Simulation based decision support for strategic communication and marketing management concerning the consumer introduction of smart energy meters

Sanden, Maarten C.A.van der; Dam, Koen H. van; Kobus, Charlotte B.A.; Stragier, Jeroen

Simulation based decision support for strategic communication and marketing management concerning the consumer introduction of smart energy meters

Maarten C.A. VAN DER SANDEN
Assistant Professor, Delft University of Technology,
the NETHERLANDS
m.c.a.vandersanden@tudelft.nl

Koen H. VAN DAM
Research Fellow, Centre for Process Systems Engineering, Imperial College London,
UNITED KINGDOM
k.van-dam@imperial.ac.uk

Jeroen STRAGIER
Researcher, iMinds-MICT, Research Group for Media & ICT, Ghent University,
BELGIUM
Jeroen.stragier@ugent.be

Charlotte B.A. KOBUS
Researcher, Asset Management, Enexis B.V./Delft University of Technology,
the NETHERLANDS
Charlotte.cba.kobus@enexis.nl

Abstract: Communication and marketing professionals make strategic decisions in highly complex and dynamic contexts. These decisions are highly uncertain on the outcome and process level when, for example, consumer behaviour is at stake. Decision support systems can provide insights in these levels of uncertainty and the professional process of decision making. However, literature describing decision support tools for strategic communication and marketing management that provide

ESSACHESS. Journal for Communication Studies, vol. 6, no. 1(11) / 2013: 75-104
eISSN 1775-352X

clear insights in uncertainty levels is lacking. This study therefore aims at developing a consumer behaviour simulation module as an important element of such a future decision support tool. The consumer behaviour simulation we propose in this paper is based on data collected from a survey among 386 households with which a behavioural change model was calibrated. We show how various decision scenarios for strategic communication and marketing challenges can be explored and how such a simulation based decision support system can facilitate strategic communication and marketing management concerning the introduction of a smart energy meter.

Keywords: strategic communication and marketing management, decision support, agent-based simulation, consumer behaviour/technology adoption, smart energy meter, digital city

***

Aide à la décision basée sur la simulation pour communication stratégique et marketing management: l'introduction de compteurs d'énergie intelligents

Résumé : Les professionnels de la communication et du marketing prennent des décisions stratégiques dans des contextes extrêmement complexes et dynamiques. Ces décisions sont très incertaines sur le plan des résultats et du processus lorsque par exemple, le comportement des consommateurs est en jeu. Les systèmes d'aide à la décision peuvent apporter des éclaircissements sur ces niveaux d'incertitude et sur le processus de prise de décision. Cependant, la littérature qui décrit les outils d'aide à la décision pour la communication stratégique et la gestion du marketing donnant des indications claires des niveaux d'incertitude fait défaut. Cette étude vise donc à développer un module de simulation du comportement du consommateur en tant qu'élément important d'un futur outil d'aide à la décision. La simulation du comportement des consommateurs que nous proposons dans cet article est basée sur un modèle d'adaptation technologique étalonné sur 386 personnes. Nous montrons comment divers scénarios de décision pour les défis de marketing et de communication stratégique peuvent être explorés et comment un tel système d'aide à la décision basée sur la simulation peut faciliter la communication stratégique et le marketing management.

Mots-clés : communication stratégique et marketing management, aide à la décision, simulation orientée agent, comportement du consommateur/adoption technologique, compteur d'énergie intelligent, ville numérique

