Smart meters are a complex product (see in Chapter 1) that requires the evaluation from multiple perspectives, which is achieved with our concept illustrated in Figure 4. We will derive the values from multiple literature streams according to the dimension of acceptance.

We have also set the ground for Sub-RQ2: "*Which values should be considered for the social acceptance of smart meters?* in this chapter. We reviewed the literature regarding energy policy for the dimension of socio-political acceptance to derive the important values of these stakeholders. For market acceptance, network economics and technology management literature was reviewed to depict the important values for these stakeholders. Technology acceptance and energy policy literature was utilized to derive the important values for the stakeholders of household acceptance. These values have been refined with the value sensitive design (VSD) approach, which is based upon applied ethics and ethics of technology literature. This approach adds social and moral aspects to the important values for smart meters, which is essential for the acceptance of a technology. In later stage, these values will be evaluated by the methodology depicted in the following section.

3 Methodology

In this chapter, we will review the methodologies to answer Sub-RQ2 - *Which values should be considered for the social acceptance of smart meters?* and Sub-RQ3 - *What is the importance of the values in each of the conceptualized dimensions for the social acceptance of smart meters and how can this be explained by the extant literature?*.

A qualitative validation of the derived values from the literature will ensure that the set of values are applicable for the social acceptance of smart meters.

A method to effectively compare the importance of criteria (values) is the best Worst Method (BWM), which belongs to a branch of decision-making theory, namely multi-criteria decision making (Rezaei, 2015a, 2015b). The method enables assigning weights for each value in a dimension, thus depicting the importance of the values in each dimension. However, prior to applying the method, it has to meet certain requirements.

3.1 Qualitative validation

The framework and especially the set of values derived from the literature review needs to be validated by researchers in the field of smart meters and smart grid studies. A qualitative validation guarantees that the set of values are applicable for the framework for the social acceptance of smart meters. After the validation, experts can determine the importance of the values for each dimension for the social acceptance of smart meters, which will be conducted with the best-worst method. The validation will be conducted with three experts. One expert is an advisor in the market, an end user and also has experience with the institutional design of smart meters. The second expert conducts research about smart meters and smart grid systems, especially focused on the consumer behavior. The third expert undertakes research about social acceptance and energy projects. Qualitatively validating the values with all these experts enables assessing their views and preferences about the values. Comparing their views and preferences, a defined set of values for each dimension can be distinguished, which is required to compare the importance of the values.

3.2 Best-Worst method and requirement

The requirements to conduct the BWM will be covered in the following sections. Prior to this, BWM will be evaluated in terms of whether it is applicable to measure and compare values.

3.2.1 Applicability of Best-worst method (BWM) to measure Values

A problem or differences of opinion may be resolved by measurements that can be solved as empirical problems. However, methods for measuring values are lacking. Analyzing measurement principles in physics, Chang (2004) depicts that if an abstract physical concept can be operationalized and connected to a real physical system, it can be called a 'good correspondence' measurement. Similar Kroes and Poel (2014, p. 165) have addressed the notion of good measurement for values, which enables to assess the applicability of a method to measure values. They argue that to settle any issue or disagreement in an empirical way, the notion of objective measurement for values has to be met to 'force' consensus among the rational disputant, which can be achieved by their the notion of good measurement.

Values can be measured in the domain of quantitative scale like an interval scale (e.g. how much morally better is one value than the another?) if a measurement is objective and the outcome does not depend on the subject performing the measurement (Kroes & Poel, 2015, p. 157). The measurement is objective if the measurement outcome only manifests the object's features. Hence, the measurement is objective if the measurement's outcome does not depend on a particular feature of the subject, namely the person who performs the measurement. In this scenario, an objective measurement is intersubjectively valid. Kroes and Poel (2015, p. 158) state that "a measurement of which one of two objects is heavier with the help of scales satisfies this condition; the outcome does not depend on who performs the measurement and is the same for every subject". In order to ensure that a measurement reveals only features about the object of the measurement, we have to require that the measurement outcome is not influenced by features of the measuring device. For the objectivity of the measurement, Kroes and Poel (2015, p. 166) have set three requirements regarding the notion of a good measurement for methods to measure values: validity, reproducibility and accuracy.

A measurement method is valid if it measures the theoretical concept that it is supposed to measure, termed by Kroes and Poel (2015, p.166) as constructed validity. They give the example of a mercury thermometer as a constructed valid measurement method, because the theory on the temperature proportionally expansion of liquid is based upon the physical concept of temperature. Hence, constructed validity implies that the measured hypotheses are derived from a theoretical concept (Carmines & Zeller, 1979). The concept for social acceptance is built upon the notion of acceptance for a technology by different groups of stakeholders (Sauter & Watson, 2007; Wüstenhagen et al., 2007). Accordingly the literature was assessed to derive the values of the groups of stakeholders for the social acceptance of smart meters. Therefore, we have taken the theory referred by Taebi & Kadak (2010, p. 3) and van de Poel (2009, p. 976) regarding intersubjective value, concerning values within the view of the subjects. Experts representing a group of stakeholders perform the BWM measurement to derive the importance of the values for the concept of social acceptance. Thus, the best-worst method to measure the importance of the intersubjective values with experts is *constructed valid* for the concept of social acceptance.

The good measurement has to be reproducible, because the outcome may not depend on the subject performing the measurement (Kroes & Poel, 2015, p. 167), which should especially be guaranteed for the objectivity of the measurement as we have discussed in the previous paragraph. Kroes & Poel (2015, p.167) depict reproducibility by comparing how a thermostat can reproduce the measurement of temperature and how a subject measuring the temperature with their hand is an issue about reproducibility. We have grouped the subjects (experts) conducting the BWM measurement according to their particular expertise's dimension of acceptance (group of stakeholders), which should enable reproducible measurements. Meaning the outcome of the evaluation does not depend on a specific subject; just as, any experts representing a particular group of stakeholders can be used to measure the importance of values for that particular dimension of acceptance. Accordingly, BWM can guarantee *reproducibility*, because the measurement does not depend on a specific subject performing the measurement.

For accuracy of the measurement, the outcome should not be influenced by the measuring instrument's features as a notion for objective measurement. Accordingly, the measurement of an object should not depend on the kind of measurement equipment's method. Koes & Poel (2015, p. 159) state an example that the temperature of an object can be measured by different equipment – namely a mercury thermometer – as well as by a thermocouple. Hence, to measure temperature it does not depend on one kind of measurement method. BWM meets this requirement, because the weight for the importance of the values can as well be measured with AHP method (Analytic Hierarchy Process) or a regular comparison method.
Furthermore, accuracy relates to the extent to which the outcome of the measurement coincides with 'the real value'. Again, Koes & Poel (2015, p. 168) take the example of a mercury thermometer, which measures the temperature from heat transferred from the tip of the thermometer. If the tip is placed in a cup of tea, an accurate temperature of the tea can be measured, whereas if only a drop of water is placed on the tip, the thermometer can only measure the temperature of the environment. This inaccurate measurement occurs due to constructed invalidity, which is also a reason why Carmines and Zeller (1979) designate accuracy as a part of the notion of validity. We could already prove the construct validity for BWM to measure the importance of values for the concept of social acceptance and it also meets the previously-mentioned aspect of accuracy; hence, BWM meets the notion of *accuracy*.

Meeting all the notions for good measurement for an objective measurement of values enables us to proclaim the applicability of the BWM to measure the importance of values in field of ethics of technology.

3.2.2 Dependency of the values

BWM as a discrete multi-criteria decision-making problem, is also referred as multi-attribute decision-making (Rezaei, 2015a, p. 49). Chen et al. (2013, pp. 25–26) state that for multi-attribute decision-making a decision maker's preference for the criteria (values) should not be dependent. Therefore the values should not be dependent among the set of values meaning that the values in one dimension of acceptance or group of stakeholders should not be dependent. We will assess the literature and search for dependency between the values. In case there are dependent values, we will link the values and change the definition of the values to integrate both values. Hence we will search for dependency rather the independency between the values, because to some extent each value is dependent on the other.

The values compatibility and availability of complementary goods for market acceptance are related values. Compatibility is referred as the ability of a product to adequately perform its function in conjunction with other apparatus according to van de Poel (2015, p. 673). Hence the values compatibility contains already availability of complementary goods, but will explicitly extant the definition of compatibility with the definition for availability of complementary goods (see Appendix 6).

The value trust has been conceptualized differently in the academic literature (Nickel, 2015). Nickel (2015) reviewed trust for design and differentiated two perspectives for trust. One related to reliability and trustworthy of a product and service and another perspective of trust relates to the psychological state of trust, the relationship between the actors. Moreover Nickel (2015, pp. 552–554) states that “trust is sometimes overridden by security”, however “rigorous security and safety measures, seems to take the place of trust rather than encouraging it”. Therefore we focus and defined trust in a relationship, meaning between the actors in a sense that it is not dependent to the other values.

Furthermore, a study by Verbong et al. (2013, p. 122) state that ‘control is a multi-dimensional topic dealing with data-ownership, privacy, complexity of the system, responsibilities, risks etc.’. We have defined autonomy as users having control over the smart meter to plan and execute their actions in way to achieve their goals., which relates to control, which in turn - according to Verbong et al. (2013) - relates to privacy. However, the relation of privacy with control is meant regarding control or the freedom to choose which data about oneself can be shared, which was also included in the definition for privacy (see Appendix 6). On the other hand, we defined autonomy as the value for end users to control their devices associated with smart meters (smart appliance, HEMS-device).

The definitions for each important value (Appendix 6) for the social acceptance of smart meters ensures that the experts evaluating these values have the same understanding and meaning of the values and not the meaning they bear in mind for the values.

Moreover, in the qualitative validation of the values, the experts will also examine the dependency between the values in each dimension. Therefore, we can ensure that the values are not dependent, empirically and based upon literature.

3.3 Best-Worst Method (BWM)

The aim of a multi-criteria decision-making method (MCDM) is to select the most desirable, important alternative depending on a set of decision-making criteria (Rezaei, 2015a). Weights are assigned to the criteria (values) based upon a pairwise comparison between the criteria. Our research goal is to determine the importance of the values for the social acceptance of the smart meters. Pairwise comparison between the values enables us to assign weights for values in each dimension, which can be associated with the importance of the values. The main advantage of the best-worst method (BWM) over the existing MCDM is its pairwise comparison approach, which require less comparison, leading to higher consistency to derive the weights(Rezaei, 2015a, 2015b). Additionally, the method provides a consistency indicator to check the reliability of comparison between the criteria (values). The benefits of fewer comparisons – namely not using fractional numbers and bring easier to understand by the decision-makers (experts) compared to most MCDM - results in more reliable results (Rezaei, Wang, & Tavasszy, 2015, p. 9163; Rezaei, 2015a). The BWM has been applied to determine the relative weight of criteria to evaluate suppliers’ capabilities and willingness to collaborate (Rezaei et al., 2015). Furthermore, the importance of external forces that could drive or hinder the sustainable supply chain management for the Oil&Gas industry has been evaluated based upon BWM (Sadaghiani, Ahmad, Rezaei, & Tavasszy, 2015).

Even though BWM fulfills requirements for the notion of a good measurement (Kroes & Poel, 2015) (see section 3.2.1), values have been viewed by some philosophers as incommensurable. Van de Poel (2015, p. 100) state that incommensurability can be avoided if the score of all options on all individual values (criteria) can be measured on interval scales that share a common unit of measurement (unit commensurability). A direct trade-off between value where the individuals value is measured on an interval scale assumes unity commensurability, which enables avoiding Arrow's theorem and values incommensurability (van de Poel, 2015, p. 103). The BWM is based upon pairwise comparison, where two values are compared on an interval scale; hence, it is similar to the direct trade-off approach. In practice, comparing values will be challenging, especially in terms of achieving consistent comparisons between all the values. According to Rezaei (2015a, p. 50), a decision-maker (expert) has no problem in expressing the direction, whereas expressing the strength is a difficult task and almost the main source of inconsistency. The direction determines whether one value is more or less important than the other, while the strength quantifies how much one value is more important than the other. The pairwise comparison of BWM particularly addresses this difficulty. Rather than comparing between each value, first the most important (best) and the least important value (worst) of each dimension (set of values) are determined. Based upon this reference value, the rest of the values from the dimension are subsequently compared.

The process of determining the weights of the values (criteria) in a dimension (set of values) is divided into five steps (Rezaei, 2015a, 2015b). We depict the method for the values of socio-political acceptance (s_1, s_2, …, s_n):

Step 1
The values (criteria) relevant for each dimension of acceptance are determined. There three set of values (criteria) (m_1, m_2, …, m_n) important for market acceptance, (s_1, s_2, …, s_n) important for socio-political acceptance and (h_1, h_2, …, h_n) important for household acceptance.

