ERASMUS MUNDUS MASTER PROGRAM IN EUROPEAN PUBLIC POLICY

MUNDUS MAPP 2013-2015

2013/2014: Central European University, Department of Public Policy

2014/2015: University of York, Department of Politics

THE POTENTIAL OF SMART METERING FOR ENVIRONMENTALLY RESPONSIBLE BEHAVIOR

The effectiveness and efficiency of the Dutch implementation strategy

Thesis project Simone Kranendonk

Exam candidate number: Y2127730

June 2015

Supervisor University of York: Neil Carter

Supervisor Central European University: Uwe Puetter

Word count: 12.496

Includes: abstract, body, footnotes, references, bibliography and appendices.

Excludes: tables and figures.

ABSTRACT In the framework of the EU directive on smart grids, smart metering policies are implemented across Europe aiming at more energy efficiency and less greenhouse gas emissions. Smart metering seems to have the potential to significantly contribute to residential energy savings, environmental awareness and consciousness and ultimately more environmentally responsible behavior, provided they serve as a feedback intervention. By not including comprehensive feedback mechanisms the Dutch policy implementation strategy is likely not to exploit this full potential of smart metering and missing out the potential of more ERB across society. Consequently, the societal business case underlying smart metering policies is unlikely to be realized because of the ineffective and inefficient aspects of the Dutch implementation strategy.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

I. INTRODUCTION

Environmental protection, climate change and ecological sustainable development are themes referring to one of the main challenges for today's governance institutions and governments. Many of environmental problems like global warming, (urban) air pollution, sea pollution and loss of biodiversity are mostly rooted in human behavior, consequently they can be managed by changing the relevant behavior so as to reduce their environmental impacts. Behavior that harms the environment as little as possible, or even benefits the environment is called environmentally responsible behavior (ERB) or pro-environmental behavior (PEB) (Steg & Vlek, 2009: 309). Smart metering is partly implemented as a policy instrument to change people's energy consumption behavior to lower greenhouse gas emissions and thus benefit the environment. Smart grids are energy networks that can automatically monitor energy flows and adjust to changes in energy supply and demand accordingly (European Commission website 2015c, Energy). In the framework of the 2020 Strategy of the European Union on the pathway to more sustainable growth, the goal is to have 80% of EU households connected to a smart grid. For European consumers, this means that they are offered to have a smart meter installed to their homes. Because the roll out of smart metering policy is not specified by the EU directive, Member States can tailor their implementation strategy to fit their specific energy markets.

The implementation strategies, roll out policies and processes differ between Member States, as well as in their effectiveness and efficiency. Focusing on the consumer side of smart metering, smart meters as feedback intervention seem to have great potential to reach the goal of more residential

energy saving. Specifics with regards to feedback are essential in order to make smart metering an understandable, accessible and visible learning process for the consumers. The smart metering policy program in the Netherlands differs from others by not including in-home devices (IHD) in the offer of smart meters simultaneously. Consequently, the Dutch implementation strategy is likely to miss out on a great opportunity to exploit the full potential of smart metering because of the policy's potential ineffectiveness and inefficiency.

Looking at smart metering policy in the Netherlands, the first aim is to define the smart meters' potential to contribute to more sustainable societies and secondly, to determine the effectiveness and efficiency of the Dutch implementation strategy in relation to smart metering for realizing this potential. Smart metering potential is defined in three stages: residential energy savings, environmental awareness and consciousness and ultimately more ERB. The potential of smart metering and its effectiveness and efficiency are studied by constructing it as a feedback intervention policy aiming at influencing behavior by providing feedback on specific behavior (Wilson & Dowlatabadi, 2007: 170; Steg & Vlek, 2009: 310, 313). Smart metering in the Netherlands is potentially missing out on great learning potential for consumers across society by not including feedback monitoring in their current implementation strategy. Consequences of this and its implications are extensively discussed. The two research questions reflect the puzzle in this study:

1/ *Does the smart meter as a digital monitoring and feedback device has the potential to significantly contribute to an increase of environmentally responsible behavior in the Netherlands?*

2/ *Does the current policy strategy of the Dutch government make effective and efficient use of the full potential of the smart meter as a digital monitoring and feedback device?*

Smart metering policy in this study refers to the installation of smart meter devices (replacing traditional electro-mechanic meters) in households. We thus focus on households and private consumers, not on businesses (big or small) or the production side of energy supply and smart grids. Residential energy consumption includes both electricity and gas use of households because they are displayed together in energy meters.

Organization

The next chapter lays out different theoretical perspectives on the potential of smart meters as a feedback intervention with regards to ERB as well as the theoretical relevance of a comprehensive feedback approach to smart metering. This is followed by a discussion of the literature, questionnaires, and participant and expert interviews utilized as methods to study these relationships. The main section covers the analysis of the two parts in this study, answering the first and second research question respectively. A critical discussion of these results and implications is presented in chapter five, which is followed by a concluding chapter on the results and further research needed on this topic.

II. THEORETICAL FRAMEWORK

Many environmental problems are related to human behavior, consequently this hazard may be reduced through behavioral changes. The past two decades, the emphasis placed on encouraging action by individual citizens for sustainability has proliferated. Active engagement and participation in ERB is

seen as one of the main subjects in policies targeting ecological protection. This is based on the idea that without participation across societies, no significant effects in decreasing the effect of human behavior on environmental problems can be reached.

Across social sciences, a lot of research has been done on the drivers of individual behavior. Each perspective from the different disciplines suggests particular lessons for designing interventions to change behavior. Interventions herein are 'any regulation policy, program, measure, activity or event that aims to influence behavior' (Wilson & Dowlatabadi, 2007: 170). This study does not look at 'interventions' in general, but more specifically at feedback interventions. In energy consumption studies there are four theoretical perspectives on feedback measures and behavioral change: sociological, economic, psychological and educational (Darby, 2011: 5). These categories refer to the main ideas and underlying rationale of theories, with many possibilities of mixtures of different theoretical perspectives. Barr, for example, uses a 'social psychological approach' (2003: 228), also including knowledge as one of the main factors in studying ERB from a psychological perspective. It is not surprising that sociological, economic, psychological and educational factors are interrelated when it comes to attitudes, opinions and behavior. Feedback measures combining these factors are expected to be very efficient. Smart meters and their complementary displays and applications are considered as a comprehensive feedback measure when it comes to sociological, economic, psychological and educational accounts from the different theoretical perspectives on changing behavior. These relations are explained separately in the following paragraphs.

Sociological theory

Sociological accounts on sustainable development covers a broad range of studies and research. Long before the term 'sustainable development' came into swing, sociological theorists have been studying the relations between human activity and nature, especially in the context of modernization (Burns, 2012: 2, 5-7). Besides the study of the relationship between human activity with nature and its sociological consequences, sociologists also study the emergence, development and formulation of the concepts 'sustainability' and 'sustainable development' themselves (ibidem: 8-10). More relevant for this study is how sociological theory sees chances for behavioral change and the role of innovations in this. Ecological innovation is an often used term in sociological theory when studying sustainable development, sometimes referred to as 'ecological modernization'. Innovation has, and also had in other major sociological transitions, a significant impact on social structures and relations in societies.

Taking this discussion more specifically to (residential) energy use and behavior, smart meters can be seen as an innovation changing relations between consumers and producers in energy management and grid, but also the relations between energy use, resources, and individuals. According to Darby, sociological theory is based on the idea that people use energy as they do because they have particular ideas about what comfort is and how to achieve it (2011: 4). Ideas of comfort originate from what people are used to or what they perceive as necessary. This, in turn, is related to demographic factors. The two main determinants for this are 1/ income and 2/ culture, but a wider range of sociological factors should be considered for a comprehensive approach (Steg & Vlek, 2009). Because energy usage is directly

linked to ideas of 'normal' behavior and comfort, it is hard to change these ideas and consequently the performed behavior. From a sociological perspective, it is mainly the complexity of energy consumption and its 'invisibility' that limits the potential for change. At the same time, sociological theory suggests that single, stand-alone interventions are not likely to have much effect, especially in the long term: energy usage is too complex. In these terms, the installation of a smart meter as a device does not provide the feedback that is needed to stimulate energy savings and significantly cut down energy consumption because it doesn't provide insight in its complexity. Consequently, sociological theory suggests that improved feedback can make consumption more visible, bringing it more within the perceived control of the energy user and demonstrate the success of different actions, behavioral patterns and investments (Darby, 2011: 4).