***

1. Introduction

Communication and marketing (C&M) management issues are complex and uncertain. Therefore, C&M professionals have to make decisions in highly complex, dynamic and uncertain contexts. Sometimes these decisions, based on (implicit) knowledge, professional experience, gambits and heuristics, are effective, but in all cases there is uncertainty in the process, implementation and outcome. Existing tools, protocols and planning schemes fall short because they lack clear insights in uncertainty levels and the dynamics of the processes (Van der Sanden et al, 2013; Van der Sanden and Osseweijer, 2011; Gruenfeld, 1998). As a result, these solutions are not flexible and do not contain any dynamic aspects, such as changes over time in the process itself and developments in its environment. That is also true for the case considered in this research project, namely the introduction of smart energy meters to households: there is no clear insight in how smart energy meters diffuse into the consumer population, which makes it difficult for C&M professionals to make the right decisions while steering this process. Therefore, a *communication and marketing management decision support system* (CM-DSS) that supports the C&M manager is needed. Part of such a future decision tool could be a simulation module in which consumer behaviour is simulated which allows the user to test scenarios and gain insights into the response to certain decisions. The aim of this paper therefore is to demonstrate how C&M professionals could be supported in their strategic decision concerning the development of C&M processes and means. Simulation may inform decisions on the following type of questions: on which social psychological constructs should the communication focus? What evidence is there for the proposed approach to have the desired effect on consumer intentions to use a device?

This paper is structured as follows. First, in Section 2 we introduce the topic used as a case in this paper: the introduction of smart energy meters. Next, in Section 3, we show how decision support systems can help C&M professionals in combining theory and practice in the uncertain and highly complex context of strategic communication management dealing with high-tech developments such as smart energy meters. In Section 4, we explain the methodology and the research behind the data which was collected in a consumer survey carried out by Dutch Distribution System Operator (DSO) Enexis, and the agent-based model which was developed using this data and the insights from technology adoption models. This is followed in Section 5 by showing the results of simulation runs in which the various C&M scenarios are tested based on typical communication management scenarios obtained from Enexis, leading to a target audience approach. Possible consequences of these results on C&M professionals are then discussed in Section 6. In this concluding section we focus on what this all means concerning the theories used, the practice of strategic C&M management and future research.

2. Smart Energy Meters

As Kobus et al. (2012) describe, more and more domestic energy users are becoming energy producers as well as consumers by installing, for example, photovoltaic solar panels in their homes. One of the difficulties of this sustainable and local energy production is that it is often not demand driven, unlike large scale generation plants, and that the intermittent nature of sustainable resources such as sun and especially wind makes it more difficult to predict how much will be produced and when. Research carried out by Kobus et al. focuses on domestic consumers in an effort to change household electricity consumption to a more supply-driven character. Currently, the energy market is changing because electricity produced by fossil fuels is becoming more expensive, while new energy technologies, like solar panels, are becoming less expensive. As a result of these changes, as Kobus et al. all argue, domestic consumers are adopting solar panels very fast. If households are able to match the locally produced electricity with their own electricity consumption, this implies that solar electricity will be used most efficiently and thus in a more sustainable manner. In addition, the overarching issue is that the EU stimulates and even enforces energy savings from a climate target perspective and countries are bound to reduce emissions through international agreements such as the Kyoto protocol.

These aforementioned developments are implemented in smart energy grids, which typically includes the installation of smart energy meters in houses. The "smart grid" may be defined in two ways as Clastres (2011) says. The first approach, generally used in Europe, defines them as 'electricity networks than can intelligently integrate the behaviour 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'. Furthermore, Momoh (2009) writes that smart grids with intelligent functions are expected to provide self-corrective, reconfiguration and restoration, and able to handle randomness of loads and market participants in real time, while creating more complex interaction behaviour with intelligent devices, communication tools, etc.

It has been revealed by many researchers that giving feedback helps households to reduce energy demand (e.g. Abrahamse et al. 2005, Darby 2006). Therefore, directive 2012/27/EU on energy efficiency states that at least 80% of consumers should be equipped with smart meters by 2020. A smart meter is defined as an electronic meter that can measure energy consumption, providing more information than a conventional meter, and can transmit and (and sometimes receive) data using a form of electronic communication, enabling feedback. This is valuable information for grid managers because it enables real-time insight into the state of the network and can help them take the right actions. Other advantages for energy companies include not having to send people out to take meter readings, as these can now be obtained remotely, and gaining new insight into when and where electricity is consumed, making it easier for them to predict the amount of energy to be bought at the whole sale market. While there are some advantages to households, such as the potential to save money provided the smart meter is combined with an in-house display and no longer having deal with estimated meter readings, there are also worries related to privacy as the real-time data gives companies direct information on activities going on within the house.