Step 2
The expert (decision maker) identifies from each set of values (criteria) (m_1, m_2, …, m_n; s_1, s_2, …, s_n; h_1, h_2, …, h_n) the best (most important) and the worst (least important) value for that particular dimension of acceptance.

Step 3
Expert's preferences of his or her most important value from a dimension over the other values of that particular dimension are determined using an interval between 1 and 9. These comparisons result in a best-to-other vector (Most-important to other).

e.g. socio-political acceptance $S_B = (s_{B1}, s_{B2}, \ldots, s_{Bn})$ *B*: best or most important value

s_{Bj} indicate the preference of the expert of the most important value *B* over value ***j*** from the socio-political dimension (s), evidently $s_{BB} = 1$.

Step 4
Similarly, the expert's preferences of all the other values of a dimension over his or her least important value from that particular dimension are determined using an interval between 1 and 9. These comparisons result in an others-to-worst vector (Others to least important).

e.g. socio-political acceptance $S_W = (s_{1W}, s_{2W}, \ldots, s_{nW})^T$ W: worst or least important value

s_{iW} indicates the preference of the expert value ***j*** over the least important value W from the socio-political dimension (s), evidently $s_{WW} = 1$.

Step 5
The last step focuses on deriving the optimal weights (importance) for each set of values (dimension) ($w_{s1}, w_{s1}, \ldots, w_{sn}; w_{m1}, w_{m1}, \ldots, w_{mn}; w_{h1}, w_{h1}, \ldots, w_{hn}$). A solution can be found when the maximum absolute different for all j is minimized for the following set $\{|w_B - S_{Bj}\, w_j\,|, |w_j - S_j\, w_w\,|\}$ (Rezaei, 2015b). The formulation for the solution

s.t.

$$\min_j \max\{|w_B - S_{Bj}\, w_{sj}\,|, |w_{sj} - S_{jw}\, w_w\,|\}\ j$$

$$\sum_j w_{sj} = 1$$

$$w_{sj} \geq 0, \text{ for all } j$$

This formulation can be translated to a linear programing problem:

$$\min \xi_L$$

$$|w_B - S_{Bj}\, w_{sj}\,| \leq \xi_L, \text{ for all } j \quad (1)$$

$$|\, w_{sj} - S_{jw}\, w_w\,| \leq \xi_L, \text{ for all } j$$

$$\sum_j w_{sj} = 1$$

$$w_{sj} \geq 0, \text{ for all } j$$

Model (1) has been formulated as a linear problem, which has a unique solution. The solution to this model is the optimal weights for the importance ($w_{s1}, w_{s2} \ldots, w_{sn}$) for the values, in this case for socio-political acceptance.

For the linear model of BWM, the consistency ξ_L can is considered as a consistency indicator of the comparisons and values of ξ_L closer to zero shows a higher level of consistency (Rezaei, 2015b, p. 5).

This example is for the socio-political acceptance dimension, although optimal weights for the other dimensions are derived with the same model.

3.4 Conclusion of Methodology

In this section, we have depicted the methodologies to evaluate the importance of the values. In first step, the values will be qualitatively validated, which will enable us to have a definite list of values for the social acceptance of smart meters. Thereby, we can answer Sub-RQ2 – *Which values should be considered for the social acceptance of smart meters? .* In the second step, the applicability of the best-worst method to measure the values was evaluated. It was assessed with the requirements of good measurement from Kroes & Poel (2015). We could conclude that the BWM is applicable to measure the importance of values. Furthermore, the independence between the values was assessed. In the final step, all the steps for the best-worst method were depicted to evaluate the importance of values. Therefore, the Sub-RQ3 - *What is the importance of the values in each of the conceptualized dimensions for the social acceptance of smart meters and how can this be explained by the extant literature?* – can be answered with best-worst method.

4 Evaluation

As was discussed in the Methodology, our research will be evaluated in two steps. First, a qualitative assessment of the values will be done to answer Sub-RQ2, which enables to have definite list of values for the social acceptance of smart meters. Following the Best-worst method will be applied to set the ground to answer Sub-RQ3 - *What is the importance of the values in each of the conceptualized dimensions for the social acceptance of smart meters and how can that be explained by the extant literature?* . We will conduct three interviews for qualitative validation of the values and ten interviews to evaluate the importance of the values for the social acceptance of smart meters.

4.1 Qualitative validation

Three experts will be qualitatively assessing the values for the social acceptance for smart meters. Including three expert's opinions, enables the process to decide on a Value in case of conflicting opinion. The first expert is an advisor for the industry and is end-user of the smart meters (Theo); the second expert focuses on the research on smart grid, sustainability and social acceptance (Marloes), whereas the third expert focuses on research regarding the consumer behavior and energy consumption of end-users (Jochem). Table 2 illustrates the values for each social acceptance dimension and the opinion of the experts. They have been asked which values are absolutely important and which values can be neglected. Furthermore, the experts will be asked to for a value, which in their opinion is missing. Moreover the researchers will be asked about the dependency between the values in each dimension. With the qualitative validation of the values the shortcoming of VSD, lacking opinion from the stakeholder involved with smart meters, is then remediated.

Table 3: Qualitative Validation of the values for socio-political acceptance of smart meters

Value	Theo	Marloes	Jochem
Privacy	Important	Important	Important
Environmental sustainability	Important	Important	Important
Compatibility	Important		
Cost-effectiveness	Important	Important	
Trust	Important		Important
Reliability	Important		
Autonomy	Important		Important

The experts didn't find any additional values relevant for the socio-political acceptance; hence, the list of value can now be fixed.

Table 4: Qualitative Validation of the values for household acceptance of smart meters

Value	Theo	Marloes	Jochem
Security	Important	Also Saftey	Important
Usability		Related to compatibility	Easy to use related to compatibility
Compatibility		Related to usability	Related to usability
Cost-effectiveness	Less important		Important
Trust	Important	Important	Less important
Privacy	Important	Important	Less important
Autonomy	Relates to privacy	Relates to privacy	Relates to privacy
Distributed justice	Less important		
Environmental sustainability	Important	Important	Less Important
Comfort	Access of information (Apps for Smart meters)	Convenience	Fun and entertainment

Compared to the socio-political acceptance, the opinions for the values for household acceptability varies between the experts. However experts also pointed out the values which are related to each other, hence the value of compatibility can be subordinated to usability (Marloes's statement). All three experts had an additional value for household acceptance for smart meters, which can be associated with welfare (Marloes) and more specifically value has be defined comfort (see Appendix 6).

Table 5: Qualitative Assessment of the values for market acceptance of smart meters

Value	Theo	Marloes	Jochem
Efficiency	Important	Important	
Reliability	Important		Relates to trust
Compatibility	Important	Related to availability of complementary goods	Related to availability of complementary goods
Availability of complementary goods	Important		
Flexibility	Important		Important
Procedural justice	Important	Important	

Ownership	Important	Important	
Cost-effectiveness	Less important		Important
Commitment	Less important		
Publicity	Important	Not a value	Important but related to popularity
Popularity	Less important	Related to publicity	
Trust		Important	Important

For the set of the values for market acceptance, the experts did not have suggestions for additional values. They suggested some unnecessary value: for instance for cost-effectiveness, Theo evaluated it as less importance, because the energy market is highly regulated and prices for energy is rather low and does not show any major changes regarding higher cost however their opinions varies. Jochem on the other hand, evaluated cost-effectiveness as important value and a driver for the market players. Availability of complementary good has been synonymous to compatibility, hence can be summarized to compatibility. Commitment and popularity is either seen as less important or does not have high importance.

Summarizing all the different opinions of the sub-sets of values for the social acceptance, the following Table of values results for the next step of the evaluation.

Table 6: The final set of values for the social acceptance of smart meters.

Socio-political acceptance	**Household acceptance**	**Market acceptance**
Privacy	Security	Efficiency
Environmental sustainability	Usability	Reliability
Compatibility	Cost-effectiveness	Compatibility
Cost-effectiveness	Privacy	Flexibility
Trust	Trust	Procedural justice
Reliability	Distributed justice	Ownership
Autonomy	Autonomy	Cost-effectiveness
Procedural justice	Environmental sustainability	Disclosure
	Comfort	Trust

4.2 Results of BWM

The experts for smart meters in the Netherlands assessed the values in each dimension of social acceptance. The experts have different backgrounds of expertise, however are working or have worked with the smart meter technology for several years (> 4 years). The smart meter was introduced in the Netherlands in 2008, hence experts with experience of longer than 10 years have been difficult to find or would not have the time to evaluate the values. However we managed to interview three experts, with expertise exceeding 10 years to evaluate the values for the social acceptance of smart meters. (See in Appendix 2 a list with information about the experts.)

In total 10 interviewees have evaluated the importance of the values in interval between 1 and 9 for acceptance with the help of the Best-Worst Method. Table 7 illustrates the calculated average of the weights of importance for values in each dimension of acceptance. Furthermore, the average consistency indicator ξ_L (see Section 3.3) of comparison is included. The comparisons had high consistency, since the consistency index is low (< 0.06) and closer to zero than one.

Table 7: Average weight for the important of the values for the social acceptance of smart meters

Socio-political acceptance	**weight**	**Household acceptance**	**weight**	**Market acceptance**	**weight**
Privacy	0.176 /	Privacy	0.157	Cost-effectiveness	0.159
Environmental sustainability	0.150	Security/ Safety	0.147	Reliability	0.134
Procedural Justice	0.146	Usability	0.135	Efficiency	0.129
Reliability	0.121	Comfort	0.127	Compatibility	0.124
Cost-effectiveness	0.113	Trust	0.111	Procedural Justice	0.112
Trust	0.110	Autonomy	0.104	Trust	0.095
Compatibility	0.093	Cost-effectiveness	0.092	Flexibility	0.0834
Autonomy	0.091	Environmental sustainability	0.080	Ownership	0.0830
		Distributive Justice	0.048	Disclosure	0.079
consistency ξ_L	0.056	consistency ξ_L	0.053	consistency ξ_L	0.052

Evaluating the result there is dispersion between the experts evaluation (see Appendix 3), hence the difference between the weights of importance of values in dimension is low. The division of the social acceptance into different dimension enables us to group the experts with same backgrounds, which allows accentuating the importance of the values.

The group of experts for a particular dimension of acceptance was composed of experts with expertise or research experience in that particular dimension of acceptance and their weights have been accumulated to calculate the average weight of importance for the values. (see Appendix 4, grouped experts for each dimension for the social acceptance of smart meters). Table 8 depicts the calculated weight for the importance of the values, however the dispersions of the weights of between the group of experts with same background is lower (see Appendix 5).

Table 8: Average weight for the important of the values for the social acceptance of smart meters (grouped)

Socio-politcal acceptance	weight	Household acceptance	weight	Market acceptance	weight
Privacy	0.179	Privacy	0.176	Cost-effectiveness	0.173
Procedural Justice	0.167	Comfort	0.150	Efficiency	0.143
Environmental sustainability	0.147	Usability	0.128	Reliability	0.136
Compatibility	0.111	Autonomy	0.121	Compatibility	0.134
Reliability	0.103	Security/ Safety	0.117	Procedural Justice	0.097
Trust	0.101	Trust	0.104	Disclosure	0.088
Cost-effectiveness	0.100	Cost-effectiveness	0.092	Flexibility	0.087
Autonomy	0.093	Environmental sustainability	0.069	Trust	0.084
		Distributive Justice	0.044	Ownership	0.058
consistency ξ_L	0.057	consistency ξ_L	0.055	consistency ξ_L	0.053

By grouping the experts' background to the dimension of acceptance, importance of values can be distinguished much better. The most important value stayed the same for both calculations. However, the result for grouping the experts according to their backgrounds has a lower dispersion of weights and the importance of the values is be better highlighted.

An explanation for low variance in importance of the values in the dimension of socio-political and market acceptance is that experts had difficulties to evaluate the importance of the values; many experts had difficulties to distinguish the least important value, because in their opinion all the values of that particular dimension are important for the social acceptance of smart meters.

4.3 Conclusion of Evaluation

The Qualitative and BWM evaluation of the values enabled us to distinguish the most important values for social acceptance of smart meters in the Netherlands.

The Sub-RQ2: *Which values should be considered for the social acceptance of smart meters?* - has been answered with a qualitative validation, which is presented in Table 6, the final set of values for social acceptance of smart meters.