Economic theory

From an economic perspective ERB is seen as a voluntary effort of the individual to provide an environmental public good (Clark et al, 2009: 239). Public goods are, traditionally, defined as goods which are 'non-rivalry' and 'non-excludable' (ibidem). The environmental public good in this case is society running on less traditional, 'grey', energy resources resulting in lower greenhouse gas emissions. Because of its non-rivalry and non-excludability, there is a problem of collective action and – according to economic theory – contributions are based on voluntary efforts, which partly depends on the individuals' own 'taste' towards the public good (ibidem: 239). In micro economics, the theoretical model in utility theory sees consumers as rational actors in a normative sense of having preferences that are ordered, known,

invariant, and consistent (Wilson & Dowlatabadi, 2007: 172). From this perspective, the individuals' taste is placed high in their order of preference to perform ERB. Taking the voluntary effort and cost/benefit analysis together as factors in making rational decisions towards ERB, incentivizing policies (mostly subsidies) are widely considered as successful policy strategies. However, the evidence of a rational-economic mechanism behind long-term energy-related decisions is mixed (Darby, 2011: 5). Time inconsistency is in this case is an extremely relevant concept, originated in behavioral economics. Behavioral economists seek to integrate a more robust psychological understanding of decision making into microeconomics (Wilson & Dowlatabadi, 2007: 173). Other concepts from behavioral economics relevant for the potential of smart metering are: framing and reference dependence, bounded rationality and decision heuristics. At the household level, framing and reference dependence mean that income and budgeting decisions may be assigned to different mental accounts; the 'willingness' to invest in a specific good or service (ibidem: 173). Bounded rationality and decision heuristics refer to the available information and weighting of this information by decision makers (ibidem: 174). Heuristics also 'classify' information and leads to 'automatic elimination' of the 'worse' (most of the times most expensive) alternatives (ibidem). These behavioral economics concepts allow us to see where a feedback intervention can be successful in manipulating the taste from traditional economics (framing, reference dependence, bounded rationality and decision heuristics) of consumers towards the environmental public good. In other words, behavioral economics provides us with valuable insights in changing behavior through feedback intervention and influencing decision making processes with regards to ERB.

Psychological theory

Environmental psychology is a growing stream in psychology and behavioral sciences, currently in transition to a fully-fledged theoretical approach on its own. In the introduction of the journal of environmental psychology, Uzzel states that "*… instead of treating values, attitudes and norms as independent variables as is typically the case in psychology, the emphasis in a transformative environmental psychology should shift to the relations of production and consumption and the social and political relations within which values, attitudes and behaviors are formed*" (2009: 308).

In psychological theory, the expectation that feedback measures are likely to be successful in terms of energy savings and at the same time satisfying for households is "…*based on actual consumption and frequent, involve interaction and choice for household, involve appliance-specific breakdown, are given over a specific period and may involve historical or normative comparisons presented in an understandable and appealing way*" (Fischer, 2008). Also according to Darby (2011: 6) the more clearly someone can link consumption of specific appliances and activities, the more clearly behavior patterns become relevant to the size of the energy bill. Feedback mechanisms are seen as an instrument to make people actively think about the impact of their residential energy consumption patterns: "*energy use can be affected by stimulus – response mechanisms and by engaging attention*" (ibidem: 6). Although all of these findings and studies point in the direction of positive predictions with regards to smart metering (as a feedback mechanism) and behavioral change, one of the major psychological studies in this field point out that information may increase knowledge but may not necessarily affect behavior (Abrahamse et al, 2005). Also Wilson &

Dowlatabadi (2007: 179) note that, in relation to the theory of planned behavior, perceived behavioral control, 'intentions' to perform a certain behavior (based on information, beliefs or attitudes), depends heavily on contextual factors and is very much unpredictable. Therefore, interventions trying to change behavior should target particular processes that influence change at each stage and with a multi-disciplinary perspective (ibidem: 180).

Educational theory

Education, or 'knowledge', is traditionally one of the most used measures in policies targeting ERB. Knowledge and educational theoretical perspectives in changing behavior go beyond 'just' providing information. Feedback mechanisms in this account are thus constructive, users of a smart meter are 'educated' through these feedback mechanisms.

Part of the theoretical model looking at the greater potential in the use of smart meters and ERB is based on the so-called US linear model. These old and simple models of pro-environmental behavior are based on a linear progression of environmental knowledge leading to environmental awareness and concern (environmental attitudes), which in turn was thought to lead to PEB (Kollmus & Agyeman, 2002: 241). Studies after the 1970's report that there is no statistical evidence that knowledge alone would lead to more environmental awareness and thus to ERB; quantitative studies have shown there is a discrepancy between attitude and behavior. Rajecki (1982) defined four causes to explain this discrepancy:

- *"Direct versus indirect experience: Direct experiences have a stronger influence on people's behavior than indirect experiences. In other words,*

indirect experiences, such as learning about an environmental problem in school as opposed to directly experiencing it will lead to weaker correlation between attitude and behavior.

- *Normative influences: Social norms, cultural traditions, and family customs influence and shape people's attitudes, e.g. if the dominant culture propagates a lifestyle that is unsustainable, pro-environmental behavior is less likely to occur and the gap between attitude and action will widen.*
- *Temporal discrepancy: Inconsistency in results occur when data collection for attitudes and data collection for the action lie far apart (e.g. after Chernobyl, an overwhelming majority of Swiss people were opposed to nuclear energy; yet a memorandum two years later that put a 10-year halt to building any new nuclear reactors in Switzerland was approved by only a very narrow margin). Temporal discrepancy refers to the fact that people's attitudes change over time.*
- *Attitude-behavior measurement: Often the measured attitudes are much broader in scope (e.g. Do you care about the environment?) than the measured actions (e.g. Do you recycle?). This leads to large discrepancies in results*" (as listed in Kollmus & Agyeman, 2002: 242).

This list makes clear that, although the relation between knowledge and behavior is contested, the smart meter has great potential in changing behavior. The usage of a smart meter as a feedback device addresses the temporal discrepancy and attitude-behavior measurement: because of the digitally accessible information and tailored advice coming with the smart meter, these shortcomings of the US linear model are overcome. Moreover, it provides a direct experience of the effect of human behavior on energy

consumption. Consequently, in this model it is not only 'knowledge' and 'awareness' as factors influencing ERB, but it is also the continuous feedback and direct behavior-consequence information on residential energy consumption so it becomes a learning process.

Educational theory utilizes feedback devices as educational measurements, increasing knowledge and skills (Darby, 2011: 5). Effective energy use in this theory is seen as a skill that is learned through experience in specific situations (ibidem: 6). In this study, the learners are not a unitary group, but a mixed-skilled and multi-level group of participants across society. They have differing levels of skill and understanding, and different motives for learning. For some the main motive would be to see how much 'better' they will be (how much more skilled they are) at saving energy compared to their peers. Others, for example, would want to know what is 'wrong' in their energy consumption patterns (and bills). Users of smart meters and feedback measures enable people to experiment with their energy consumption and learn through these experiments, having a long-term effect on residential energy consumption.

The potential of smart metering with regards to ERB

Following the four theoretical perspectives on feedback mechanisms, it is expected that the smart meter and its complementary applications have the potential to change residential energy behavior. Moreover, through sociological, (behavioral) economic, psychological and educational accounts, it is expected that including comprehensive feedback mechanisms could have a positive impact on awareness and consciousness of environmental problems and ecological protection, and ultimately more ERB. This is based on an idea of

Osbaldiston & Sheldon in their article on promoting internalized motivation for ERB. Their model is, as they state, "*based on the underlying assumption that fostering ERB consists of a 3-step process. The first step is for people to initiate new behaviors. The second step is for these behaviors to be maintained (or performed regularly). The third step is that the specific behaviors be generalized, such that they cover a larger range of behaviors within a domain*" (2003: 355).

This study aims to show to what extent smart metering has the potential to foster ERB and stimulate people to take the first, second and ultimately third step as in the model of Osbaldiston and Sheldon (2003). Secondly, the aim is to present evidence of the importance to exploit the possibilities of smart metering in order to significantly lower the impact of residential energy consumption on greenhouse gas emissions and ultimately make more progress towards more sustainable societies by fostering ERB in general. A simplified and systematic display of this theoretical model is presented in figure 1.

Figure 1 Schematic display of theoretical model

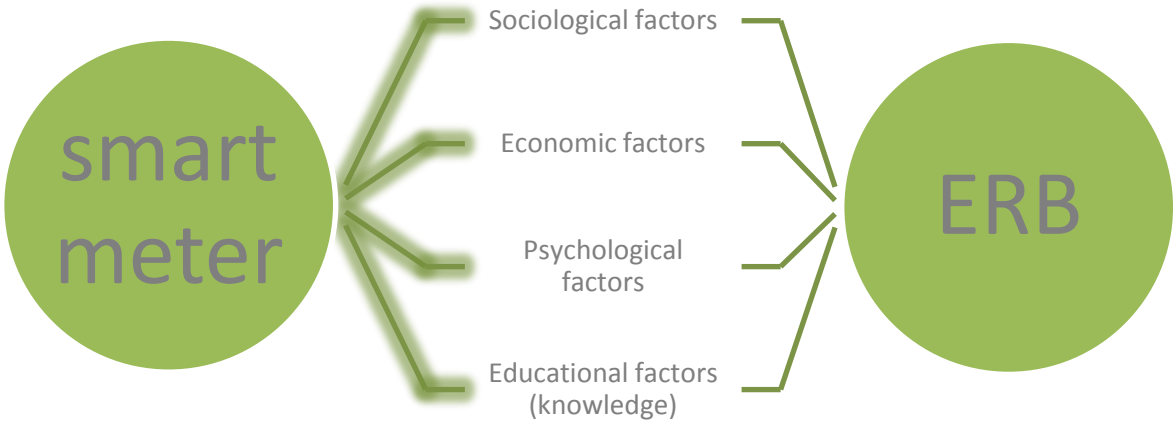


Figure representing our theoretical model. The first part includes the analysis of the relations between the smart meter and ERB through sociological, economic, psychological and educational theoretical perspectives. The second part of the analysis looks at the power and intensity of the relations between the smart meter and these factors influencing ERB and how these are affected by policy implementation strategies with regards to including the learning potential of smart metering.