Taking the complexity and uncertainty of the smart meter development, market introduction and its according communication management concerning consumers together, one can conclude that C&M managers deal with a network of actors and high levels of uncertainty concerning energy market, stakeholders identities and images and high-tech development. Moreover, this can be considered as a so called complex socio-technical system (Van Dam et al, 2013) in which a network of actors interacts with a system of physical components.

3. Strategic communication management

Strategic C&M and its management starts from the moment the project is initiated and researchers, policy makers; planners start working together (Flipse et al, 2013). This is the very point in which processes, services, products and strategic alliances are developed. Strategic C&M management may support (i.e. enhance) the cooperation between the various actors in the network and its resulting processes, products and services. Within this network identities of actors are communicated and negotiated (Balmer & Stuart, 2004). Identities of organizations, companies and consumers are considered as a multi-identity network. Moreover, strategic communication supports/translates the philosophy of organisational management and knowledge management to the other project members (Van Riel and Fombrun, 2007).

This means that from the initial idea of a new product until after market introduction there is cooperation supported by strategic C&M management and actual C&M activities. Moreover, all the actors in the network inherently have a C&M task, so there is no single node that "does all the talking" nor is there a single actor able to fully control C&M that takes place. There is a distributed network of actors that communicate from their own point of view about various stakeholders outside the project group and these changes over time. Within this socio-technical system the according problems are not easy to solve because such systems have many components and levels, involving different parties who all primarily pursue their own local objectives in a dynamic environment and regulatory regime (Dijkema et al, 2013).

Such a complex C&M system cannot be managed based on simple protocols or step-by-step communication management tools (Van Ruler, 2013; Van der Sanden and Meijman, 2012; Wehrmann and Van der Sanden, 2007). Although such protocols inform the thinking of a communication professional, these 'classical tools' underestimate the complexity, dynamics and resulting uncertainty at stake and do not fit to a complex and adaptive reality.

System thinking as such is not new to sociology and communication. This kind of research fits into the tradition of the new systems theory in sociology (Bailey, 1994) and the cybernetic-tradition in communication science (Littejohn & Foss, 2008). It is based on the idea of social entropy theory and the theory of autopoiesis (Bailey, 1994). *New systems theory* does not divide between the conceptual, empirical and operational level, but rather it emphasizes the dialectical interaction over time and amongst all three levels. That is exactly what we try to combine: on the one hand from a consumer perspective and on the other hand from a strategic C&M management perspective.

3.1. *C&M management: uncertainty management*

There are various kinds of uncertainty a C&M professional has to deal with: "*uncertainty is a situation of inadequate information, which can be of three sorts: inexactness, unreliability, border with ignorance"* (Walker et al, 2003). A distinction is made between uncertainty due to a lack of knowledge and uncertainty due to variability inherent to the system under consideration. It should be made clear within the communication management system how much uncertainty is allowed. Walker et al. (2003) explain that there is a three-dimensional concept of uncertainty: *location uncertainty*, *level of uncertainty* and *nature of uncertainty*. Location uncertainty has to do with the question to where in the system the uncertainty manifests itself while the level of uncertainty covers a range between an unachievable ideal of complete deterministic understanding and total ignorance. The nature of uncertainty breaks down to two extremes: a) *epistemic uncertainty*, the uncertainty due to the imperfection of our knowledge, which may be reduced by more research and empirical efforts, and b) *variability uncertainty*, the uncertainty due to inherent variability, which is especially applicable in human and natural systems and concerning social, economic and technological developments.