The experts of smart meters had to be grouped to their background of expertise to have incisive result. The reason for dispersion of results without grouping resulted, because all the values were seen important for socio-political and market acceptance. The result from the BWM showed the most important values for the social acceptance of smart meters, which sets the grounds to answer Sub-RQ3 - *What is the importance of the values in each of the conceptualized dimensions for the social acceptance of smart meters and how can that be explained by the extant literature?* . The most important values for the social acceptance of smart meters are privacy for household and socio-political acceptance and cost-effectiveness for market acceptance. To demonstrate the translation of a value to design requirements, we will create a value hierarchy for privacy in the following chapter, hence, will address Sub-RQ4. In chapter 6 we will explain the important value based on the extant literature, which will finally answer Sub-RQ3.

5 Value Hierarchy

The previous chapter enabled us to determine the importance of the values for the social acceptance of smart meters. Value hierarchy is a method for design for values (Kroes & Poel, 2015); through this, we can demonstrate the translation of a value to design requirements based upon this method. We will also address the implications to formulate design requirements based upon only one value - privacy - which can conflict with other values. Accordingly, we will answer Sub-RQ4 - *How can the important values for the social acceptance of smart meters be translated to design requirements?* based upon this chapter.

5.1 Description of the method

Even though value sensitive design (VSD) addresses the values for a technology, it neglects the translation from values into design requirements. Van de Poel (2013, p. 253) introduces the notions of values hierarchy - "a hierarchy structure of values, norms, and design requirements" (see Figure 5) - which aims to formulate design requirements for a value.

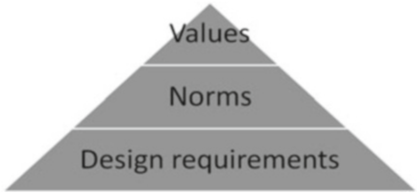

Figure 5: The three basic layers of value hierarchy (van de Poel, 2013, p. 259)

The approach to translate values into norms and design requirements is associated as *specification*, which is the relation of the higher-level elements to the lower and a top-down approach. We will utilize this approach because we identified the important values for each dimension for acceptance.

Translation requires specific expertise - which could be outside of the engineering domain - especially to specify norms. Van de Poel (2013, p. 254) pointed out that to translate values such **privacy** and **trust**, philosophical analysis may help to better understand these and for values like **safety** and **usability**, expertise regarding safety science and ergonomics is required.

For the final translation from norms to design requirements, we have to rely on specification from legislation to technical codes or standards. Nevertheless, translating the values should be evaluated with the feasibility of the current technology and trade-offs with other values. Our evaluation from stakeholders' values for the acceptance of the technology depicts the most important values.

The evaluation of the importance of the values for the social acceptance of smart meters in the Netherlands showed that privacy was the most important value for household and socio-political acceptance; hence, we will create a value hierarchy based upon privacy to demonstrate the translation of a value to design requirements. Nevertheless, the most important value for market acceptance cost-effectiveness should be compared to the design requirements created from the value hierarchy. We will depict that translating only one value to design requirements will result in conflicts with other values.

5.2 Translating privacy into design requirements for the smart meters in the Netherlands

The first step is to translate the value privacy into norms. Norms can be identified as 'rules or expectations about behavior that are socially enforced' (Horne et al., 2014). Smart meters as a key part of the smart grid have the main function to transmit the information about the energy usage of their end users to the utility companies; however, an energy profile of the end users enables estimating their behavior in the households (Horne et al., 2014). This means that utilities (DNOs and energy suppliers) have access to the information about the behavior of the end users of smart meters (Efthymiou & Kalogridis, 2010). Therefore, the smart meters can reveal more information than the end users are willing to share (AlAbdulkarim & Lukszo, 2011, p. 288). Norms can be divided into norm content, explaining the content of expectation of norms and sanctions (Horne et al., 2014), We will focus on norm content, because we will need to specify design requirements based upon the norms.

According to Horne et al. (2014, p. 67), revealing information about electricity usage is less sensitive than the information about a person's financial transaction. Nevertheless, the frequent transmission of the information about electricity use will enable analyzing the end users' behavior and activities in their household, which is their private space and needs be excluded from intrusions. Hence, the end users will demand norms to govern the frequency of transmitting their electricity usage data and analyze it (Horne et al., 2014). Cuijpers & Koops (2013, p. 273) pointed out that Article 8 of the European Convention of Human Rights (ECHR) requires end users' consent before meter reading is transmitted to the utilities (DNOs and energy suppliers) and also if forwarded to third parties. Article 8 concludes that data protection and privacy law must be in center of smart metering design. In the Dutch case regarding the mandatory rollout of smart meters, privacy was undermined in the design of the legislative proposal. The voluntary rollout of smart meters gives the end users the option to decide whether they want to share the their data with the utilities (see section 2.1.2 for the options). Therefore, the first norm for privacy of smart meters should be that *end users should have options to decide if they want to share their electricity usage data with utility firms and in what frequency*. (Norm 1)

Institutional policies should demand DNOs to provide unbiased information about smart meters' data processing and functionalities, which should enable the end users to make consent about sharing their usage data, in what frequency or not to share(Cuijpers & Koops, 2013). End users should be informed about the purpose of the smart meters, including the options and their consequences, which should enable end users to make an unbiased decision about smart meters in their household. (*Institutional Design Requirement 1*, Figure 6)

According to Cavoukian & Dix (2012, p. 13), multiple options (regarding either the type meter reading or its initial settings) with the consequences and processes of these options should be presented to the consumer and the default option must be the more privacy-protective one. DNOs or utilities should provide multiple options, various frequency options to transmit the end users' meter readings and even the option to not share any data. Additionally, the default setting should be not sharing the data and only with the consent of the end users should their electricity usage be transmitted and shared via the smart meter. End users of smart meters should have multiple options, including not sharing their data and various frequencies with which to transmit the meter reading. The default setting should be not share data, which can only be changed with end users' consent. (*Institutional Design Requirement 2*, Figure 6)

Additionally, Cuijpers and Koops (2013, p. 289) added that an ex ante privacy assessment would help to find privacy concerns and implications prior to legislative proposals will be rejected due to privacy issues. Accordingly, the following norm is stated for smart meters: *Ex ante privacy assessment should be conducted, which will provide implication for the legislative proposal of smart meters* (Norm 2, see Figure 6). An ex ante privacy assessment would require the utilities to determine what smart meter-based information should be accessible that is legitimate to privacy concerns, rather than utilizing all the available information from smart metering (Cavoukian & Dix, 2012, p. 12). It would show a privacy-friendly smart metering option to achieve the European Directive. For instance, smart meters with a home display would only show the data to end users or the aggregation of individual energy usages data should only be used for electric network management. In the Dutch case of the smart meters, in addition to the EU directives (energy efficiently and liberalization of the market), a goal was to detect fraud and illegal activities with smart meters' implementation, which resulted in neglecting and undermining the privacy concern regarding the introduction of the smart meters (Cuijpers & Koops, 2013).

The ex ante privacy assessment should be executed with design guidelines. In the Dutch case, the Ministry of Economic Affairs solely based their assessment on the data protection law. Higher instances like Article 8(1) of ECHR for privacy - as the most important codification of the fundamental human right to privacy (Cuijpers & Koops, 2013, p. 277) - and Privacy by Design - a widely recognized design principle (Cavoukian & Dix, 2012, p. 3) - should be included in the ex ante privacy assessment. Hereby, the legislative proposal will meet the privacy requirements. *Utilize design principle, Privacy by Design, article 8 ECHR and the Dutch data protection act for the privacy assessment of the smart metering design* (Institutional Design requirements 3 – *Compliance Guidelines* Figure 6)

Countries planning to introduce smart metering with more detailed reading (more frequently than hourly or daily) of electricity usage need to consider the privacy and data protection implications for smart meters. However, as previously stated, network management does not require the personal information of the end users in meter reading. To give an example, the planning and optimization purpose of the train system the information on Dutch OV chip cards (transport card) needs to be collected, which only needs to collect the number of travelers per train. Storing the personal travel history of each individual would only be for commercial reasons (Warnier, Dechesne, & Brazier, 2015). Therefore, the third norm is: *Smart meters should only store and process anonymized personal data* (Warnier et al., 2015, p. 437). In general, people are not concerned about their privacy, although they fear what can be done with their personal data to harm them. Thus, anonymized personal electricity usage data will ensure that the further processing of end users' data will not harm them.

The third norm for privacy is similar to the option for individuals to increase privacy for their Internet browsers, where they can switch to a privacy browsing mode that prevents the internet page from access to cookies (previous browsing setting) of the individuals. However, to design such a mode, one needs to install an energy storage system (batteries) for their private energy consumption mode, which requires much more effort in terms of costs and set-up compared to switching to privacy mode in a browser. Privacy-preserving concepts have been designed, based upon the third norm of anonymization, pseudonymizaton or data aggregation. Several researchers and utility firms have designed processes that strip away the personal information, but still enable network management and even fraud and leakage detection (Cavoukian & Dix, 2012, p. 13). The reasoning is that aside from billing purposes (only required monthly or even annually) and consumer awareness (can be kept locally), individual consumption data is not required for utilities and it is sufficient to have aggregated data for network management and demand management (end users generating electricity) (Kursawe, Danezis, & Kohlweiss, 2011). The aggregation approach utilize the Diffie-Hellman-based Private Aggregation (DiPA) method, which is based on the homomorphic commitment scheme (Cavoukian & Dix, 2012; Kursawe et al., 2011; Warnier et al., 2015). This commitment scheme will exclude the end users' information and will only commit the electricity usage data, which will be aggregated with other end users (households) and hence is anonymized. This aggregation attributable to a specific location (e.g. a group of houses or apartments) within the electricity distribution network will be provided to the DNOs or utilities, which can utilize the data for network management as well as demand management without the individual household consumption. The demand management is possible because the DNOs could analyze all end users' aggregated usage and compare it with the aggregated usage of end users who generate electricity. According to Efthymiou & Kalogridis (2010, p. 239), "the smallest 'unit' of electrical energy consumers that needs to be known to an electrical distribution network is a distribution sub-station or any other entity which forms part of the electrical distribution network and which directly supplies energy consumers"; hence, a sub-station should be the point of aggregation, which ensures that utilities cannot retrieve specific end users' personal information. The personal data of the electricity usage for billing purposes should be separated from the aggregation mechanism. Two ID forms (identification or identifier) should be incorporated in the smart meter, one for the aggregation and the other only for billing purposes, which will set only the electricity usage of an individual household once a day, week or month according to the end user's consent and thus will not enable utilities or DNOs to analyze the end user's behavior or lifestyle in their household. The frequency of transmitting the aggregated and anonymized electricity data is high (>=1min) and for billing - as previously mentioned - it will be low. The concept of this system was developed by Efthymiou & Kalogridis (2010). The smart metering architecture should be designed by combining the concept by Efthymiou & Kalogridis (2010) to divide the meter readings with low frequency readings with person identification for billing and high frequency reading anonymized according to the Diffie-Hellman-based private aggregation (DiPA) approach by Kursawe et al (2011), which guarantees the privacy of the end users (*Technical designrequirement 1*).

Additionally, the privacy must be maintained end-to-end, meaning in the process of collection, transmission and use/retention (*Technical design requirement 2*). The transmission of any personally identifiable information should be encrypted if communicated wirelessly or over networks and rather than personal end users' information, a unique numeric ID should be transmitted. The retention of personal end users' information should be kept in a minimal number of systems and need-only access should be incorporated to retrieve the personal information.

Similar to our value hierarchy for privacy of smart meters, Aldewereld, Dignum, & Yao-hua (2014) have created norms based upon privacy for cookies for internet browsers, which also stated the importance for consent by the end users and anonymized personal data.