III. METHODOLOGY

This chapter discusses, explains and justifies the research design, strategy and methods used of the present study respectively.

Research strategy

The research strategy of this study is mainly qualitative. A minor part of the study consists of a questionnaire which aims at collecting generalities about the population and aids in selecting appropriate respondents for participant interviews. The more in-depth data collection on behavioral patterns and attitudes of Dutch households using a smart meter is collected through interviews. Insights in smart metering potential and effectiveness and efficiency of the Dutch roll out strategy is collected through expert interviews. A literature study frames the findings and implications and is woven into the result section.

Research design

Both research questions require a case study design. Case studies focus on understanding the dynamics present in a single setting (Eisenhardt, 1989: 534). The perspectives between the two parts of this study regarding Dutch smart metering policy differ slightly. The first research question, studying the potential of smart metering, focuses on behavior, underlying dynamics and influences on individual ERB. The topics have experienced increased attention in the past decade, but there are no existing studies on the effects of smart metering beyond the direct environment on the generalization of ERB as an external effect. Thus, answering this component of the first research question entails a design called 'theory building from case study research' (ibidem;

Eisenhardt & Graebner, 2007). The case selection is theory driven, which means that the people interviewed and data collected is specifically related to whether a small apparatus, in this case a smart meter, leads to more ERB both in- and outside the direct spheres of such an apparatus.

Answering the second research question, we look at the case of Dutch smart metering with a focus on the implementation strategy. Although UK policy strategy is sometimes used as a 'best practices' or 'lessons learned' example, this study cannot be considered as comparative research as the focus is on the Dutch policy strategy and its implications specifically.

Methods: mixed method approach

Case studies typically combine data collection methods, such as archives, interviews, questionnaires and observations. The empirical evidence may be qualitative, quantitative, or both (Eisenhardt, 1989: 534). According to Yin, the opportunity to use multiple sources is one of the major strengths of case studies (1994: 97). In this study the sources are: questionnaire, literature study, participant interviews and expert interviews. A mixed-method approach is often referred to as triangulation (Bryman, 2008; Jick, 1979; Yin, 1994). Triangulation is defined as "*the combination of methodologies in the study of the same phenomenon*" (Yin, 1994). In general it is believed that using a mixed method approach leads to more valuable findings as there are multiple viewpoints to one phenomenon and therefore provides different insights. Additionally, triangulation makes cross-validation of findings possible. Cross validation is very important for our purpose because the potential of smart metering is hard to define – multiple perspectives are needed – and the findings of the first part are extremely relevant in answering

the second question on the effectiveness and efficiency of the current Dutch policy in exploiting this potential.

Literature study

Intertwined in the analytical body of this research, a literature study complements the results from empirical research. The purpose of the literature review in this research is more than it is usually seen as, namely not only presenting literature on the topic and relations studied, but also a component of interpretation (see also Onwuegbuzie, 2012). Complementing the data from the questionnaire, participant and expert interviews, insights from literature will further explain why the installation of a smart meter could lead to a change in individual ERB. Thereby it contributes to defining its full potential. The data collection for the literature review is selected upon by a set of criteria. Firstly, all articles and other written sources used are written on smart metering and ERB, pro-environmental behavior (PEB) or more specifically residential energy use and motivational policy strategies. Additionally, in answering the second research question discussing the effectiveness and efficiency of the current Dutch policy, 'best practices' and 'lessons learned' from evaluation reports and research on implementation strategies from other countries (mostly UK) are included, as well as research on the importance of accessibility and visualization in feedback interventions.

Questionnaire

Questionnaires enable the researcher to collect information pertaining to a large number of people (sample) from the population and are mostly used to construct profiles and categories in the population and to study relationships between demographic features, beliefs, opinions and behavior in social

sciences. Because of a limited number of respondents (83[1]) we are not able to study these relationships with inferential statistics or talk about statistical relationships between different demographic factors. The questionnaire served to 1/ explore the population of smart meter users; 2/ get an idea of their generalities; 3/ get an idea of their thoughts on the relation between smart metering and their individual ERB; and 4/ to select respondents for the participant interviews. The questionnaire data collected is illustrated in our results section, not relying heavily on the responses.

Besides the low response rate, the questionnaire also has problems in reliability and validity in sampling and distribution methods (Agresti & Franklin, 2009; Boynton & Greenhalgh, 2004; Bryman, 2008; Goodman, 1997). An online distribution method is used for the questionnaire due to its potential to reach more of the population. However, this means there is no random sampling, increasing the likelihood that respondents have a similar, in this case, high position on the socio-economic ladder as the researcher. This has consequences for the results and the reliability which are taken into account in the analysis and conclusions. A stratified sampling method is used, only including people in our sample (1) claiming they are actively involved in decision making on services in the household (like TV, internet, telephone connections) and/or (2) those saying they significantly contribute financially to the household (groceries, bills, services etc.).

The questionnaire was carefully formulated to be as objective as possible in order to minimize the risk for bias. The formulation and design of

[1] The goal was to reach 225 respondents, the 'holy grail' in statistics to execute inferential statistics.

the questions asked originate from the European Values Survey, EVS 2008[2], and the European Social Survey, ESS 2012[3]. Some more subjective or more prone for bias statements and questions have been asked in an item-reverse format to control for most of these inconsistencies (Bryman, 2008; Fowler, 2008; Goodman, 1997). Because the questions asked are formulated as in the EVS and ESS, only changing wording to fit our research questions, the reliability of the responses is quite high and the quality of the item-reverse questions meets international standards. Although the fact that leading institutions designed these major questionnaires does mean they are unchallenged or not to be discussed, it is safe to say that the formulation used and answer categories used are the most developed and trustworthy.

Participant interviews

One of the most common research methods in qualitative methods is interviews. The main reason seems to be the belief that language, talking to be people, goes beyond meaning of words and therefore is very valuable in qualitative research – as the main aim is to reveal people's viewpoints and opinions (words) rather than their demographic features (numbers). This already exactly points out the choice for participant interviews as one of the main methods in data collection for our purpose. To find an answer to both of the research questions it is crucial to talk to people having a smart meter installed in their household. Besides providing information on the potential of smart metering in the Netherlands, the participant interviews also give information on the opportunities and limitations in the current Dutch policy.

[2] Master questionnaire European Values Survey: file:///C:/Users/10263357/Downloads/ZA4800_q.pdf. Last accessed on April 23, 2015.

[3] Questionnaire European Social Survey: http://www.europeansocialsurvey.org/docs/round6/fieldwork/source/ESS6_source_main_questionnaire.pdf. Last accessed on April 23, 2015.

Even though all participants had a smart meter installed before January 2015, their perceptions and comments give us an idea of how efficient and effective the policy is in realizing the smart meters' full potential.

The interviewees are selected on basis of their answers in the questionnaire, namely if they indicated they have a smart meter installed or not. This means that we used purposive sampling for the interviews, specifically sequential sampling (Teddlie & Yu, 2007: 78, 80). Purposive sampling is defined as a type of sampling in which ''*particular settings, persons, or events are deliberately selected for the important information they can provide that cannot be gotten as well from other choices*'' (Maxwell, 1997: 87). The number of interviews conducted is 3 interviews, with 4 individuals participating[4]. This is a rather limited number, but due to time and willingness to participate this shortcoming could not be overcome. However, the diversity (with regards to occupational background, interests, study and perspectives on environmental policy and ecological protection) of the participants and the in-depth interviews conducted lead to interesting findings on which we can rely in answering both research questions.