A decision support instrument needs to elaborate on these aspects of uncertainty. The big question then is how to make this uncertainty explicit. How to support so called bounded rationality (Kahneman, 2003), which all professionals have to deal with? As Jones (1999) writes, bounded rationality asserts that decision makers intended to be rational; that is, they are goal oriented and adaptive, but because of human cognitive and emotional architecture, they occasionally fail in important decisions. Limits on rational adaptation are of two types: procedural limits, which limit how we go about making decisions, and substantive limits, which affect particular choices directly. The communication management scenarios we have developed in this study are based on the idea of various kinds of uncertainty and the occurrence of bounded rationality, and are meant to make clear to the communication professional what kind of uncertainty he or she has to deal with.

Scenarios, as Schoemaker (1995) writes, are amongst the many tools a manager can use for strategic planning, and it stands out for its ability to capture a whole range of possibilities in rich detail. By identifying basic trends and uncertainties, as Schoemaker writes, a manager can construct a series of scenarios that will help to compensate for the usual errors in decision making: overconfidence and tunnel vision.

3.2. *Decision-support system*

As a means to cope with this uncertainty and play with various C&M scenarios, decision support systems can be used. Such a system could help make assumptions explicit and provides an environment to test different scenarios and expected outcomes. An ideal support system describes the decision process of C&M management in which theory, data (e.g. consumers), C&M management information, C&M management goals, professional's experience, creativity, intuition and feedback is realized. C&M management is defined in this paper as strategic *questions* a C&M manager might have concerning the *design* of a C&M processes towards customers resulting in a C&M *strategy* that might change the *behavioural intent* of the customer and their view of smart energy meters.

Modelling and simulation are key words in our approach towards a decision support system, eventually leading to a so called C&M management dashboard for C&M professionals. The prototype tool presented in this paper contains various decision scenarios for strategic C&M management concerning smart energy meters. Simulated representations of consumers have been developed by various researchers on e.g. consumer needs (Jager and Janssen, 2012). The insights obtained from these studies show the dynamic psychological and sociological aspects of consumers and are valuable for this research project. However, with the consumer simulations described in this research we focus on bridging the simulated outcomes of the consumer behaviour concerning smart meter technology, and the resulting strategic C&M scenarios from a C&M management perspective. When we combine all the aforementioned into various C&M scenarios, the complexity, possibilities and challenges of the C&M becomes more tangible.

The main challenge in developing decision support systems is to keep outcomes understandable, manageable and meaningful for the C&M professional and to provide a useful interactive tool with which to test possible effects of communication efforts. The user of the tool, guided by the results from simulations and visualisations of available data and theories, can then make a better-informed decision. The decision support systems should not be considered as a decision-

making entity, but the intelligence and creativity is in the professional using the tool (Pommeranz, 2012).

4. Case and agent-based modelling

To test our ideas in a specific environment and to find out in practice how a decision support system could assist the work of a communication professional, we built a simulation module for the roll-out of smart meters to households. In this section we introduce the problem from a communication perspective, our methodology and the data and literature we used to build our model.

In the Netherlands the Distribution System Operators (DSO) are responsible for the roll-out of smart meters. But the roll-out of smart meters in the Netherlands has not been easy. Privacy issues, as mentioned above, were the main objection against smart meters. Therefore, questions arose about what would be the best approach to communicate with the customers about this new technology because it offers significant advantages to the energy companies and network operators. As a pilot, Enexis, a Dutch DSO, installed smart meters at a 787 households. At 518 of these households Enexis also installed an Energy Management System (EMS). An EMS is a device that can give real time feedback and consumption overviews. A survey was conducted and questionnaires had to make the attitudes towards smart meters and EMS apparent. The respondents, all participants in the pilot, were asked to fill out the online questionnaire in April 2012 (n = 386) which took approximately 10 minutes to complete. The questionnaire was taken again in November 2012 to measure change in attitude (n = 319).

Mapping the data that companies already obtain by surveys and log data to models could help gain new insights in the attitude of consumers and elucidate where to focus the company's efforts in follow-up studies as well as their marketing and communication practice. In our approach we use the agent-based paradigm to create a simulated population which has a behavioural intent to adopt a technology. We use data collected from the case study described above.