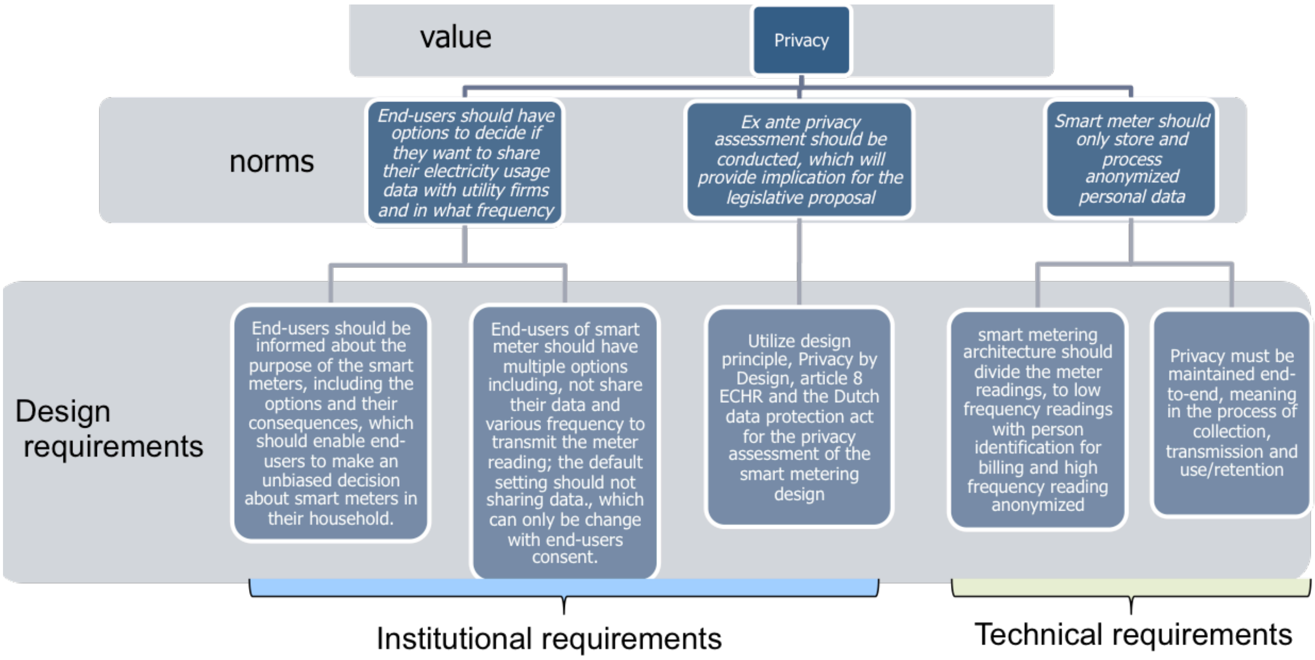

Figure 6: Value Hierarchy for Privacy of smart meters

Our value hierarchy for privacy in the context of smart meters for the Netherlands provides institutional and technological design requirements, which enables facilitating the social acceptance of smart meters in the Netherlands.
The Netherlands has changed the mandatory roll-out of smart meters from to a voluntary one where end users can choose to have a traditional meter or 'dumb' meter and different smart meter option (see in section 2.1.1) (Cavoukian & Dix, 2012, p. 19; Cuijpers & Koops, 2013, p. 283). Comparing the legislation in the Netherlands with our institutional design requirements, it fulfills providing options for the end users, although there is less emphasis given to inform the end users about the smart meter functionalities and consequences.
Furthermore, the smart meter technical design requirements need to be evaluated with the current development of the Dutch smart meter systems. Increasing the privacy of end users of the smart meter will provide social acceptance and hence will open the market, which is essential for DNOs and utilities to be cost-effective (see section 6.1)
Therefore, our design requirements should be analyzed and compared with the current design requirements and further assessments with the stakeholder

groups for social acceptance will provide inputs for improvements or verification of these design requirements. As Cavoukian & Dix (2012, p. 23) state about the development for smart meters, "regulation and technical measures associated with this system cannot be defined or enacted by any single provider or jurisdiction – a collaborative effort is required."
Several scholars (Correljé, Cuppen, Dignum, Pesch, & Taebi, 2015, p. 197; Taebi et al., 2014) have stated that a value hierarchy enables identifying and understanding conflicting values and controversies.

5.3 Implications and conflicting values

We have created three institutional and two technical design requirements based upon privacy. Reviewing the design requirements with the other important values, we can illustrate the conflicting points.

First, cost-effectiveness – as the most important value for market acceptance - will be compared with the formulated design requirements from privacy. Even though cost-effectiveness relates to the market size and thus the acceptance from the end users of smart meters (discussed in Chapter 6), it also relates to the affordability regarding costs and benefits for the smart meter's design and services (Erlinghagen et al., 2014;Taebi & Kadak, 2010). The institutional design requirement 1 (see Figure 6) requires stakeholders from market acceptance (DNOs & energy supplier) to provide information about the purpose of the smart meters, including the options and their consequences and institutional design requirement 2 to provide multiple options. Both design requirements can be associated with costs for DNOs and energy suppliers, which is negative for the cost-effectiveness value. Especially providing an option where smart meter design does not share data reflects only costs with little or no benefit for the market stakeholders (Gerwen et al., 2010, p. 50). These design requirements need to be adapted with the value of cost-effectiveness, as well as the technical design requirements 1 & 2 for privacy, demands cost for their implementation. On the other hand, the technical design requirement 1 & 2 do not have a negative effect on the benefits of the DNOs and energy suppliers.

Therefore, creating a value hierarchy requires trading off between the important values to formulate design requirements. This is especially relevant in conflicting points like institutional design requirement 2, where the value privacy requires an option for end users not sharing the data, although cost-effectiveness requires at least a standard sharing to create benefits for their costs. Therefore, this design requirement needs to be reviewed within each group of stakeholders to reach a consensus about this conflict. Even though the values are not dependent, the realization of one value has an influence on the other value, which can be called realization dependency.

The BWM evaluation of the importance of the values illustrated that there is less difference in importance to the second or even third most important value in each dimension of social acceptance of smart meters. For instance, procedural justice and environmental sustainability are also important values for socio-political acceptance, whereas comfort and usability are also important for household acceptance. For market acceptance, besides cost-effectiveness, the efficiency and reliability of the smart meter have high importance. Hence, to create design requirements that foster the social acceptance of the smart meters, all these values need to be taken into account, which lies beyond the scope of this thesis.

5.4 Conclusion

We have created a value hierarchy - “a hierarchy structure of values, norms, and design requirements”(van de Poel, 2013, p. 253) - to formulate design requirements for privacy. Based upon three norms, we have formulated three institutional design requirements and two technical design requirements. Our value hierarchy for privacy in the context of smart meters for the Netherlands provides institutional and technological design requirements of smart meters in the Netherlands (see Figure 6). Figure 6 demonstrate how design requirements are formulated based upon a value, which answers the Sub-RQ4.

We depict that other important values conflict with the design requirements based upon privacy; in particular, institutional design requirement 2 is conflicting with cost-effectiveness. Therefore, we have suggested that value hierarchies (norms and design requirements) for the second and third important values in each dimension of acceptance should be created. Accordingly, the conflict design requirements should be evaluated and traded off by the groups of stakeholders for the social acceptance of smart meters (Figure 4) to reach a consensus between the requirements. Formulating design requirements based upon all these values lies beyond the scope of this research. Further research needs to be conducted based upon the result from BWM evaluation and the demonstrated method to translate values to design requirements.

6 Discussion

In this section, we will discuss the result of the BWM evaluation, the importance of the values for the social acceptance of smart meters, an infrastructure (see Section 2.1) and complex technology (see Chapter 1). Hereby, we will explain Sub-RQ3 by the extant literature - *What is the importance of the values in each of the conceptualized dimensions for the social acceptance of smart meters and how can that be explained by the extant literature?* We will focus on the three most important values for each dimension of acceptance and suggest factors related to these values. Moreover, we will highlight the scientific contribution of the thesis. Furthermore, we will mention the limitations of our research, their implications and possible further studies to address these limitations.

6.1 Most important values for the social acceptance of smart meters

Assessing the result from the evaluation of the values by the experts with the best-worst method (BWM), the most important values for the social acceptance of smart meters are identified. Comparing both calculations – namely the grouped and ungrouped average weight of importance for the values - results in the same most important value for each dimension of acceptance. Privacy is the most important value for household and socio-political acceptance and cost-effectiveness for market acceptance.

Privacy has been evaluated as the most important value for household and socio-political acceptance. We defined privacy for smart meters as 'smart meters should keep the private space of the end users free from intrusion and also should enable the users to determine what information about herself or himself can be communicated' (based upon Warnier et al.'s (2015) definition for privacy). Many studies and literature referred to privacy as a crucial factor for smart meters.

Policy-makers at different level – namely the EU and national level - have addressed privacy regarding smart meters. The legal challenge about the privacy of the measurement data from the smart meters has caused halting the roll-out in the Netherlands (Darby, 2012). The Dutch data protection authority (DDPA) proclaimed their concern regarding the mandatory roll-out of smart meters owing to the lack of a clear structure and coordination of the meter reading, which will violate the Dutch data protection act (Wet bescherming persoonsgegevens) (Cuijpers & Koops, 2013, p. 279). The Ministry of Economic Affairs and DDPA had to ensure that the Dutch data protection act was met for the approval of the Dutch chamber for the mandatory rollout. However, discussions and evaluation about the privacy of the meter reading continued, leading to a voluntary roll-out of smart meters (Bellantuono, 2014; Cuijpers & Koops, 2013; Ligtvoet et al., 2015) (see in section 2.1.2). Hence, without addressing the value of privacy, there will be no socio-political acceptance for smart meters.

Since the roll-out of the smart meters is voluntary, households can refuse to install a smart meter without a punishment (Cuijpers & Koops, 2013). Verbong et al. (2013, p. 120) state that privacy is particularly important for the consumers' willingness to accept smart meters and for the successful introduction of smart grid. Darby (2010, p. 449) added that “there are growing reports of backlashes against smart meters from customers in the Netherlands, California… from perceived invasion of privacy”. The Dutch consumer union was not convinced that all privacy matters regarding the smart metering data had been resolved and required further requirements to the process the metering data for the Dutch households, because in their opinion privacy is also “the right to inviolability of the home and respect of family life” (Cuijpers & Koops, 2013, p. 280; Darby, 2012). These aspects are the reason why the experts also evaluated privacy as the most important value for the household acceptance of smart meters.

The *cost-effectiveness* of the smart meters has been evaluated as the most important value for market acceptance. We have defined cost-effectiveness as affordability regarding cost and benefit when embarking on the smart metering system and ensuring its continuation over the course of time (based on Behnam Taebi & Kadak, 2010, p. 1347 definition). Erlinghagen (2014, p. 1254) states that the cost-effectiveness of smart meters for the utilities (DNOs or energy supplier) depends on the size of the market, because economies of scale will reduce the overall cost of production and deployment for smart metering systems. Hence, a wide-roll-out of the smart meters is the goal of the market stakeholders, whereby DNOs benefit in the sense of improving the management of the grid, while energy supplier and HEMS suppliers can gain benefits by providing services over the smart meters. Since the voluntary roll-out of smart meters prevents wide-scale application due to the privacy concerns, the end users have the option to reject and keep the traditional meter or require an ‘administrative off’ agreement but prevent DNOs from any meter reading (see section 2.1.1). Knyrim and Trieb(2011, p. 122) state that the roll-out of smart meters is only economically feasible if the vast majority of households are furnished with a smart meter. The cost-benefit analysis after the voluntary rollout proposal indicated that only in case of 80% acceptance by the end users (with standard reading option– see in 2.1.1) is a positive business case achievable. Therefore, acceptance by end users to provide meter readings of the smart meters is crucial for the cost-effectiveness; otherwise, the huge investment in the smart metering system and smart meters will not provide any benefits for market stakeholders of smart meters.

The evaluation of the values for the social acceptance of smart meters points out that privacy is the most important value that needs to be to analyzed and incorporated into institutional and technology design of smart meters in the Netherlands.

6.2 Scientific contribution

We have addressed a complex technology from different perspectives, namely institutional (socio-political acceptance), social (household acceptance) and economic (market acceptance). Narayan and Chen (2012) addressed the evolution of technology standards from macro (environment) and micro (firm) forces and stated that more research is required to invoke multiple perspectives and literature streams, especially from institutional environment and governmental action to understand the complex phenomenon of technology standards (2012, p. 1392). They utilized the natural selection perspective to analyze technology standards, built upon the economic and organizational theories from 1980. Economic concepts such as two-sided market or ecological and institutional theories can avail to this perspective. We have built our research regarding smart meters social acceptance from energy policy literature (Wüstenhagen et al., 2007), which is based upon ecological and institutional theories. Additionally, the smart meter can be characterized as two-sided market technology (see Chapter 2.2.3). Shin et al. (2015, p. 156) stated that the future research of standardization should incorporate interdisciplinary perspectives. Furthermore, Brunsson et al. (2012, p. 623) have pointed out that "standards represent a faulty and fragile compromise between the different interest groups, rather than a solution that represents an expert judgment". Our research has reviewed the technology from different stakeholder groups and their acceptance for a technology, which shows important literature streams (level of analysis) for a complex technology. Narayanan and Chen (2012, p. 1393) pointed out that from a macro-level of analysis about technology standards, the research lacks inputs from complex technologies as well as institutional and social literature. We meet this shortcoming through our approach to include energy policy literature and applied ethics and ethics of technology literature as well as network economic and technology management literature, whereby addressing a technology's aspects from these literature streams reflects a new approach to assess a complex technology's acceptance and its institutional environment. Ligtvoet et al. (2015, p. 173) addressed a complex technology from technology management and philosophy and ethics literature and provided a first notation that the societal acceptance of a platform (technology) will grow if a technological design is modified to changing user requirements related to ethical and societal values surrounding the technology. Our research also integrated the social and ethical values of end users into the analysis of a complex technology. For the acceptance of a complex technology, our study makes a first notion for a multidisciplinary approach to include three levels of analysis: the institutional literature, technology management and network economic literature, and philosophy and ethics literature.