The participant interviews followed a semi-structured strategy, meaning that that a list of specific questions served as a guide for the researcher through the interviews, with room for additional comments and follow-up questions by both the interviewee and the researcher. As already mentioned, the purpose of the interviews is to gain deeper understanding in the effects of

[4] Two of the participants are from the same household and have been interviewed at the same time. The second person of the household included expressed her interest before the start of the interview with her husband. She did not participate in the questionnaire. I agreed to her participating and thus being present during the interview with her husband. Before we started I presented some survey questions to her to include in my data as well. The dynamics between the two participants and their differences in approach and opinions appeared to be extremely interesting and significantly contributed to the conclusions.

smart meters and their complementary applications on households using them and so studying the full potential of smart metering and the importance of feedback. A description of the interviewees and their way of thought on the subject is a valuable addition as it provides first-hand experience information (Opdenakker, 2006; Legard et al, 2003). Grasping the point of view of users of smart meters on the effects of environmental awareness, consciousness and ERB enables us to go beyond previous (quantitative) studies and go deeper into the relation between the intervention and actual change of behavior. All participant interviews in this research are face-to-face interviews, a technique with major advantages with regards to synchronous time and space (Opdenakker, 2006: 4).

Interpreting interview data is a heavily criticized practice. In order to report interview data in a meaningful matter and thus come to valuable conclusions it is essential to code and categorize the data structurally. Using a coding scheme in analyzing interview data minimizes the disadvantages of reliability and external validity of in-depth interviews because of its structured and transparent character: the degree of interpretation by the researcher is made clear and visible, just as the relation between value and context of the individuals participating. The coding scheme used in this research is presented below, in table 1. The development of a coding scheme is not a linear process: it does not happen before the analysis and is used rigidly and fixed during analysis. It is rather an iterative, back-and-forth, process and part of the analysis itself because the development of a coding scheme provides deeper insight and usually changes the understanding of the data when carried out (Bryman, 2008; McLellan et al, 2003; Weston et al, 2001).

The first aim of the participant interviews is to gain insights into the dynamics and relationship between the installation of the smart meter and environmental consciousness, awareness and ultimately ERB. The categories and presence of environmental concern to categorize the interview results are the following:

- Residential energy saving
- Consciousness and awareness
- ERB

For every respondent of the participant interviews this table is completed in order to provide a transparent insight in the expressions and opinions of the different participants (attachment IX.1).

Table 1 Coding scheme participant interviews

ENVIRONMENTAL CONCERN								
	Not present		Somewhat present		Present		Very much present	
Categories ↓	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Residential energy saving								
Consciousness and awareness								
ERB								
- **within household**								
- **outside household**								

Expert interviews

Complementing the empirical data collected through the questionnaire and participant interviews, a total of 6 expert interviews are conducted (list of respondents in attachment IX.2). Advantages and limitations of expert interviews generally overlap with participant interviews unless high-stake issues are discussed. Because this is not the case in this study, this is not of our concern. The expert interviews in this study provide more information on the topics discussed, which is reflected in the results of the analyses with a perspective from both practitioners as academic point of view. Thereby they contribute to the credibility and validity of our results and put forward some shortcomings and further points of discussion.

Validity and reliability

Validity, reliability and replicability are terms representing the quality of research based on its methodology. All methods used in this study have their own strengths and weaknesses in terms of validity and reliability.

Validity refers to the quality of the results in three ways. Internal validity refers to the extent to which we can say that the results produced are caused by the variables studied. In other words, that there are no third (external) variables contributing to the causality or producing an inconsistency or error in the data (Bryman, 2008; Johnson, 1997). In terms of validity, methods like a literature review and interviews have a high score because of the active role and involvement of the researcher and opportunities to control for third variables. In questionnaire results it is usually easier to control for these perverse effects, but because of the lack of responses in this study we are not able to execute any form of significant

statistics on the results and thus cannot control for these measures. Secondly, external validity (or generalizability) of the findings is an important feature when discussing the quality of the research. External validity refers to what extend the findings will hold outside the research project – i.e. to what extend the findings can be generalized. External validity is often considered one of the main shortcomings of qualitative research, and especially case study research because of its context-embedded character and focus. In almost all cases more research is needed in order to generalize the findings outside of their context, which holds true in this case. This study has a low external validity as it is based on only a limited number of people's opinions and perspectives on the possible effects of a smart meter on their pro-environmental behavior. However, triangulation and therefore the cross-validation methods in this study add to the external validity of this study. Moreover, the literature review and expert interviews back up the findings from the other, more ambiguous research methods, and contribute to the likelihood that the findings will hold outside of the boundaries and focus of the study. However, the external validity of this research is still rather low, which is acknowledged in the results section and has implications for our findings. Our data collection methods hold a high ecological validity. This means they fit the 'real world': the data is collected in the society we the conclusions refer to, and not in an isolated manner.

In terms of reliability, there are some issues challenging this research. First of all, the only research method that is usually more assured of a high reliability, the questionnaire, does not satisfy the standards and therefore does not fit the criteria. Not only the low response rate, but also the distribution strategy has an impact on reliability; although it was attempted to distribute randomly and target a random sample of the population (Dutch

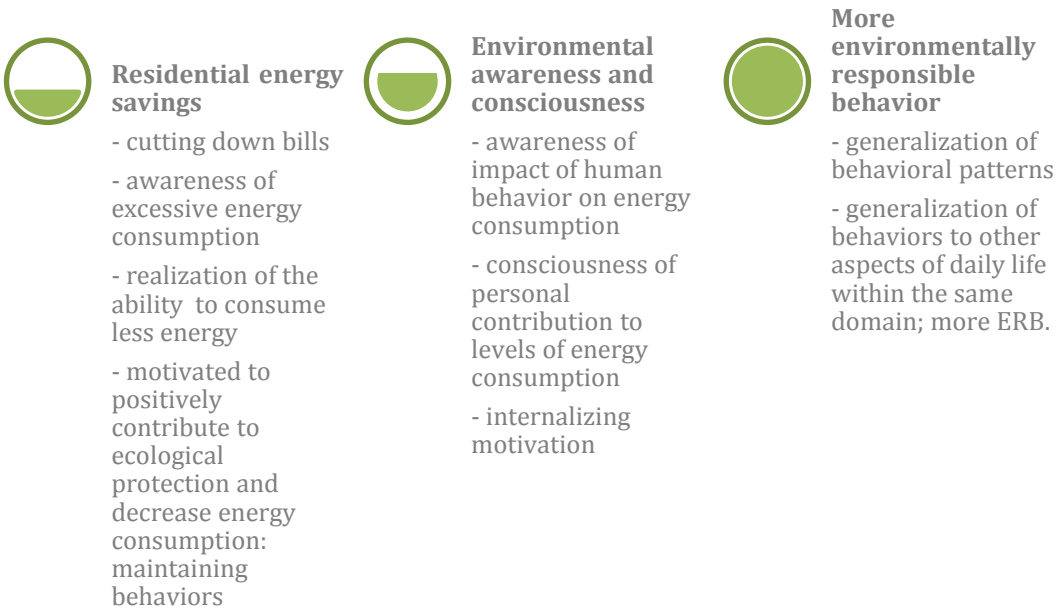
households), there is a high possibility that only a select group – people close to the researcher – has been reached. However, the questionnaire includes questions to control for this (on household features, income and educational level).

IV. ANALYSIS PART 1: defining the potential of smart metering with regards to ERB

The first part of the analysis answers the first research question: *Does the smart meter as a digital monitoring and feedback device has the potential to significantly contribute to an increase of environmentally responsible behavior in the Netherlands?*

'Potential' for this purpose focuses on the function of the intelligence of the smart meter in energy and gas monitoring for the consumer and goes beyond residential energy consumption. The concept refers for our purpose also to the possibility of increased awareness and consciousness of environmental problems and ecological protection and ultimately to the possibility of more ERB. The aim is to show that the smart meter can lead to (1) the initiation of new behaviors; (2) maintaining these behaviors and; (3) generalization of these specific behaviors through sociological, economic, psychological and educational theoretical perspectives as presented in the theoretical framework. This is schematically represented in figure 2. This chapter is organized following the three steps presented.

Figure 2 The potential of smart metering



Theoretical perspectives on fostering ERB through smart metering as a feedback intervention policy: sociological, economic, psychological and educational.

New initiated behavior: residential energy savings

Smart metering is mostly promoted (to both the producers and consumers) as a device to save energy. For consumers individually this has financial benefits, as their energy bills could turn out to be significantly lower. Contrary to popular belief, this is not a 'direct' and 'automatic' result of the installation of a smart meter, but rather because of the influence of information on energy consumption to the consumer. The almost-real-time information provided digitally through the smart meter ensures that people are able to control their energy consumption more effectively (Darby, 2010 & 2011). Besides the digital information through the website, a bi-monthly report also gives feedback and information to the consumer directly about their specific energy consumption (Van Elburg, 2014). It is known from various reports, research projects and policy evaluations (DECC, 2012; Darby, 2015: 9; Darby, 2006; -, 2010; -, 2011; European Commission, various publications, website tab 'Smart

Grid Task Force', 2015d; KEMA, 2010; Schrijner et al, 2012; Van Elburg, 2014) that that the smart meter has led to significantly less residential household consumption. Although the opinions and thoughts in the questionnaire responses were split on this issue, all respondents in the participant interviews experienced a decrease in their household energy consumption. The decrease varied between the different households due to post-energy consumption levels (if you already have a conscious approach towards energy consumption there is less to 'save'). Nevertheless, all interviewees expressed that they were happy with the amount of energy saved and expressed that they did not find it difficult to change their behavior. Especially the least environmentally-conscious participant said that his (and his household members') idea of comfort and ease have changed as they did not experience any difficulties with, for example, lower thermostat settings. Here we see that the smart meter as a feedback device does have the potential to break sociological structures and the ideas of comfort (Darby, 2011: 4).