4.1. *Agent-based modeling*

An agent-based model describes a system by modelling the specific behaviour of individual actors (represented by an agent in the model) and observing the outcomes at a system level as well as at the level of the individual, if desired. It is a bottom-up approach in which agent activities lead to emergent behaviour. An agent can thus be defined as "an encapsulated computer system that is situated in some environment, and that is capable of flexible, autonomous action in that environment in order to meet its design objectives" (Jennings, 2000). This approach is particularly suitable for capturing socio-technical systems (van Dam et al, 2013). Because we model the behaviour of agents rather than the outcomes of this behaviour, agent-based models allow experiments with different scenarios in how people act based on their decision rules as well as the context from the environment.

To support the development of agent-based models incorporating technology adaption by consumers, we previously developed ontology of consumer acceptance (Van der Sanden and Van Dam, 2010; Van der Sanden, Van Dam & Stragier, 2013), based on the consumer acceptance of technology (CAT) model of Kulviwat (2007). In this paper we took a similar approach to develop agents representing households deciding on the acceptance of smart meters based on data collected in a consumer survey carried out by DSO Enexis.

4.2. *Survey on adoption of a home energy management system*

A psychological model was compiled using the data collected in the experiment. Data from the questionnaire of 386 respondents (obtained April 2012) was available. The goal of the model was to provide us with insights on those constructs that are assumed to influence the adoption intention of energy meters, smart meters, smart plugs and smart thermostats. After factor reduction the constructs used in the model were:

Environmental responsibility: refers to the degree to which one feels responsible for environmental issues. This was measured by the items: "I feel partly responsible for the depletion of energy resources", "I feel partly responsible for the greenhouse effect". Cronbach's alpha for these items was 0.81, which implies that the two items can be taken together and considered to measure the same dimension: responsibility for the environment[1].

Environmental concern: refers to the degree to which one wants to make a commitment to an environmentally friendly future, measured by letting the respondents indicate how important they consider it to "Have less environmental pollution ", "Prevent running out of energy", "Ensure the future for the next generations" (α= 0.87).

Emotional responsibility: refers to the degree to which one considers it important to act environmentally responsible measured by the items: "I think it's a challenge", "I think it should," "It gives me a good feeling" (α= 0,79).

[1] Abrahamse & Steg (2009): Ascription of responsibility was measured with three items and reflected the extent to which respondents felt responsible for energy-related problems (''I take joint responsibility for the depletion of energy resources", ''I feel jointly responsible for the greenhouse effect" and ''I take joint responsibility for environmental problems"). These items formed a reliable scale, with Cronbach's alpha's of .84 and .86 for the before and after measurement. A higher score indicates stronger feelings of responsibility for energy-related problems.

Financial motivation: refers to the degree to which one wants to act more sustainable to: “save money” and “keep control of my energy bill” ($\alpha = 0{,}81$)[2].

Attitude towards knowledge function: refers to the degree to which the respondents consider their smart device a tool that delivers insight into their energy use measure by two items: "To what extent ___ helps you in getting insight into your energy use?", "The ___ helps me understand my energy use" ($\alpha = 0{,}87$)[3].

Information satisfaction: refers to the degree to which the respondents is satisfied with the information provided by their smart device: "access to information", "reliability of information", "gas usage information", "electricity consumption information” ($\alpha = 0{,}90$)[4].

Overall satisfaction: refers to the overall product satisfaction measured by two items: "How satisfied are you with ___ in general?” and “The ___ meets my expectations” ($\alpha = 0{,}89$)[5].

Ease of use: measures the ease of use of the smart device and is more specifically measured by the perceived complexity of use. Two items were used: "The use of ___ is easy to learn" and "Using the ___ is easy” ($\alpha = 0{,}95$)[6].