Furthermore, assessing the smart meter technology as a complex product (technology) (see Chapter 1.1), we depict the important factors for the market acceptance of complex technology. Narayanan and Chen (2012, p. 1392) have stated that the increasing technological complexity requires future direction of studies to include complex technologies in standardization process. The current natural selection of technology is built from the experience of simple products (Anderson & Tushman, 1990; Narayanan & Chen, 2012). Our finding can be a first set of factors for complex technologies standard selection process. Especially factors like compatibility, flexibility and openness (procedural justice) (see 2.2.3) are essential factors (values) for complex technology such as smart meters. However, we need to further analyze our approach and findings for other complex technologies and different regions before we can generalize.

In design with values, it is pointed out by Taebi & Kadak (2010, p. 1343) that the "acceptance of a technology relates more to the way values are prioritized and traded off than how one single value is conceived". Utilizing the best-worst method enables prioritizing the values, reflecting the first time that the BWM has been used to evaluate values. Hence, our research illustrates how the BWM can

be utilized to prioritize or find the importance of the values, which will enable research in the ethics of technology to compare the values to ascertain their importance. However, we do not mean to claim that the BWM should replace qualitative analysis. On the contrary, the result from the BWM indicates the direction for the qualitative analysis.
Additionally, the BWM with highest consistency for pairwise comparisons of factors (Rezaei, 2015a, p. 55), has only been utilized for supply chain topics and to compare factors. After assessing the applicability of the method to measure values, we could verify that the BWM complies with the criteria validity, reproducibility and accuracy according to Kroes & Poel (2015, p. 166). Therefore, we have provided a first notion that the BWM is applicable to measure values and an approach towards measuring the importance of the values.

6.3 Limitations

We have built our research based upon the concept that social acceptance can be divided into different stakeholders' perspectives of acceptance, which can be presented as important values of these groups of stakeholders. Every stakeholder in each group (dimension) can have different set of values, which are important for her or him to accept the smart meter. However, accessing the value of each individual and aggregating their importance would be impossible owing to the diversity of opinions to gather and access all the individuals. Therefore, we simplified the social acceptance of smart meters into three stakeholder groups with the assumption that the importance for the values in a group is the same. Nevertheless, to assess the acceptance of smart meters in each group of acceptance, it should be further segmented to find the exact important values.

For example, the household acceptance was conceptualized as all the end users of the smart meters holding the same values. Therefore, we gathered the literature values that are described as important for end users of smart meters. For instance, Kaufman et al. (2013, p. 236) state that the end user value should be further segmented and they identified four different smart meter customer groups for the Swiss market. Experts who evaluated the values also pointed out that the household acceptance could be further segmented into different interest of groups, e.g. price-sensitive, tech-savvy or end users who want autonomy from the grid. This and further segmentation will enable us to find specific values for the acceptance of smart meters, which can be utilized to offer different service options for each segment of end users. Our goal on the other hand was to identify the overall important values for acceptance and create the design requirements for it. In a follow-up study, the important values for each of the segmentation would provide insights and design requirements for specific services of smart meters and could foster more involvement from the end users with the smart meters.

In our simplification, we only identified market acceptance, even though in the Netherlands the market is divided into the liberalized and regulated market. Further segmentation of the market acceptance - e.g. to liberalized and regulated - would provide different importance of the values. This segmentation would enable socio-political actors to provide the right incentives and institutionalizations to foster the acceptance of the smart meters by both market stakeholder groups. For example, an expert active in the liberalized market (supplier of HEMS product and services) suggested that the regulated market player would evaluate values important for liberalized market stakeholder as low (which was the case), because the regulated market lacks perceiving the benefits and reasons for it. Further studies should access this limitation with a special focus on analyzing the collaboration between these actors, which will provide insights into the cooperation between regulated and liberalized market players for a complex technology.

Smart meters as a complex technology requires acceptance from different stakeholder groups to create legislative proposals for it. It is important for institutionalization and socio-political acceptance to include the insight and demands of different stakeholder groups as well as guaranteeing compliance with previous and other regulations. Our research has focused on the different stakeholder groups' important values, although further studies should access and analyze the compliance of our findings with current and previous regulation, which is also important for socio-political acceptance.

The BWM depicts the importance of the values, even though the other values should not be neglected. There are especially some values - like security and safety - which are not the most important value for the social acceptance of smart meters, although neglecting these values will result in the rejection by the society. A technology that cannot guarantee the security and safety of the meter reading will be valued as undesirable and unreliable technology by the end users and thus they will reject the smart meter. On the other hand, several experts stated that all the values in the socio-political and market acceptance are important; hence, the BWM depicts the importance of the important values. For the further development of the technology and institutional design, these values should be incorporated to meet the requirements of the stakeholder groups. In a further study, these minimal requirements for the other important values - we call them 'veto-values' - should be analyzed, which will help to create smart meter technology that meets all the criteria for social acceptance.

For the BWM, we take the assumption that a single expert (or a few experts) represents a group of stakeholders and decides about the importance of the values. However, even in the group of stakeholders, importance can deviate based upon experts' views, who also have their own preferences and importance for values. We have to utilize the result with this limitation. Therefore, implications (design requirements) should be discussed in this group of stakeholders before applying it to the technology.

6.4 Conclusion of the Discussion

Privacy is the most important value for both the socio-political and household acceptance of smart meters. We have learned that due to different regulations about privacy, there was no socio-political acceptance for smart meters (Bellantuono, 2014; Cuijpers & Koops, 2013; Ligtvoet et al., 2015). Several scholars have stated that for end users privacy is particularly important for the acceptance of smart meters (AlAbdulkarim et al., 2014; Cuijpers & Koops, 2013; Darby, 2012; Verbong et al., 2013) and the Dutch consumer union demands a voluntary rollout for smart meters. For market acceptance, cost-effectiveness was the most important value, which depends on the size of the market or installed base (Van de Kaa et al., 2011) for economies of scale (Erlinghagen et al., 2014). Hence, for the cost-effectiveness, the acceptance by end users to provide meter readings from smart meters is crucial and for end users privacy is the most important value.

Several scholars have suggested that the analysis of technology standards - especially for a complex technology - lacks inputs from institutional and social literature and hence they propose a multidisciplinary approach (Brunsson et al., 2012; Narayanan & Chen, 2012; Shin et al., 2015). Our research reviews the acceptance for a complex a technology from different group of stakeholders' literature streams. Hence, our study makes a first notion for a multidisciplinary approach, which includes the institutional literature, technology management and network economic literature as well as philosophy and ethics literature to analyze a complex technology's selection.

Another scientific contribution of the thesis is that we have verified the applicability of the BWM to measure values. We also illustrate how the BWM can be utilized to prioritize or find the importance of values, which enable researchers in ethics of technology to trade-off between values. However, we do not mean to claim that the BWM should replace qualitative analysis. On the contrary, the result from BWM indicates the direction for the qualitative analysis.

We have built social acceptance into three groups of stakeholders (dimensions) based upon the assumption that the important values for this group of stakeholders are the same. However, every stakeholder has his/her own importance and preference in values, which is limited in our research. We suggest different studies to further segment each group of stakeholders to analyze their subset of values, which enables offering different services for specific end user segments or different market players' incentives to cooperate for the smart meters.

For the BWM evaluation, we took the assumption that a single expert (few experts) decides about the importance of the values. However, even in a group the preference and importance for a value deviates. We suggest only incorporating our design requirements after discussing and analyzing it among this group of stakeholders.

Furthermore, the BWM pointed out the most important values, even though other values still have to be meet for minimal requirements, otherwise end users would still reject the smart meters.

7 Conclusion

The thesis has addressed the acceptance of a complex technology, namely smart meters. We conducted an exploratory study on the technology selection based upon the Dutch case of smart meters. Analyzing the Dutch case for smart meters demonstrated the rejection and problematic issues for the smart meters in the society of the Netherlands. Therefore, we set our research objective to address the social acceptance of smart meters in the Netherlands and find implications to improve the social acceptance.

A main research question was formulated to address the acceptance of the smart meters:

> *"Which values are important for the social acceptance of smart meters and the successful implementation of the smart grid in the Netherlands?"*

A sub-set of questions were also formulated, offering insights and building the answer to the main-research question:

- Sub-RQ1 – *How can the acceptance for the smart meter be conceptualized?*

We have reviewed social acceptance literature and found multiple literatures (Künneke et al., 2015; Ligtvoet et al., 2015; Narayanan & Chen, 2012; Shin et al., 2015) stating that a complex technology such as the smart meter should be assessed from multiple perspectives. We build our concept on the social acceptance concept of Wüstenhagen et al. (2007), adapted the dimensions to socio-political, market and household acceptance, which are the important stakeholder groups for smart meters. The literature regarding each perspective of acceptance was defined, which was essential to identify the values for each dimension of acceptance. We analyzed the socio-political acceptance based upon energy policy literature stream, market acceptance on the network economics, technology management and energy policy literature stream, as well as household acceptance on technology acceptance, applied ethics and ethics of technology literature stream.

Figure 4 illustrates the dimensions and the groups of stakeholders representing the dimension. On this basis, we accessed the literature about the important values for each group of stakeholders. This framework for social acceptance enables utilizing experts representing and having insights about the group of stakeholders to evaluate the importance of the values, which is essential for our methodology. On the other hand, this is also a limitation of the thesis, because even among the stakeholders of a group their preferences and importance for values differ and using experts' opinions it will be influenced to their preference and importance for values. Further segmentation in each dimension of acceptance could resolve this limitation.

- Sub-RQ2 – *Which values should be considered for the social acceptance of smart meters?*

Building the framework for the social acceptance of smart meter enabled us to group the stakeholders for acceptance of the smart meter. Friedman et al. (2013, p. 57) defined 'value' as "what a person or group of people consider important in life". Therefore, accessing the important value of smart meter for each dimension (group of stakeholders' perspective) of acceptance will enable us to evaluate the most important values for the social acceptance of smart meters. We utilized the set of literature stream as perspectives for each group of stakeholders to derive their values. We utilized the value sensitive design (VSD) approach and the literature from the Handbook of Ethics, Values, and Technological Design to redefine the derived values from the literature. This approach disclosed the social and moral aspects of the values, which is essential for the social acceptance of a technology. After defining the values according to the stakeholders' perspectives, we conducted a qualitative validation of the values to analyze whether these values are applicable and if there are additional values for the social acceptance of smart meters. Table 6 shows the relevant values for the social acceptance of smart meters. Further segmentation (to an individual-level) would have allowed us utilize each specification of the value, although it would have also complicated the evaluation and implication for the thesis.

- Sub-RQ3 – *What is the importance of the values in each of the conceptualized dimensions for the social acceptance of smart meters and how can this be explained by the extant literature?*

To find the most important values for the social acceptance of smart meters, the importance of the identified values needs to be evaluated. Experts of smart meters with years of experience with smart meters have evaluated the identified values of social acceptance of smart meters. We have grouped experts who have expertise and can represent the opinion of the group of stakeholders to each dimension of acceptance. The BWM - a method for pairwise comparing the values - depicted that privacy is the most important value for both socio-political acceptance and household acceptance of smart meters. For market acceptance, cost-effectiveness was the most important value. The different policies and regulation regarding privacy and concern from the Dutch consumer association demanded the legislative proposal for the smart meters to adapt, which changed the mandatory to a voluntary roll-out for smart meters. Therefore, institutional design requirements should be based upon privacy to guarantee socio-political acceptance. Cost-effectiveness for the market stakeholders largely depends on the size of the market (Erlinghagen et al., 2014), which on the other hand depends on the acceptance by the end users owing to the voluntary roll-out of the smart meters.

- Sub-RQ4 – *How can the important values for the social acceptance of smart meters be translated to design requirements?*

We have formulated three institutional design requirements and two technical design requirements based upon three norms for the value of privacy for smart meters. The approach to formulate the design requirements is based upon the value hierarchy. These design requirements should foster the social acceptance of the smart meters, although they are limited due to the conflict with another important value, namely cost-effectiveness. Our aim was to demonstrate how design requirements could be formulated based on important values of the smart meter; hence our design requirements (Figure 6) should be analyzed and evaluated by the groups of stakeholders for acceptance before they are implemented.

The Main-RQ answer is that privacy and cost-effectiveness are the most important values for the social acceptance of smart meters and a value hierarchy based upon the importance of the values (Table 8) will enable creating the design requirements for the social acceptance of smart meters in the Netherlands.