Even the most environmentally-conscious respondent indicated that he did not realize the high costs of hot water (both financially as in terms of KwH) and said he, and his spouse, changed their behavior on the basis of this new information. This can be explained through both psychological and educational theoretical perspectives. People's awareness about the impact of their behavior is raised, and together with knowledge this leads to less energy consumption. Here we see that the priorities of these respondents are ordered in such a way that they made a voluntary effort (Clark et al, 2009: 239), whether this was for the 'environmental public good' or not differs for the individual respondents. The environment was for all respondents part of their cost/benefit analysis of purchasing a smart meter, but financial considerations (less energy consumption, more insight in energy flow and subsidies) were

the determining factor. We also see this in the questionnaire results. The presence of financial considerations is not surprising as it is a very relevant factor for households. In behavioral economics though we can see that 'mental accounting' is usually present in decision making as well, the individual may divide monetary/nonmonetary, energy/non-energy, positive/negative elements and assess them separately (Wilson & Dowlatabadi, 2007: 176).

Following theoretical accounts and data from the UK, Italy and Sweden (countries which already implemented a large-scale smart meter policy), the smart meter as a monitoring device also stimulates energy savings in households in general (as opposed to our sample people who purchased them on own initiative). The importance of feedback and thus implementing the smart meter as a comprehensive feedback intervention becomes very clear in these results. If people are able to see the consequences of their usage, in their work place or homes, literature shows that they typically increase control over consumption and may even form new habits. However, data and research shows that this only holds when the smart meter functions as a comprehensive feedback measure (DECC, 2012; Darby, 2006; -, 2010; -,2011; - , 2015: 9; Uitdenbogerd & Uitzinger, 2014; Van Elburg, 2014; Van Houwelingen & Van Raaij, 1989). The effects of sociological, economic, psychological and educational accounts only strongly hold when accurate, real-time and tailored feedback is provided (Darby, 2011; -, 2015; Van Elburg, 2014; Wilson & Dowlatabadi, 2007). According to Darby (2011: 6): "*Effective feedback adds to what householders already know about their own energy system'- the nature of their home, appliances, comfort preferences, daily routines and exceptional events – and helps them discover what is within their power to change, day by day or over longer periods, such as switching of, cutting 'default' usage by altering settings, investment in efficiency measures or home*

alterations". When accurate feedback is provided, people are likely to change their behavior. Thus, with regards to the first stage in the process, the smart meter as a policy instrument has the potential to lead to new initiated (desired) behavior because it targets specific patterns and particular processes (Steg & Vlek, 2009; Wilson & Dowlatabadi, 2007: 179).

Environmental awareness and consciousness

As mentioned in the previous paragraph, the respondents in the participant interviews have different levels of environmental concern and awareness and consciousness with regards to environmental issues. Using more or less the same wording, all interviewees expressed that, after installation of the smart meter, they (even more) realized that human behavior has its impact on the environment. From the questionnaire responses we get a diffused picture, with most of the respondents, 54% percent, saying they do not think the installation of such a monitoring system leads to more environmental awareness and consciousness. The data on these relations points in different directions. From different disciplines in social sciences it seems likely that the installation of a smart meter as a feedback device leads to more awareness and consciousness about both the individuals' behavior and more generally human behavior, but existing data lacks conviction.

Although respondents in the participant interviews indicate they find themselves more aware, also more generally on the impacts of human behavior on the environment, it is important to note that all of the interviewees referred to their in-home display (IDH) when talking about their 'smart meter'. It is the IHD that for them has an effect on their awareness and consciousness about daily energy consumption, and consequently about the

impact of human behavior on environmental issues. In a report published by the UK Department of Energy and Climate Change on household engagement in smart metering, data shows that the British population, as a result of the large roll out of smart meters, has adopted a more environmentally conscious attitude towards energy consumption (DECC, 2012; Darby, 2015). Among the main findings of the Early Learning Project research are (1) *"*a well-designed IHD for helping increase energy awareness and understanding, and promoting reduced consumption; (2) "*ensuring that the ambient 'traffic light' real-time feedback is suitably calibrated to the consumption range of individual households; and (3) particular emphasis on encouraging a 'monitoring approach' to the use of the IHD in installer explanations, Smart Energy GB advisory material and any follow-up support*" (Darby et al, 2015: 9). In the same study, Darby et al conclude that there is still room to increase environmental awareness and consciousness at large by an individual, tailored, approach to make sure people use the smart meter more effectively.

Generalization of behaviors

The third step, generalizing these newly initiated behaviors to more ERB, is what we hope happens in terms of smart meters meeting their full potential to decrease the impact of human behavior on the environment. To see if this could be stimulated by smart metering in the Netherlands we mostly rely on literature and the participant interviews. In social and environmental psychology, much research has been done on residential energy efficiency and maintaining these behaviors. On the spillover effect of these behaviors, no empirical research has been done. The potential of spillover and cognitive dissonance of ERB in general have not shown strong correlations (Thøgersen

& Ölander, 2003; Thøgersen, 2004). Feedback features in smart metering increases the chance of this final stage in potential towards ERB theoretically. According to Wilson and Dowlatabadi, values, knowledge and attitudes towards ERB failed to show strong correlations (2007: 182). One of the key findings was that behaviors need to be distinguished by their psychosocial characteristics, including frequency (or repetitiveness), cost, and associated amenity losses. The scattered nature of household energy efficiency and its complexity means that attitudes and even intentions to change behavior do not predict household energy efficiency accurately, this is better predicted by using house characteristics, occupancy and composition (ibidem). These two main findings combined show a great potential for smart metering. Firstly, smart metering enables people to 'check' their behavior and the impact of changed behavior on their energy consumption directly. Moreover, the smart meter includes household characteristics in the analysis which means that the information provided is comprehensive and complete. Theoretically, it is not a far-fetched expectation when including the concept 'activated norms'. Activated norms are "*personal obligations to act in a way that reduces adverse consequences to things of value*" (ibidem: 182-183). In other words, newly adopted behavior motivated by a specific value leads to behavioral change in other aspects motivated by the same value.

From the interview responses we learn that this spillover effect do not necessarily take place. The interviewees do say they take their newly adopted behavior to their work place, if they did not so already. One of the respondents explicitly made clear he did not have the ambition to take the environment more into consideration in other aspects of daily life. On this he commented that one 'should not lose the joy of life'. This corresponds to sociological ideas on perceived comfort and easy, structures in behavior and the complexity to

'break' these patterns. Interesting is that this is the respondent who reported to find reducing his household energy consumption much easier than expected and did not encounter any 'discomfort' in doing so. Also cognitive dissonance does not play a part in generalizing their new initiated ERB, even though one of the respondents actively shared and compared his 'accomplishments' in energy savings with neighbors and friends. The specifically defined behavior targeted by the smart meter in his case did not lead to other behavior in order to be consistent with their stated attitudes (ibidem: 177). Another, more environmentally minded, respondent said that he sometimes has to stop himself thinking of changing his behavior with regards to the impact on the environment even more although he would like to, because 'it never stops': you can always do more but setting carbon-neutral living as a goal would ask too much for him. Nevertheless, he actively recycles and has solar panels installed. Moreover, he and his wife started to eat vegetarian (with sporadically a meat-containing meal), reducing their ecological footprint is the motivation to do so.

Interim conclusions on the potential of smart metering

Based on the results of the first part in the analysis, some conclusions on the potential of smart metering can be made with regards to household energy savings, environmental awareness and consciousness and ultimately ERB. Taking into consideration literature, the questionnaire and participant interviews, we see a decrease in residential energy consumption in households using a smart meter. Sociological, economic, psychological and educational theoretical perspectives complementary explain this effect. Moreover, respondents indicate that they have actively changed their

behavior with regards to residential energy consumption. Important to note here is that the respondents in the participant interview referred to the IHD when talking about their 'smart meter'. In literature and evaluation reports we found that especially this feedback mechanism is effective in lowering energy consumption. Also in terms of environmental awareness and consciousness, feedback devices are found to have a positive effect, rather than 'just' the smart meter replacing the traditional electro-mechanic meter. Although respondents indicated that they have found themselves being more aware of the impact of their individual behavior on greenhouse gas emissions by energy consumption, the analysis does not satisfyingly present evidence for this relation. The ultimate form of the potential of smart metering in this study, the generalization of ERB to other aspects in daily life, does not hold on the basis of the empirical data. Theoretically it is still not unlikely that these new initiated behaviors have the potential to spill over to other aspects of daily life. ERB can still be fostered by smart metering because of its feedback characteristics and activated norms potential. Research with a more long-term perspective and a bigger sample is needed to see if this theoretical expectation holds.