---

[2] Concerning “Environmental concern”, “Emotional responsibility” and “Financial motivation”. Varimax rotation reveals for example that “saving money, and keep sight on my energy bill” (α= 0.81) are important. Money overall seemed to be an important motivational driver for saving energy (M= 4.26, Sd = 0.55), followed by “Ensure the future for the next generations” (M=4.08, Sd=0.63) and finally “It pleases me” (M=3.81, Sd=0.63)

[3] Scaling based on: Attitude Toward the Product (Knowledge Function) Grawal, Mehta, and Kardes (2004) reported a construct reliability of .98 for the scale.
1. My ____ makes my world more predictable.
2. My makes it easier for me to structure and organize my daily life.
3. My ____ facilitates in understanding what happens in everyday life.
4. If I woke up and realized that I no longer had my ____, I would be totally lost.
5. My makes me feel secure and safe in an uncertain world.
6. I would be confused without my
7. My makes it easier for me to comprehend my surroundings.

[4] No literature found for scaling.

[5] Scaling based on: satisfaction (General) Mägi (2003) reported an alpha of .84 for the scale.
1. How satisfied are you with your primary_____?
very dissatisfied I very satisfied
2. How well does your primary____ match your expectations?
not at all I completely
3. Imagine a perfect How close to this ideal is your primary ____?
not at all close I very close

[6] Scaling based on: Ease of Use (or complexity) Alphas of .83 and .88 were reported by Meuter et al. (2005) for use of the scale in Studies 1 and 2, respectively.
1. I believe that the ____ is cumbersome to use. (r)
2. It is difficult to use the ____ (r)
3. I believe that the_____ is easy to use.

Attitude: measures the attitude towards the smart device and is measured by three items: “The ___ is valuable”, “The use of ___ offers me benefits” and “I would recommend the ___ to others” ($\alpha = 0{,}89$)[7].

Use depth: measures the degree to which the respondents use all possibilities of the smart device: “I know the various options of ___"and"I use all features of the ___" ($\alpha = 0{,}85$)[8].

The constructs were entered in a structural equation model using Amos 16.0 software. Figure 1 presents the structural equation model that integrates the aforementioned constructs. The goodness-of-fit parameters for the model indicate a good fit to the data (NFI=.929; RFI=.914; IFI=.959; TLI=.951; CFI=.959; RMSEA=.056). In the model, Environmental responsibility, Environmental concern, Emotional motivation, Financial motivation, Attitude towards knowledge function, Information satisfaction, Overall satisfaction, Ease of use, Attitude, Use depth are considered as predictors of the adoption intention of the smart devices in the model.

From the results it is clear that Responsibility, Environmental concern, Emotional motivation and Financial motivation have no major significant impact on the attitude toward the devices. In structural modelling, attitude is often regarded as a strong predictor of adoption intention. In our model however, no direct impact can be observed of attitude on adoption intention. Still we see an indirect impact of this attitude through Overall satisfaction, which appears to be a strong predictor of adoption intention. This Overall satisfaction in turn is strongly influenced by the satisfaction of the user with the information that is delivered by the smart device. If a respondent considers his smart device to be a tool that delivers the needed insights on his energy use, this results into a better satisfaction about the information, which in turn leads to better overall satisfaction and consequently a higher adoption intention. The degree to which the user considers the smart device easy to use (Ease of use) and he/she uses more of the device’s possibilities also leads to better perception of the delivered insights. Attitude towards knowledge function has no direct impact on the overall satisfaction, but does so indirectly through satisfaction about the information delivered.

Summarized, the promise of satisfaction about the device is heavily important in motivating consumers to adopt smart devices. More specifically, the information about and the increased insight into the energy use that the device delivers are important factors when it comes to consumer satisfaction and adoption intention. This result in the figure below (fig.1).

---

[7] Many possible scales found in literature but we used 3 items scale.
[8] Based on the construct of innovativeness.