7.1 Further studies

As suggested in section 5.4, the segmentation of the social acceptance can be further divided. Especially household acceptance can be divided into the end users with similar characteristics, which will enable us to depict the most important values to create the specific services and design for each group of end users. Providing services and solutions depends on the important values of each group of end user segmentation will have further acceptance by the end users (Kaufmann et al., 2013). Future studies should focus on the segmentation of the market stakeholders, especially in the Netherlands, with the regulated and liberalized electricity market (Bellantuono, 2014). This study will enable ascertaining the important value for each group, which will enable creating an institutional design to foster more collaboration and acceptance between these parties.

Our scientific finding for a complex product to review its selection or acceptance from multiple perspectives is seminal, through combining institutional, ethical, network economic and technology management literature. Conducting our multiple perspective approach for other complex technologies and in other countries will enable generalizing our approach, which is essential owing to increasing technological complexity (Narayanan & Chen, 2012).

We have shown the applicability for the BWM to measure and evaluate values. Even though the BWM provides the importance of the values for social acceptance, the results should be compared with other methodologies used for comparing values. For example, Ligtvoet et al. (2015) utilized the Q-methodology to find the important value. Therefore, in a further study, both methodologies could be compared, which will verify the applicability of the BWM to evaluate value in literature of ethics of technology.

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9 Appendix 1 - List of derived values

<u>Socio-political acceptance</u> (reference list with sentences)

Literature stream	Value	Definition	Reference
Energy Policy	Privacy	legal action in the Netherlands, where consumer bodies objected to the mandatory rollout of a piece of equipment (smart meters) that gave utilities detailed information about consumption, but without offering any apparent benefits to customers. The judgement of the case led to a revision of government policy, with rollout on a voluntary basis.	Darby (2012, p. 104)
Value sensitive Design (value definition)	Privacy	Smart meter should keep the private space of end-users free from intrusion and also should enable to determine what information about herself or himself can be communicated.	(Warnier et al., 2015, p. 433) (Friedman et al., 2013, p. 58)
Value sensitive Design	Privacy	After several rounds of reviews and discussions about privacy, and amendments as a response to the Dutch Data Protection Authority	(Ligtvoet et al., 2015)
Energy Policy	Environmental sustainability	One of the primary goals for policy maker is to address the environmental issue	(Geert P.J. Verbong et al., 2013, p. 124)
Value sensitive Design (value definition)	Environmental sustainability	By utilizing the smart meter functionalities the energy consumption does not burden the	(Behnam Taebi & Kadak, 2010, p. 1347) (Friedman et al.,

		environment.	2013, p. 59)
Energy Policy	Compatibility	uniform, national standard and ubiquitous compatibility will provide a significant edge for the adoption rate of the Smart grid	(Peretz, 2011, p. 24)
Value sensitive Design (value definition)	Compatibility	Smart meters ability to adequately perform its function in conjunction with other apparatus (similar product and complementary devices) and infrastructure	(van de Poel, 2015, p. 673)
Energy Policy	Cost-effectiveness	the market-based policy-setting process have the goals regarding cost-efficiency (incentive-mechanism for utilities as well as end-users). Therefore the policy for smart meter should have a cost-effective nature for firms as well as end-users.	(G.P.J. Verbong & Geels, 2010, p. 1227) (Wüstenhagen et al., 2007)
Value sensitive Design (value definition)	Cost-effectiveness	Affordability regarding cost and benefit, when embarking on the smart metering system and ensuring its continuation over the course of time	(Behnam Taebi & Kadak, 2010, p. 1347)
Energy Policy	Trust	Trust in the government and in the energy industry in given context will affect the nature of the debate	(S. J. Darby, 2012, p. 104)
Value sensitive Design (value definition)	Trust	The smart meter promotes the expectation that exists between the people (actors) who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal	(Huldtgren, 2015, p. 746) (Friedman et al., 2013, p. 56)
Energy Policy	Reliability	Reliability issues concern regulations of energy	(Wolsink, 2012, p. 824)

		flows as ell as balancing market forces; for both it is essential to install and use smart meters as part of smart grid	
Value sensitive Design (value definition)	Reliability	The smart meters' ability to perform without failing and without the grid malfunctioning (as in blackouts).	(van de Poel, 2015, p. 673).
Energy Policy	Autonomy	policies will be increasingly designed to enhance the autonomy of (local) groups of end-users	(Wolsink, 2013a, p. 10)
Value sensitive Design (value definition)	Autonomy	Users have control over the smart meter in order to plan and execute their actions in way to achieve their goals.	(Friedman et al., 2013, p. 58)
Value sensitive Design (value definition)	Procedural justice	Transparency, honesty and as well as timely, full, and unbiased information in the procedure of decision-making about smart meters	(Dignum et al., 2015, p. 9).
Energy Policy	Fairness (for procedural justice)	Investments on both sides of the electricity meter should be treated equally, i.e. homeowner should also get access to tax allowances as big power companies do	(Sauter & Watson, 2007, p. 2778)

Household acceptance

Literature stream	**Value**	**Definition**	**Reference**
Value sensitive Design (value definition)	Security / Safety	Smart meters protecting the end-users from intentional harmful attacks (e.g. cyber-attack, burglary) and unintentional effects (loss	(Behnam Taebi & Kadak, 2010, p. 1347)

		of user-data)	
Technology Acceptance	Security / Safety	Failure in protecting the security of the end-users information will lead to resistance from the household will and can lead to inability to involve end-users actively for demand side management	(L. AlAbdulkarim & Lukszo, 2011, p. 287)
Value sensitive Design (value definition)	Usability	Every household should be able to successfully use the smart meter and its functionalities	(Huldtgren, 2015, p. 745).
Energy Policy	Usability	The smart meter and system around it (smart appliance or home energy management system) should reduce its complexity, meaning the system needs to be easy to use for the end-users	(Geert P.J. Verbong et al., 2013, p. 122)
Value sensitive Design (value definition)	Compatibility	Smart meters ability to adequately perform its function in conjunction with other apparatus (similar, complementary devices) and infrastructure	(van de Poel, 2015, p. 673)
Energy Policy/ Technology acceptance	Compatibility	For instance, technology-oriented value propositions like coupling smart metering with mobile devices like iPhones might be very valuable for customers who favor smart phones	(Kaufmann et al., 2013, p. 231)
Value sensitive Design (value definition)	Cost-effectiveness	Affordability regarding cost and benefit, when embarking on the smart metering system and ensuring its continuation over the course of time	(Behnam Taebi & Kadak, 2010, p. 1347)

Energy Policy	Cost-effectiveness	References to consumer behaviour in 'smart grid' configurations tend to narrow the focus exclusively on consumer response to price incentives. This basically limits the issue to 'demand side management' (DSM) by providers, emphasising price-based demand response	(Wolsink, 2012, p. 824)
Value sensitive Design (value definition)	Trust	The smart meter promotes the expectation that exists between the people (actors) who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal	(Huldtgren, 2015, p. 746) (Friedman et al., 2013, p. 56)
Technology acceptance	Trust	when people know little about a technology, acceptance mostly depend on trust in actors that are responsible for the technology…	(Huijts, Molin, & Steg, 2012, p. 528)
Value sensitive Design (value definition)	Privacy	Smart meter should keep the private space free from intrusion and also should enable to determine what information about herself or himself can be communicated.	(Warnier et al., 2015, p. 433) (Friedman et al., 2013, p. 58)
Energy Policy	Privacy	privacy is considered an issue the can block the successful introduction of smart grid and demand side management (DSM	(Geert P.J. Verbong et al., 2013, p. 120)
Value sensitive Design (value definition)	Autonomy	Users have control over the smart meter in order to plan and execute their actions in way to achieve	(Friedman et al., 2013, p. 58)

		their goals.	
Energy Policy	Autonomy	barriers relate to freedom regarding what data to communicate and degree of control over e.g. smart appliances (smart washing machine), which also relates to the complexity of the system.	(Geert P.J. Verbong et al., 2013, p. 122)
Value sensitive Design (value definition)	Distributed justice	The fair distribution of the cost and benefits and other positive and negative effect of smart metering	(Dignum et al., 2015, p. 8).
Energy Policy	Fairness	consumers should receive appropriate benefits from any cost reductions achieved by the Energy supply industry resulting from smart metering	(Kaufmann et al., 2013, p. 229)
Value sensitive Design (value definition)	Environmental sustainability	By utilizing the smart meter functionalities the energy consumption does not burden the environment.	(Behnam Taebi & Kadak, 2010, p. 1347) (Friedman et al., 2013, p. 59)
Energy Policy	Environmental sustainability	The second most commonly expressed motivation for smart meters and smart energy monitors is environmental	(Hargreaves et al., 2010, p. 6114)
Energy Policy	Comfort	the provision of technological solutions allowing the optimisation of comfort and more control over own energy use… Better comfort refers to the use of advanced technology to control and manage electricity use	(Gangale, Mengolini, & Onyeji, 2013, p. 627)

Market acceptance

Literature stream	Value	Definition	Reference
Value sensitive Design (value definition)	Efficiency	Smart meters ratio between the degree to which it fulfil its function and the effort (data-rate, latency, rang etc.) to achieve that effect.	(van de Poel, 2015, p. 673). (Erlinghagen et al., 2014, p. 1253).
Value sensitive Design (value definition)	Reliability	The smart meters' ability to perform without failing and without the grid malfunctioning (as in blackouts)	(van de Poel, 2015, p. 673).
Energy Policy	Reliability	Another important criterion for standard selection is robustness. The communication to and from the node needs to be reliable in order to transmit the data without error.	(Erlinghagen et al., 2014, p. 1255)
Value sensitive Design (value definition)	Compatibility	Smart meters ability to adequately **perform** its function in conjunction with other apparatus (similar, complementary devices) and infrastructure	(van de Poel, 2015, p. 673)
Energy Policy	Interoperability	Utilities will also look for interoperability in lower and upper layer standards. Three types of interoperability can be distinguished: Firstly, interoperability between different versions of a standard … secondly, interoperability between implementations of the same standard by different vendors... Thirdly, interoperability can be achieved among	Erlinghagen et al. (2013, p. 1253 -1254

		different standard	
Network economic and technology management	interoperability	… smart grids are becoming a practical reality. These systems connect differenet energy components into one system. In this situation, energy is not generated by large power plants but by individual consumers. To accomplish that, smart energy system is needed and to realize those systems, standards for interoperability are indispensable	Van de Kaa, 2013, p. 62
Energy policy	Availability of complementary goods	Availability of complementary goods (smart appliance, smart devices, HEM etc.) for smart meters	(Erlinghagen et al., 2014, p. 1250)
Energy Policy	Availability of complementary goods	...transformation of the energy sector can be viewed as a sustainability transition, which depends on the simultaneous development of **complementary technologies**, including new renewable energies, energy storage, energy efficiency and smart grid	Erlinghagen et al. (2013, p. 1250)
Technology managment	Availability of complementary goods	firms to secure and manage a healthy pool of producers of complementary goods for their systems, so as to make them more attractive to customers	(Suarez, 2004, p. 273)
Organizational studies/ Technology	Flexibility	Smart meter technology (standard) degree of changes over time or the ability to **adapt** to	(van den Ende et al., 2012, p. 705) (Van de Kaa et

management		changes in customer needs and new technological developments.	al., 2011, p. 1404)
Value sensitive Design (value definition)	Procedural justice	Transparency, honesty and as well as timely, full, and unbiased information in the procedure of decision-making about smart meters.	(Owen, Bessant, & Heintz, 2013, p. 220) (Erlinghagen et al., 2014, p. 1254).
Technology management		WiFi to create additional organisational opportunities for participation: **anyone could propose changes** and form 'task groups' to address the proposed change	(van den Ende et al., 2012, p. 20)
Value sensitive Design / Energy Policy	Ownership	To possess resources and competences for the communication network for smart meters, use it, manage it, derive income from it	(Huldtgren, 2015, p. 745) (Erlinghagen et al., 2014, p. 1254)
Value sensitive Design / Energy Policy	Cost-effectiveness	Affordability regarding cost and benefit, when embarking on the smart metering system and ensuring its continuation over the course of time	(Behnam Taebi & Kadak, 2010, p. 1347) (Erlinghagen et al., 2014)
Technology selection	Commitment	Market actors commitment to a smart metering technology or standard	(Van de Kaa et al., 2011, p. 1405)
Energy Policy / Technology Management	Publicity	Marketing and communication to provide publicity for the smart meter technology to attract segments of market and gain market share	'(Wolsink, 2012, p. 830) (Van de Kaa et al., 2011, p. 1404)
Value sensitive Design (value	Disclosure	Disclosure refers to providing accurate	(Friedman, Felten, & Millett,

definition)		information about the benefits and harms that might reasonably.	2000, p. 1,2)
Energy Policy / Technology Management	Popularity	Popularity of smart meter technology or standard and recognition by the end-users.	(Erlinghagen et al., 2014, p. 1254) (Farrell & Saloner, 1986, p. 945)
Value sensitive Design	Trust	The smart meter promotes the expectation that exists between the people (actors) who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal	(Huldtgren, 2015, p. 746) (Friedman et al., 2013, p. 56)
Energy Policy		Trust in government and in the energy industry in a given context will affect the nature of the debate	(Darby 2012, p. 104)