Complementary feedback devices as IHD have an important and significant effect on the effective use of smart metering with regards to residential energy savings, environmental awareness and consciousness and ERB – even when these relations are ambiguous. The importance and significance of complementary feedback devices, and thereby making the smart meter policy a feedback intervention, is the focus for the second part of the analysis on the Dutch roll out strategy of the smart meter policy.

V. ANALYSIS PART 2: making effective and efficient use of the smart meter potential

Although opinions and expectations of the potential of smart metering for a decrease in residential household consumption are split, the policy is implemented and the importance of efficient and effective implementation has not vanished. Moreover, a comprehensive implementation strategy is believed to have successful effects on the potential of smart metering. First, a brief introduction on the Dutch roll out strategy is given with information on the decision making process, implementation strategy and parties involved. Second, characteristics of Dutch smart metering policy and their implications on smart metering potential with regards to residential household savings, environmental awareness and consciousness and ERB according to literature, reports and expert interviews are discussed.

Introduction to the Dutch smart metering policy

In 2012, a small-scale roll out of smart meters was implemented, only installing these monitoring systems in case of newly built houses or renovation projects. From January 2015, the large-scale roll out of the policy was implemented. The responsibilities in the current policy are split between distribution network operators (public parties) and energy providers (the market). The distribution network operators (8 regional organizations in total) are responsible for the roll out and installation of smart meters. The energy providers, energy corporations, are then responsible to offer in-home displays or other complementary feedback measures like a phone/tablet application to the consumer.

In practice this means that households get the offer from their distribution network operator (DNO) whether or not they want to have a

smart meter. Citizens have the right to decline. They also can accept the smart meter with a limited 'level of intelligence' (only administrative digital metering; only Port-1, internal, readings and communication; both Port-1, internal, and Port-2, external, readings possible). Every DNO has their own operation region and own sequence of roll out. Feedback measures are then to be provided by the energy corporations. This means that when a household has their smart meter installed, it is the energy corporation that offers them an IHD (smartphone and tabled applications can be installed for free by the consumers themselves).

This division is based on the organization of the energy market in the Netherlands. Since 2004, in line with EU policy, the energy market is privatized. However, in order to protect the consumer from too much market involvement in a basic good like energy, DNO were installed to facilitate the energy grid. The smart meter replaces the traditional electro-mechanic meter and is thus part of the grid between the consumer and producers. However, if the DNO- funded by the government – had the responsibility of offering the IHD to the consumers in addition to the smart meters, this investment would be too large and would not fit the governmental budget.

Efficiency of roll out

By dividing the tasks in the Dutch smart metering policy, there is a loss in efficiency. Firstly, the loss of efficiency comes from the fact that the 8 regional DNO's have their own roll out sequence. Because offering an IHD is only relevant for those having a smart meter installed, it is important for the nationally organized energy corporations to know which household has a smart meter installed. From a source in the expert interviews we learned that there is problem of communication in this process. The DNO's do not have

their roll out planning complete and communication to the energy corporations is not complete either. The result is that the IHD are not offered to the consumer simultaneously, or not even within a reasonable amount of time after the installation of the smart meter. The chance of loss of interest, and thus not get an IHD, is then bigger.

This is problematic because research shows that especially these IHD significantly contribute to residential household savings. Therefore it is recommended to foster this communication and harmonize the installation of smart meters and offering IHD.

The smart meter as feedback intervention policy instrument

Not including IHD in the large roll out of smart meters by the DNO's is very likely to decrease the power of smart metering with regards to residential household consumption, environmental awareness and consciousness and ultimately ERB. Although all of these relations are contested and not proven, theoretically and with a long term perspective these are likely results of effective use of the smart meter across society.

Accessibility and inclusiveness

The accessibility and direct presence of these feedback measures are a determinant in their effectiveness. With installing 'just' a smart meter, the charts and overviews (feedback) of the households' energy consumption are only accessible through a website. This functions as a hurdle to people to take a 'quick look', as they have to sit behind their laptop/computer/tablet and actively decide to visit that specific website and log in to see their consumption patterns. Better are tablet or smartphone applications, but people would then still have to actively decide to take a look at their energy

consumption. It is expected that mostly the people interested in their energy consumption, or more general, environmental issues will be actively tracking their residential household consumption. The current implementation strategy of the Dutch smart meter policy could thus lead to a very inefficient and ineffective use of the smart meter by a large proportion of society. In terms of reducing greenhouse gas emissions and environmental protection this means that opportunities to reduce residential energy consumption are wasted.

The smart meter as a feedback intervention policy instrument does have great potential in reaching goals of residential energy consumption if it functions as a feedback mechanism properly. Many studies on the effect of smart meters and energy savings found that, especially combined with a constant feedback mechanism, the use of smart meters has a positive effect on residential energy savings (DECC, 2012; Darby, 2015: 9; Darby, 2006; -, 2010; -,2011; Uitdenbogerd & Uitzinger, 2014; Van Elburg, 2014; Van Houwelingen & Van Raaij, 1989).

Design and visualization

Not only the visibility and presence of feedback is important, but also design and visualization appear to be very much important in the smart metering policy (Tweed et al, 2014). In the UK, it is found that if people do not think the IHD fits their homes, they are put away in a corner and no-one takes a look at them (ibidem; expert interview UK researcher). Visualization is also very important, the feedback should be understandable and accessible for people from all layers in society (different expert interviews; Darby, 2011; -,2015). The educational theoretical perspective points out the importance of 'knowing your audience'. In the case of national smart metering policy, the group of

learners is very diverse. For effective learning and development of skills, information should be tailored. For example, some less analytical minded people can make better use of a 'traffic light visualization' and others from more advanced graphs (different expert interviews; Darby, 2011; -,2015). The complexity of information provided in a customer interface is thus very important as well to make it accessible.

Visualization, simplistic representation of energy consumption, seems to be the most effective in reaching a significant and long-term behavioral change in residential energy consumption across society. Because of the real-time, everyday overview of energy consumption and its related costs, the information is accessible and understandable for all citizens, resulting in significantly less residential energy consumption. Other feedback mechanisms like smartphone or tablet applications are not ruled out in their effectiveness, but research tends to show that this is rarely effective as the only form (DECC, 2015): if people have to seek it out, on the whole they do not (expert interview). Consumers will have to take an extra step to access this information, first installing the application and second checking it regularly to stay up to date about their energy consumption. IHD's are preferred because of their domestic presence, visibility and accessibility. The information displayed has to be tailored on skill level as well, which should be part of the installation process (DECC, 2015; expert interview; Van Elburg, 2014).

Interim conclusions on the effectiveness and efficiency of Dutch smart metering policy

The smart meter could, especially in combination with complementary real-time feedback, give a strong, positive, impulse to energy savings of Dutch households. According to the reviewed 'Societal Costs and Benefits Analysis'

(*Maatschappelijke Kosten-Baten Analyse*, MKBA) the effects of smart metering on energy savings are so significant that it could be made into a positive societal 'business case' (formerly KEMA now DNV-GL, 2010). Also in the United Kingdom (UK), energy savings are one of the main reasons for the roll out of an extensive smart meter policy. To put the full potential of a smart meter in use, the supply of accessible real-time IHD at the same time as installation of the smart meter is considered necessary. The Dutch government also acknowledges that these feedback systems are essential for further environmental consciousness and energy savings, but has chosen to leave the supply of these feedback systems – unlike the UK – to the market.

The choice of the Dutch government to take a market perspective could be justified, but is not without risks. The societal benefit from the smart meter and increased potential by supplying a real-time feedback system is now market-led. These companies prioritize their activities in terms of financial costs and benefits before considering the societal costs and benefits. This could lead to a problematic situation if the expected market supply does not emerge fast enough or is unsatisfactory spread. In the RVO (Netherlands Enterprise Agency) monitoring report (Van Elburg, 2014) it is ascertained that the current product- and service supply consists of very advanced (and commercially attractive) online management systems and is therefore more fitted for more motivated, more technologically minded and/or analytical consumers. More simple and in-home energy displays are not, or very rarely, offered till now (Van Elburg, 2014; expert interview). Less motivated, less technological and/or analytical minded consumers have limited access to the benefits of smart metering because these characteristics lead to a lower demand of these features.

These groups are likely to consist of relatively more vulnerable consumers as the unemployed, less educated, non-native Dutch and elderly. On top of that these are groups in society that are most effected by rising energy prices, which results in an existent social hazard already acknowledged with the term 'fuel poverty' (*energiearmoede*). One speaks of fuel poverty when an exceptional share of net income of households is spent on energy bills, usually taking a share of 10% or over as benchmark (European Fuel Poverty and Energy Efficiency, no year: 9). Especially these groups would potentially want to appeal for a simpler home monitoring system to successfully cut back on energy bills, but they are unaware, less skilled and not reached in the current implementation strategy. Consequently the societal business case underlying the smart meter policy is at stake and especially the less fortunate groups in Dutch society will be deprived of cost savings then necessary.