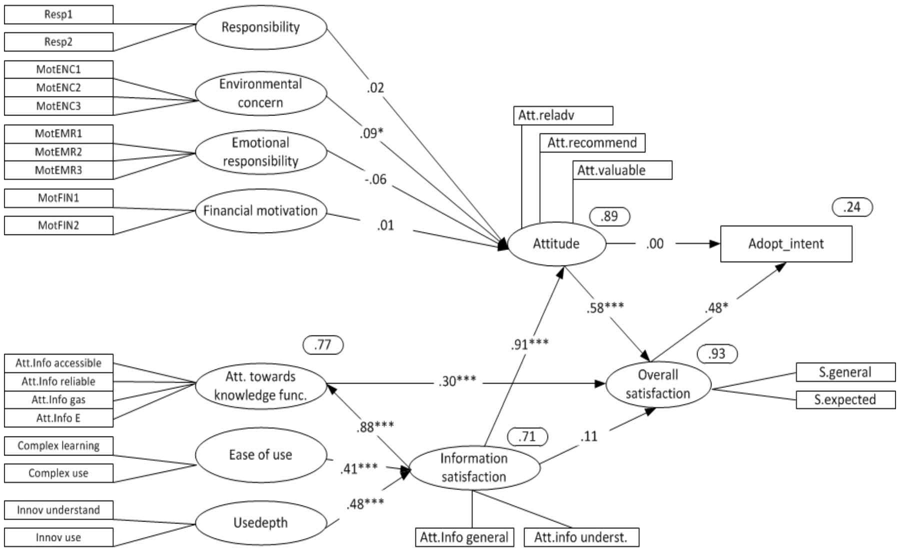

Figure 1. *Consumer Adoption Intention Model concerning the introduction of smart energy meters. After factor reduction only the ellipses are taken into account.*

4.3. *Literature: related work*

How does the above compares to other literature on consumer behaviour and smart energy meters and smart energy grids? A large volume of literature on consumer adoption of new products and use of new technologies is available in the energy domain and related fields. One of the main issues we learned from literature on the aspect of energy saving is that sustainable behaviour is not bound specifically to high income or higher levels of education (Krishnamurti et al, 2012). Even the use of energy-saving light bulbs and the purchase of 'green electricity' are bound to neither low-energy use households nor high-energy use households (Vringer et al, 2007). That means that in our model set up we should expect agents clustered in neighbourhoods based on stated income level and housing type to show various levels of behavioural intent to use or purchase a smart energy meter. In other words, classical C&M segmentation of target audiences into income and level of education might not be useful concerning the introduction of smart energy meters.

The smart meter is not considered a high status product, although the effect of using may give the user a higher status for groups that value this higher status as important. For smart meters on a product level the socialisation factor might be much less than the one for cars for example, which are directly visible. In this case it might happen that consumers change their choices without changing their preferences. In search for identity they cope with their social context. Janssen en Jager (2001) write about the process of socialisation, people changing their preferences as a result of interpersonal contact. Generally, as shown in that study, especially people with higher or equal social status have an effect on one's consumer behaviour.

Processes such as socialization, social settings of consumer choices could be seen as systems regarding consumer choices (Janssen and Jager, 2001). Psychological research, according to Janssen and Jager, states that the attributes that determine consumer preferences not only reside in the product, but also in the social setting in which the product is being used. Stated differently, the preference for a given product may partly depend on who else uses the product. Especially, when products have an important social connotation (e.g. cars, clothing) it is more likely that social decision making will dominate the market.

And if all agents are influenced equally (Allcott, 2011 and Karjalainen, 2011) there is a difference in injunctive norm change; however that change is not quite strong (Karjalainen, 2011). It might be the case that the influence of the social environment is an enhancing effect of other stronger variables such as described above. This corresponds with the idea that non-price interventions can affect consumer behaviour as well such as, historical comparison of use and neighbouring effect. It is not clear in the long run if this kind of effects sustain, cross-effects (price incentive AND historical AND neighbourhood comparison) may have this sustain effect (Caeiro et al, 2012). This kind of thinking also fits to the constructivist interpretation and according behaviour connected to energy safe or sustainable behaviour (Darby, 2006). Although, the socialisation effect was not taken into account in our model in the simulation model consumers could be virtually connected which each other to see how the consumer-system reacts on network effects. This is however, not tested in the simulation runs described in the next section, but might be a future scenario.