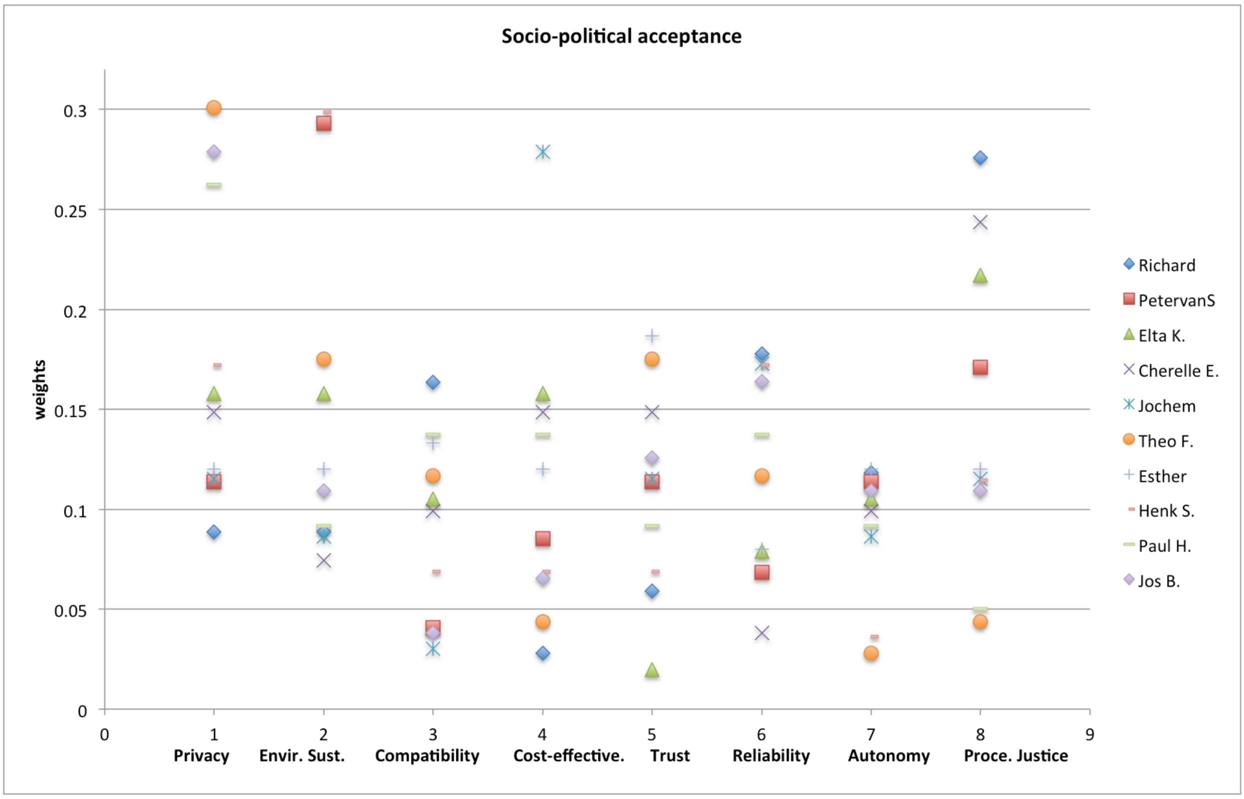
10 Appendix 2 – Experts' background

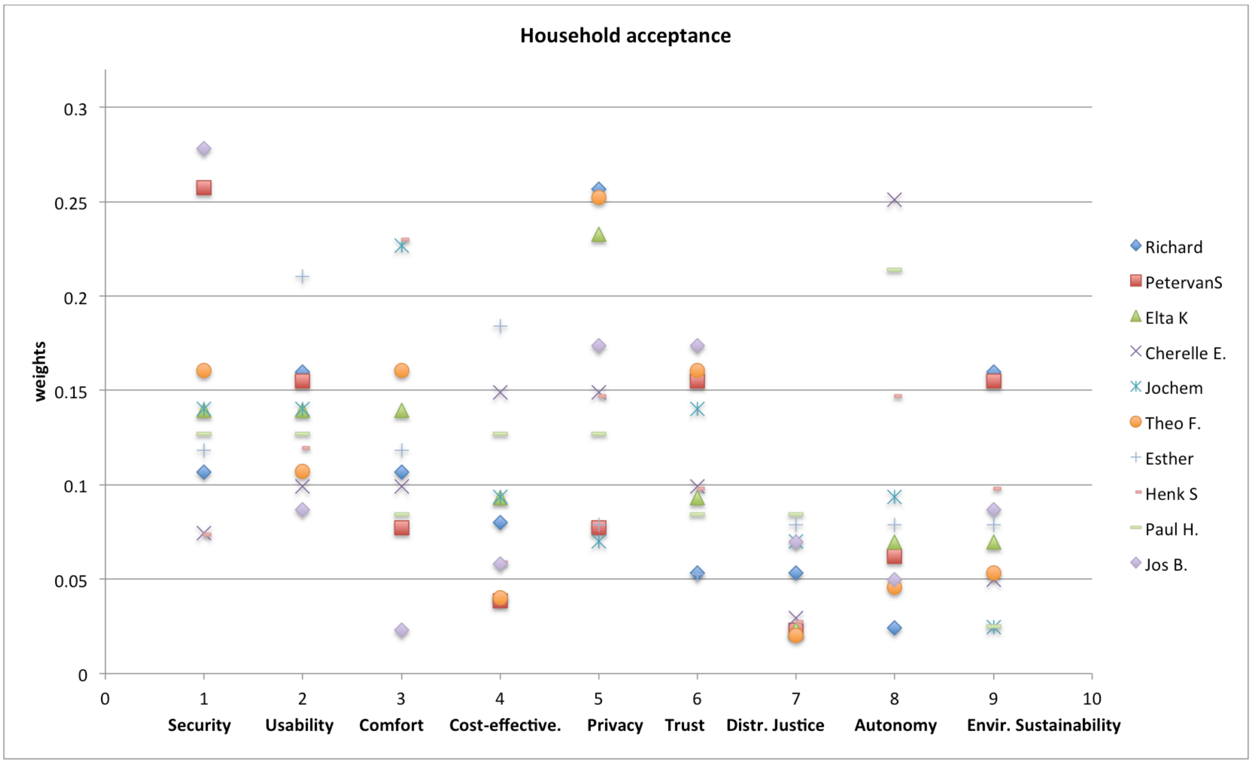
List of the experts evaluated the values according with Best-Worst Method

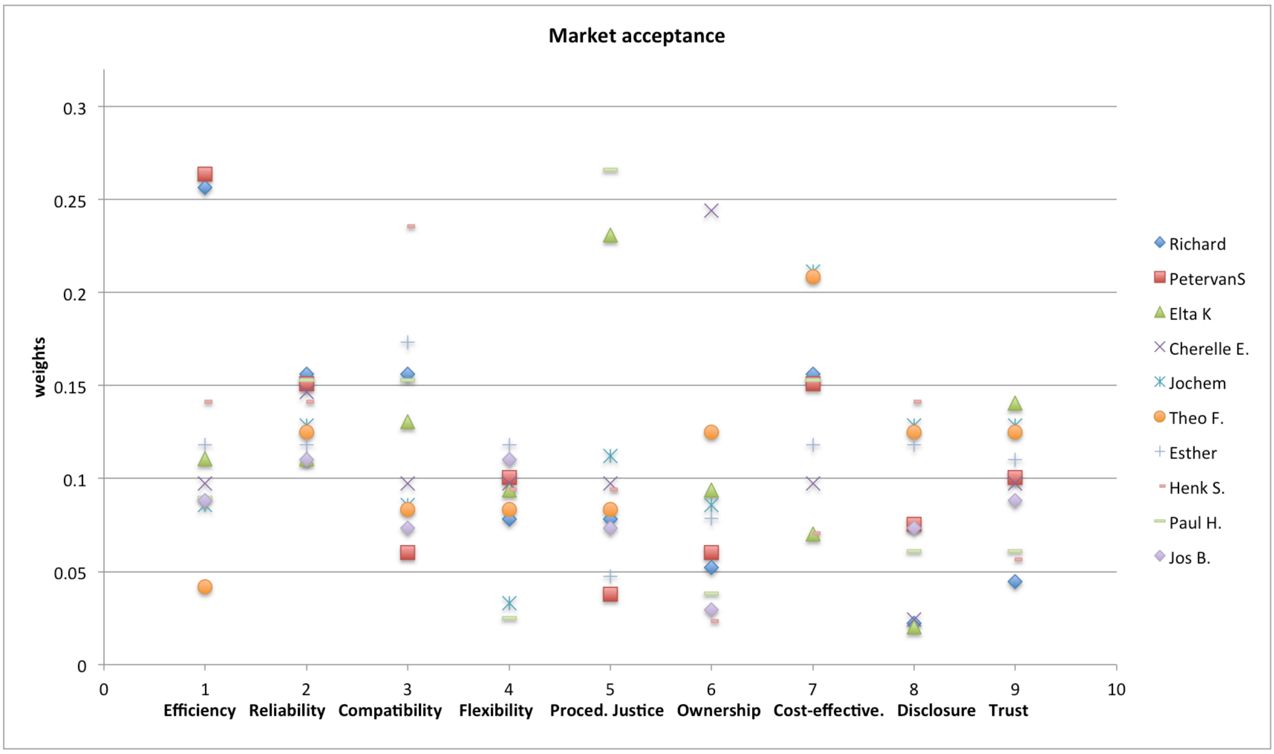
Expert	Field of expertise	Years
Theo F.	Advisor and developer of Smart meter, end-users with Home energy management system (HEMS)	>10
Esther M.	Innovation manager in DNO and worked for implementation project of smart meters	6
Cherelle E.	PhD-candidate in demand side management stakeholder analysis	4
Elta K.	PhD–candidate, Implementation and regulation for smart meters and demand response	5
Jochem D.	PhD- candidate, customer behavior of smart meter end-users	3
Richard G.	Advisor and previous work in DNO, customer center and with ministry of economic of affairs	6
Peter S.	Strategy manager at DNO, Advisor and developer of the Smart meter Policy in Europe	>10
Jos B.	Strategy manager at DNO, Advisor and developer of smart meter system	10
Paul H.	HEMS and energy management service provider, previous advisor for utility firm and expert about customer behavior in energy usage in households	6
Henk S.	Advisor and consultant, data management system of smart meters, end-users with HEMS	8

11 Appendix 3 - Deviation of BWM-results

Results of BWM of all the experts for each dimension (without grouping)






Market acceptance
weights
0.3
0.25
0.2
0.15
0.1
0.05
0
0 1 2 3 4 5 6 7 8 9 10
Efficiency Reliability Compatibility Flexibility Proced. Justice Ownership Cost-effective. Disclosure Trust
Richard
PetervanS
Elta K
Cherelle E.
Jochem
Theo F.
Esther
Henk S.
Paul H.
Jos B.