If the market does not satisfactorily supply these accessible systems for less technological oriented, analytical minded and/or with less internet skills, the potential in terms of residential energy savings of smart metering is unlikely to be fully utilized, not even for its first stage of residential energy savings.

VI. DISCUSSION

Some critical notes can be made on the relations studied in this research and methods used. The advantages and limitations of the methodology are already extensively discussed but it is still important to note that due to the small sample and limited resources, the reliability of this study is rather limited. The validity of the research is less problematic, but there are some critical comments made by the experts interviewed with regards to the relations

studied. Firstly, the question if people will maintain their newly adopted behavior is very much challenged. According to two researchers among the experts interviewed significantly lower residential household consumption cannot be expected in the long term. One of them states that smart meters probably reduce previously unknown excessive use, but it will only flatten energy consumption. Placing this in a sociological tradition on changing consumption patterns, this is because people will still think that the 'average' level of their energy consumption is necessary and thus not change this behavior. A lot depends on whether people 'domesticate' their smart meter and the information it gives, or whether they lose interest after a short period (expert interview).

Data and research from the UK showing a very positive relation between smart metering and residential energy consumption, environmental awareness and consciousness are by some experts criticized on their scope and sample. It is possible that, because smart metering is quite new in the UK as well, the reports only show data of the first 'wave' of residential energy savings. However, the surveys include people using a smart meter up to 30 months, which is considered a respectable amount of time.

Moreover, the demographic profile of people likely to participate in research is similar to those more likely to become actively involved in energy savings programs, or ERB in general. The possibility of this bias is known and acknowledged by experts working closely in the UK policy, but the survey shows that this is not necessarily the case in the DECC data (DECC, 2015b). Moreover, although there is a chance of such a bias, 'early learners' in many trials serve to indicate what can be achieved by others, given the right approach and tools (DECC, 2015; expert interview).

Another point of discussion with regards to lower residential energy consumption is the difference between statistics and feeling. The feedback devices complementing the smart meter display statistics. Ideas of comfort and necessity of energy consumption are related to feelings and do not always match the statistical information on how 'well' they are doing with regards to energy consumption. However, also from a sociological perspective, real-time feedback on in-home displays (or other directly present feedback) can alter the ideas on comfort and how comfort is affected by lower energy consumption. Also in one of the participant interviews, the idea of comfort came forward very strongly. One of the interviewees explicitly said that after the installation of his smart meter (referring to his display) he did not find himself having to give in on comfort too much and that reaching his desired level for him did not require too much alterations. Including economic, psychological and educational flows of information in smart metering as a feedback intervention is thus still expected to have complementary effects and overcome the ideas of comfort and necessity.

Another researcher in the field expects the same and says that the high expectations, sometimes even presented as promises, are based on assumptions and belief in behavioral change. According to her, we can maybe expect an overall decrease of 1 or 2 percent of residential household consumption. Although every little bit helps, she doubts if this is the case in smart metering policy as the production, transportation and all other facilitating factors cost money, time and energy as well. In response to this, a policy expert in this notes that when thinking this way, one can stop taking action at all. Additionally, he believes that the smart meter has the potential to significantly contribute in decreasing greenhouse gas emissions, unless the policy is implemented efficiently and people make use of the meters

effectively. The importance of tailored feedback and information in using the smart meter is thus very much important, as also found in research and evaluations from the UK (different expert interviews; Darby, 2011; -, 2015; Van Elburg, 2014).

VII. CONCLUSION

Although data does not provide us with definite results and cannot be considered as persuasive evidence, it is clear that the feedback component in smart metering is of great relevance in exploiting its full potential.

By not offering a comprehensive feedback device for monitoring, the current Dutch implementation strategy misses the main aim of smart metering from a consumers' point of reference. According to literature, report and experts, 'just' a smart meter is not expected to result in lower residential energy consumption. To engage citizens from across society, accessible and understandable feedback is of great importance. By not including this in the roll out strategy, a big group in society is left behind with promises of lower energy consumption, without results for both their energy bills and the environment because people learn if they have some means of learning, and the smart meter offers this provided it has a decent interface with the customer. Moreover, the theoretical possibility of more ERB as a result of smart metering is not expected to happen when comprehensive feedback devices are excluded in the policy. Obviously, more research has to be done on the relations studied and the effectiveness and efficiency of the current Dutch smart metering policy. Those who are willing to have a smart meter installed will have one by 2020. Today, mid 2015, it is not distinguish to be skeptical about the effectiveness of smart metering and the efficiency of the roll out.

Smart meters do have the potential to significantly lower residential energy savings and thus should be considered as a significant step towards more sustainability and energy security if they are put into use accurately. Smart metering without a good customer interface leaves the customer more or less in the dark about their usage, not making use of the learning process in it and not exploiting its full potential effectively and efficiently. The opportunity to make smart metering into a successful societal business case is missed by not reaching a great proportion of society with the current Dutch implementation strategy.

VIII. REFERENCES

- Abrahamse, W.; Steg, L.; Vlek, C. & Rothengatter, T. (2005) A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology* 25: 273–291.
- Agresti & Franklin (2009) *Statistics: the art and science of learning from data*. Pearson education.
- Barr, S. (2003) Strategies for sustainability: citizens and responsible environmental behavior. *Area* 35(3): 227-240.
- Becker, L. J. (1978) Joint effect of feedback and goal setting on performance: A field study of residential energy conservation. *Journal of Applied Psychology* 63(4): 428–433.
- Becker, L. J., Seligman, C., Fazio, R. H., & Darley, J. M. (1981) Relating attitudes to residential energy use. *Environment and Behavior* 13(5): 590–609.
- Bickerstaff, K. et al (2015) Living with low carbon technologies: An agenda for sharing and comparing qualitative energy research. Energy policy.
- Biesiot, W., & Noorman, K. J. (1999) Energy requirements of household consumption: A case study of The Netherlands. *Ecological Economics* 28: 367–383.
- Bittle, R. G., Valesano, R., & Thaler, G. (1979a) The effects of daily cost feedback on residential electricity consumption. *Behavior Modification* 3(2): 187–202.

- Bittle, R. G., Valesano, R. M., & Thaler, G. M. (1979b) The effects of daily feedback on residential electricity usage as a function of usage level and type of feedback information. *Journal of Environmental Systems* 9: 275–287.
- Boynton, P.M. & Greenhalgh, T. (2004) Hands-on guide to questionnaire research: Selecting, designing, and developing your questionnaire. *BMJ* 329: 1312-1315.
- Bryman, A. (2008) *Social Research Methods*. Oxford: Oxford University Press.
- Burns, T.R. (2012) Sustainable Development: Sociological Perspectives. Prepared for the International Sociological Association's electronic encyclopedia, *Sociopedia*. http://www.ceres21.org/media/UserMedia/Burns%20%282012%29%20sustainable%20development.%20sociological%20perspektives.pdf.
- Clark, C.F; Kotchen, M.J.; Moore, M.R. (2003) Internal and external influences on pro-environmental behavior: Participation in a green electricity program. *Journal of Enviromental Psychology* 23: 237-246.
- Cook, S. W., & Berrenberg, J. L. (1981) Approaches to encouraging conservation behavior: A review and conceptual framework. *Journal of Social Issues* 37(2): 73–107.
- Darby, S. (2006) The Effectiveness of feedback on energy consumption: a review for DEFRA of the literature on metering, billing and direct displays. *Environmental change Institute, University of Oxford.*
- Darby, S. (2010) Smart metering: what potential for householder engagement? *Building Research & Information* 38(5): 442-457.

- Darby, S.; Liddell, C.; Hills, D. & Drabble, D. (2015) Smart Metering Early Learning Project: Synthesis report. Research conducted for DECC by the Environmental Change Institute, Oxford, the University of Ulster, and the Tavistock Institute. *Department of Energy & Climate Change, UK government.*
- Department of Energy and Climate Change, DECC (2012) Smart Metering Implementation Programme. Government Response to the Consultation on the Consumer Engagement Strategy.
- DECC (2015) Smart Metering Implementation Programme. DECC's Policy Conclusions: Early Learning Project.
- DECC (2015b) Smart Metering Early Learning Project. Consumer Survey and Qualitative Research.
- DeYoung, R. (1993) Changing behavior and making it stick. The conceptualization and management of conservation behavior. *Environment and Behavior* 25(4): 485–505.
- Eisenhardt, K. M. (1989) Building theories from case study research. *Academy of Management Review* 14: 532-550.
- Eisenhardt, K.M. & Graebner, M.E. (2007) Theory builing from Cases: Opportunities and Challenges. *The Academy of Management Journal* 50(1): 25-32.
- European Commission (2010) Communication from the Commission. EUROPE 2020 A strategy for smart, sustainable and inclusive growth. COM(2010) 2020 final. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF. Last visited on May 5, 2015.
- European Commission website (2015a) Climate Action: The 2020

climate and energy package. Last update: April 30, 2015. http://ec.europa.eu/clima/policies/package/index_en.htm. Last visited on May 5, 2015.

- European Commission website (2015b) Climate Action: EU greenhouse gas emissions and targets. http://ec.europa.eu/clima/policies/g-gas/index_en.htm. Last visited on May 5, 2015.
- European Commission website (2015c) Energy. Smart Grids and meters. https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters. Last visited on June 15, 2015.
- European Commission website (2015d) Energy. Smart Grids Task Force. https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters/smart-grids-task-force. Last visited on June 15, 2015.
- European Environment Agency (2014) Annual European Union greenhouse gas inventory 1990–2012 and inventory report 2014 Submission to the UNFCCC Secretariat. Accessible through: file:///C:/Users/10263357/Downloads/EU%20National%20Greenhouse%20Gas%20Inventory%20Report%20May%202014.pdf. Last visited on May 5, 2015.
- European Fuel Poverty and Energy Efficiency (no year) EPEE project. European Fuel Poverty and Energy Efficiency. Commissioned by the European Commission.
- Fischer, C. (2008) Feedback on household electricity consumption: a tool for saving energy? *Energy Efficiency* 1(1): 79-104.
- Fowler, F.J. jr. (2008) *Survey Research Methods*. SAGE Publications ltd.

- Goodman, R. (1997) The Strengths and Difficulties Questionnaire: A Research Note. *Journal of Child psychology and Psychiatry* 38(5): 581-586.
- Guagnano, G..A.; Stern, P.C. & Dietz, T. (1995a) Influences on attitude-behavior relationships: a natural experiment with curbside recycling. *Environment and behavior* 27(5): 699-718.
- Guagnano, G..A.; Stern, P.C. & Dietz, T. (1995b) The new ecological paradigm in social-psychological context. *Environment and behavior* 27(6): 723-743.
- Jick, T.D. (1979) Mixing Qualitative and Quantitative Methods: Triangulation in Action. *Administrative Science Quarterly* 24(4): 602-611.
- Johnson, R.B. (1997) Examining the validity structure of qualitative research. *Education* 118(2): 282-292.
- KEMA (2010) Smart meters in the Netherlands [*Intelligente meters in Nederland*]. A revised financial analysis and recommendations for policy [*Een herziene financiële analyse en adviezen voor beleid*].
- Kollmuss, A. & Agyeman, J. (2002) Mind the Gap: Why do People act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research* 8(3).
- Legard, R.; Keegan, J.; Ward, K. (2003) In-Depth Interviews. In: McNaughton Nicholls, C.; Ormston, R.; Lewis, J.; Ritchie, J. (editors) (2003) *Qualitative Research Practice*. London: SAGE Publications ltd.
- Maxwell, J. (1997) Designing a qualitative study. In: Bickman, L. & Rog, D.J. (editors) (1997) Handbook of applied social research methods. Pp. 69-100. Thousand Oaks, CA: Sage.

- McLellan, E.; MacQueen, K.M. & Neidig, J.L. (2003) Beyond the Qualitative Interview: Data Preparation and Transcription. *Field Methods* 15(1): 63-84).
- Onwuegbuzie, A.J.; Leech, N.L. and Collins, K.M.T. (2012) Qualitative Analysis Techniques for the Review of the Literature. *The Qualitative Report* 17(56): 1-28.
- Opdenakker, R. (2006) Advantages and Disadvantages of Four Interview Techniques in Qualitative Research. *Forum: Qualitative Social Research* 7(4): Art. 11.
- Osbaldiston, R. & Schott, J.P. (2011) Environmental Sustainability and behavioral Science: Meta-Analysis of Proenvironmental Behavior Patterns. *Environment and Behavior* XX(X): 1-43.
- Schrijner, M. et al (2012) Financiële haalbaarheid slimme energiemeters in Vlaanderen: Een kosten-batenanalyse in maatschappelijk perspectief. KEMA. Only available in Dutch.
- Sexton, R. J., Brown Johnson, N., & Konakayama, A. (1987). Consumer response to continuous-display electricity-use monitors in a time-of-use pricing experiment. *Journal of Consumer Research* 14: 55–62.
- Steg L. ; Vlek, C. (2009) Encouraging pro-environmental behavior: An integrative review and research agenda. *Journal of Environmental Psychology* 29: 309-317.
- Teddlie, C. & Yu, F. (2007) Mixed Methods Sampling. A Typology With Examples. *Journal of Mixed Methods Research* 1(1): 77-100.
- Thøgersen, J. & Ölander, F. (2003) Spillover of environment-friendly consumer behavior. *Journal of Environmental Psychology* 23: 225–236.

- Thøgersen, J. (2004) A cognitive dissonance interpretation of consistencies and inconsistencies in environmentally responsible behavior. *Journal of Environmental Psychology* 24: 93–103
- Tweed, C. et al (2014) Thermal comfort practices in the home and their impact on energy consumption. *Architectural Engineering and Design Management* 10(1-2): 1-24.
- Uitzinger, J. & Uitdenbogerd, D. (2014) Monitoring en evaluatie van de slimme meter en het tweemaandelijkse verbruiksoverzicht. IVAM UvA. Only available in Dutch.
- Uzzel, D. & Moser, G. (2009) Introduction: Environmental Psychology on the move. *Journal of Environmental Psychology* 29: 307-308.
- Van Dam, S.; Bakker, C.A. & Van Hal, J.D.M. (2010) Home energy monitors, impact over the medium-term. *Building Research & Information* 38(5).
- Van Dam, S. (2013) Smart Energy Management for Households, A practical guide for designers, HEMS developers, energy providers and the building industry. Delft University of Technology, Faculty of Architecture and the Built Environment, Real Estate and Housing Department.
- Van Elburg, H. (2014) Dutch Energy Savings Monitor for the Smart Meter. RVO.
- Van Houwelingen, J. H., & Van Raaij, F. W. (1989). The effect of goal-setting and daily electronic feedback on in-home energy use. *Journal of Consumer Research* 16: 98–105.
- Weston, C.; Gandell, T.; Beauchamp, J.; McAlpine, L.; Wiseman, C. & Beauchamp, C. (2001) Analyzing Interview Data: The Development and Evolution of a Coding System. *Qualitative Sociology* 24(3).

- Wilson, C. & Dowlatabadi, H. (2007) Models of Decision making and Residential Energy Use. *Annual Review of Environment and Resources* 32: 169-203.
- Yin, R. K. (1994) *Case study research: Design and methods*. Third Edition. Newbury Park, CA: Sage.

IX. ATTACHMENTS

IX.1: COMPLETED CODING SCHEMES PARTICIPANT INTERVIEWS

Summaries of the participant interviews are available on request.

Table 2 Completed coding scheme participant interviewee household 1

ENVIRONMENTAL CONCERN								
	Not present		Somewhat present		Present		Very much present	
Categories ↓	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Residential energy saving	X					X		
Consciousness and awareness			X			X		
ERB								
- **within household**	X					X		
- **outside household**	X	X						

Table 3 Completed coding scheme participant interviewee household 2

ENVIRONMENTAL CONCERN				
	Not present	Somewhat present	Present	Very much present

Categories ↓	Before	After	Before	After	Before	After	Before	After
Residential energy saving					X			X
Consciousness and awareness							X	X
ERB								
- within household					X			X
- outside household					X	X		

Table 4 Completed coding scheme participant interviewee household 3

ENVIRONMENTAL CONCERN								
	Not present		Somewhat present		Present		Very much present	
Categories ↓	Before	After	Before	After	Before	After	Before	After
Residential energy saving							X	X
Consciousness and awareness							X	X
ERB								
- within household							X	X
- outside household							X	X

IX.2: LIST OF RESPONDENTS EXPERT INTERVIEWS

Transcripts and/or summaries of expert interviews are available on request.

NAME	ORGANIZATION/INSTITUTION	DATE	INTERVIEW SETTING
S. Barr	University of Exeter, College of Life and Environmental Sciences.	June 12th, 2015.	Skype interview
S. Darby	University of Oxford, Environmental Change Institute.	June 16th, 2015.	E-mail interview.
H. van Elburg	RVO, Netherlands Enterprise Agency. Report on Smart Metering potential.	May 27th, 2015.	Face-to-face interview. Office Van Elburg.
M. Harrison	Department of Energy and Climate Change Great Britain. Head of benefits and Evaluation, Smart Metering Implementation Program.	June 15th, 2015.	E-mail interview.
R. Osbaldiston	Eastern Kentucky University. Social/Personality Psychology & Environmental Studies.	May 19th, 2015.	E-mail interview.
D. Uitdenbogerd	IVAM UvA. Monitoring energy behavior and policy evaluation studies.	May 18th, 2015.	Telephone interview.