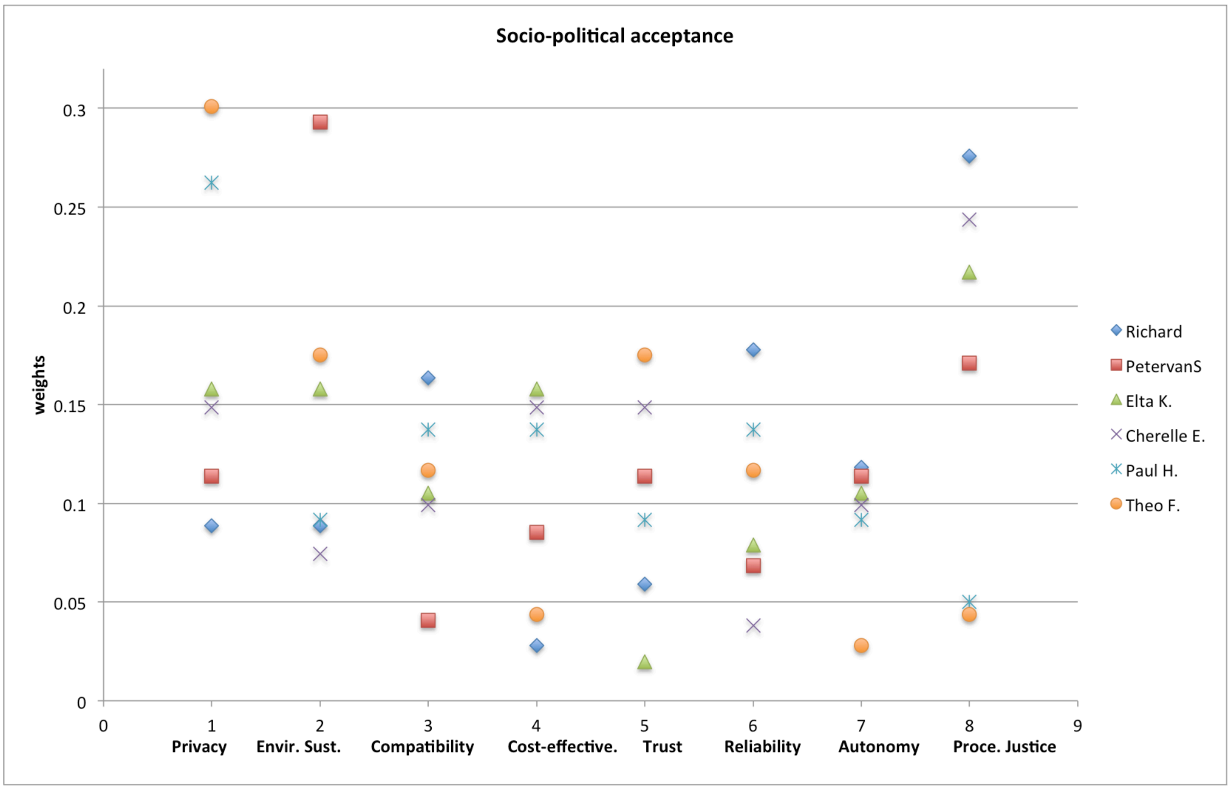
12Appendix 4 - Assignation of Experts to groups

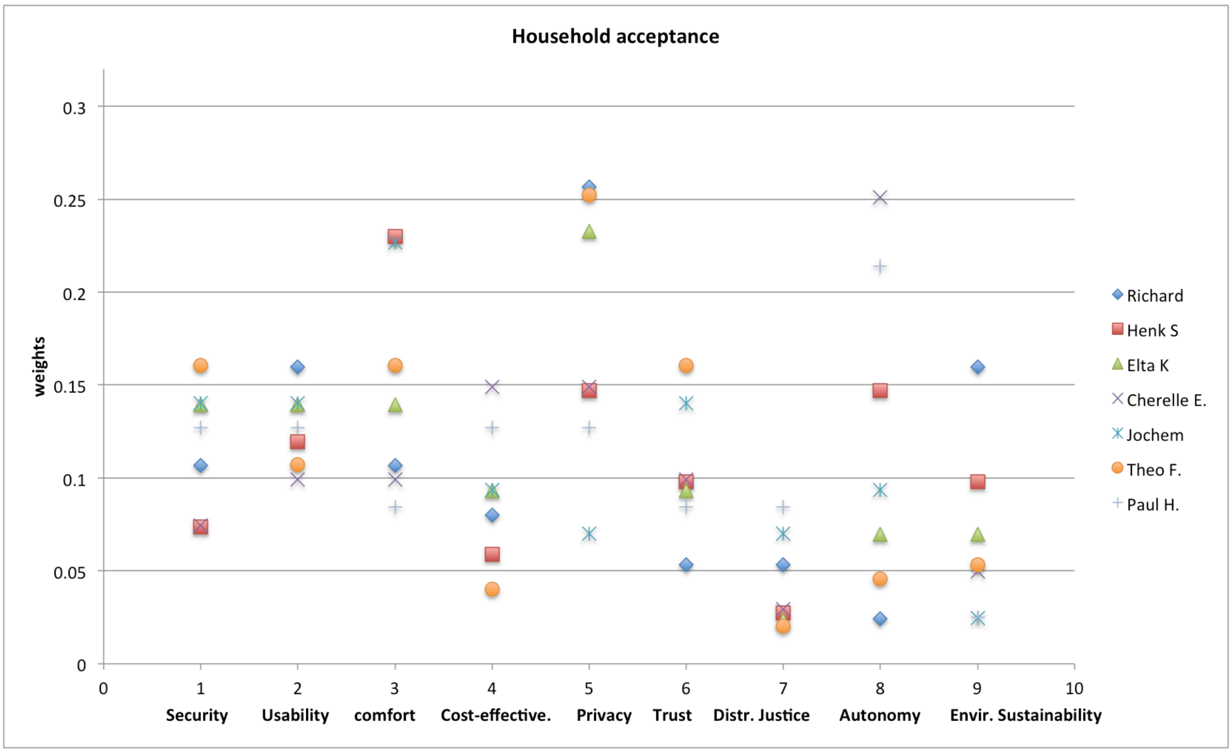
List of with experts grouped according to their expertise to the dimension of acceptance

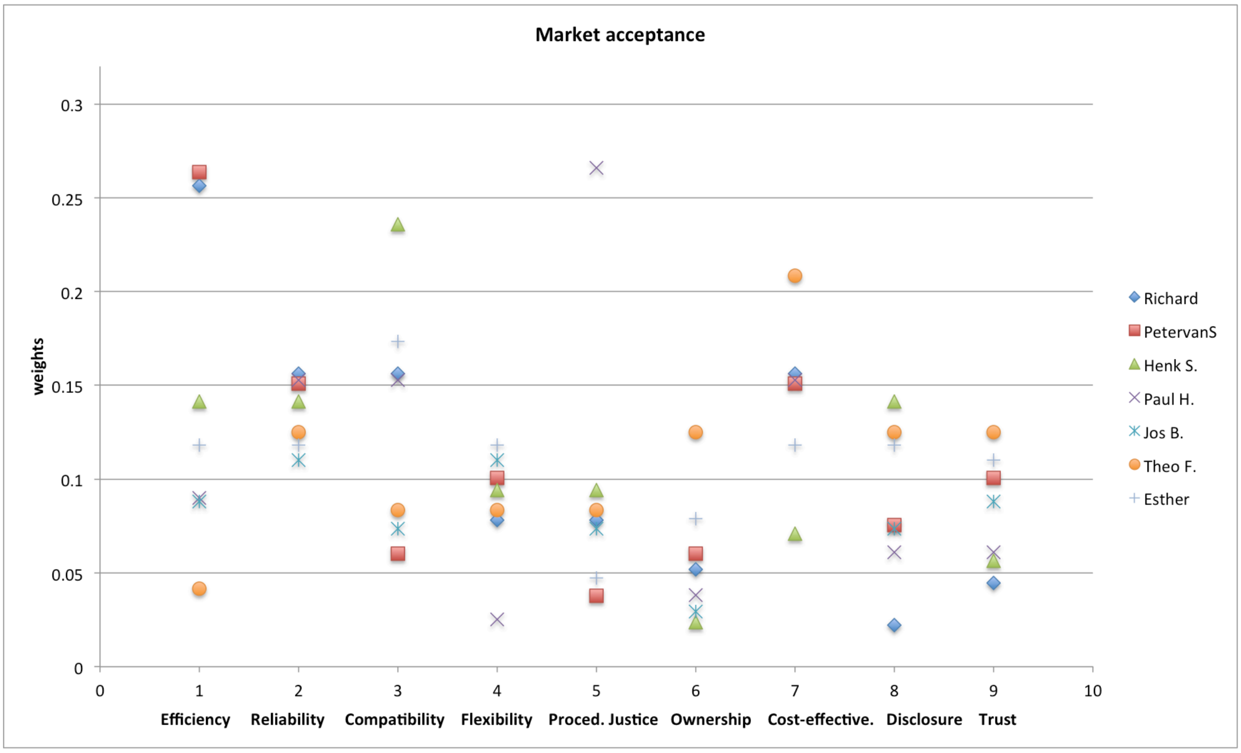
Socio-political acceptance	**Household acceptance**	**Market acceptance**
Richard G. - Collaboration with socio-political stakeholder	Richard G. – leading customer center in DNOs	Richard G. – Advisor at DNO about implementation the smart meters
Peter S. – Advisor and decision-making about smart meter policies (National & European)	Henk S. – End-user of Smart meter with HEMS	Henk S. – Advisor for DNOs for smart metering systems
Elta K. – Research about the policy-making and implementation of smart meters	Theo F. – End-user of Smart meter with HEMS	Theo F. – Advisor for DNOs about smart meters
Paul H. – Advisor and collaboration with socio-political stakeholder for policy for the HEMS-market	Paul H. – expert about customer behavior in energy usage	Paul H. – HEMS product and service provider, previous advisor for utility firm
Theo F. – Advisor and decision-making abouth smart meter policies (national & European)	Jochem D. – research about customer behavior	Jos B. – Advisor at DNO and developer of smart meter system
Cherelle E. – Research about the socio-political stakeholder	Elta K. – research about implementation of demand response for end-users of smart meters	Peter S. - Strategy manager at DNO, Advisor about smart meter
	Cherelle E. – stakeholder analysis about demand response of end-users	Esther M. - Innovation manager in DNO and worked for implementation project of smart meters

13 Appendix 5 – Deviation of BWM-results (grouped)

Result of BWM of each expert's background is grouped to the dimension of acceptance






Market acceptance
weights
0.3
0.25
0.2
0.15
0.1
0.05
0
0 1 2 3 4 5 6 7 8 9 10
Efficiency Reliability Compatibility Flexibility Proced. Justice Ownership Cost-effective. Disclosure Trust
Richard
PetervanS
Henk S.
Paul H.
Jos B.
Theo F.
Esther

14 Appendix 6 - Final set of values with definition

Below you can find the values of each dimension of acceptance with definition.

Socio-political acceptance

Value	Definition
Privacy	Smart meter should keep the private space of end-users free from intrusion and also should enable to determine what information about herself or himself can be communicated.
Environmental sustainability	By utilizing the smart meter functionalities the energy consumption does not burden the environment.
Compatibility	Smart meters ability to adequately perform its function in conjunction with other apparatus (similar product and complementary devices) and the infrastructure
Cost-effectiveness	Affordability regarding cost and benefit, when embarking on the smart metering system and ensuring its continuation over the course of time
Trust	The smart meter promotes trust and expectation that exists between the people (actors) who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal
Reliability	The smart meters' ability to perform without failing and without the grid malfunctioning (as in blackouts).
Autonomy	Users have control over the smart meter in order to plan and execute their actions in way to achieve their goals.
Procedural justice	Transparency, honesty and as well as timely, full, and unbiased information in the procedure of decision-making about smart meters

Household acceptance

Value	Definition
Security /Safety	Smart meters protecting the end-users from intentional harmful attacks (e.g. cyber-attack, burglary) and unintentional effects (loss of user-data)
Usability	Every household should be able to successfully use the smart meter and its functionalities and ability to adequately perform its function in conjunction with other apparatus (similar, complementary devices) and infrastructure
Comfort	Smart meters provides comfort by customization, remote temperature control, information about the energy usage etc.
Cost-effectiveness	Affordability regarding cost and benefit, when embarking on the smart metering system and ensuring its continuation over the course of time
Trust	The smart meter promotes trust and expectation that

	exists between the people (actors) who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal.
Privacy	Smart meter should keep the private space free from intrusion and also should enable to determine what information about herself or himself can be communicated.
Autonomy	Users have control over the smart meter in order to plan and execute their actions in way to achieve their goals.
Distributive justice	The fair distribution of the cost and benefits and other positive and negative effect of smart metering (renewable energy)
Environmental sustainability	By utilizing the smart meter functionalities the energy consumption does not burden the environment.

Market acceptance

Value	Definition
Efficiency	Smart meters ratio between the degree to which it fulfil its function and the effort (data-rate, latency, rang etc.) to achieve that effect.
Reliability	The smart meters' ability to perform without failing and without the grid malfunctioning (as in blackouts)
Compatibility	Smart meters ability to adequately **perform** its function in conjunction with other apparatus (similar, complementary devices) and infrastructure and Availability of complementary goods (smart appliance, smart devices, HEM etc.) for smart meters
Flexibility	Smart meter technology (standard) degree of changes over time or the ability to **adapt** to changes in customer needs and new technological developments.
Procedural justice	Transparency, honesty and as well as timely, full, and unbiased information in the procedure of decision-making about smart meters.
Ownership	To possess resources and competences for the communication network for smart meters, use it, manage it, derive income from it
Cost-effectiveness	Affordability regarding cost and benefit, when embarking on the smart metering system and ensuring its continuation over the course of time
Disclosure	State the purpose of the smart meters and provide accurate information about the advantage and disadvantages of the smart meters.
Trust	The smart meter promotes trust and expectation that exists between the people (actors) who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal

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