Finally, results show that presentations of costs (over a period of time), appliance specific breakdown and an historical comparison are most valued by consumers (Karjalainen, 2011; Fischer, 2008). Moreover, nearly half of the consumers do not use the programming features of their thermostat so it should be easy to learn, efficient to use, easy to remember, result in few errors and subjective pleasing (Peffer et al, 2011). Consumers also report perceived risks, including less control over their electricity usage, violations of their privacy and increased costs (Krishnamurti et al, 2012). On the product level we see (for a PV case) that barriers obstructing the adoption of PV systems should be discussed on a group level, whereas measurements should be discussed on the level of specific target groups (Jager, 2006). Some of the features such as using programming features discussed in this final paragraph are included in our model, introduced next as well. However interventions, such as discussions on group or individual level, is not yet dealt with in our model and might also be a future scenario aspect.

4.4 *Approach simulation*

Taking the survey data introduced above as a starting point, an agent-based simulation model has been implemented which allows running experiments with various scenarios for a synthetic population. In this model each household is modelled as an agent with their own characteristics (e.g. age, type of house) and personal opinion on the environment (e.g. concerns about climate change) as well as the use of smart energy technologies (e.g. ease of use or financial motivation). Each agent in the model forms an opinion on the satisfaction with a smart energy meter and decides whether or not they would like to purchase one. The decision making process is modelled according to the structural equation model calibrated with the survey data, using the set of coefficients for the various factors as weights in the decision tree (see fig.1). This means the simulation model takes the data from the survey as input and uses the behavioural model to predict the response of each individual. From that starting point it is possible to make changes to any variables and to observe how this impacts the individual's decisions or that of a group or the entire population.

As in the survey, the simulation model uses a 5-point Likert scale (where 1 is strongly disagree and 5 is strongly agree) to represent the value for the opinion of the agent. Employing the coefficients from the behavioural model we now have a computational model that allows the user to experiment with changes in these values and to generate predictions. For example, the user can see what might happen to the agents if the technology is made easier to use, or if the household would feel more strongly about their own responsibility to save energy. Adjustments can take the shape of values of the constructs or values of the coefficients, both which would represent the impact of communication efforts. They could influence the opinion of the agents and can be made to: 1) individual agents; 2) clusters of individual agents, and; 3) the entire population, where clusters could be based on for example geographical location, age, family situation, etc., specifically targeting certain areas in the city or people with certain characteristics. It is up to the user to interpret the meaning of a numerical adjustment and how realistic this assumption is, but it allows experimenting with different options and seeing how effective they could be under the conditions modelled.

By setting up realistic scenarios together with the problem owner, the model can assist in making decisions on, for example, a new advertisement campaign or the focus of a letter to the consumers. By trying out what might happen in a simulated environment the user can also evaluate his or her own experience and expectations. The results of the simulation can then help shape the decisions or lead to additional question needing to be asked. This simulation module could be part of a support decision tool in which also communication policy and strategy are taken into account. Communication policy and strategy then reflect consumer behaviour scenarios. Based on various communication management scenarios concerning consumer behaviour (see section below) and smart energy systems, we show initial simulated results and discuss how these results reflect on communication management decisions and its resulting management of expectations.

5. Definition of scenarios and simulation results

Based on informal discussions with marketing and communication professionals working for Enexis a number of scenarios have been defined to showcase the type of questions that can be answered by experimenting with the simulation model described above. In each instance the question has been translated to a change of the variables from the behavioural model so that a relevant scenario could be implemented in the software tool. All questions posed relate to the behavioural intent of the household regarding the adoption of a smart meter.

While the variables representing the opinion of the households are based on a 5-point Likert scale, we used a 10-point scale for the predicted behavioural intent because this closer matches the internal workings of the model which, when calculating the combination effect of the model variables, has more refinement than just 5 steps between "strongly disagree" and "strongly agree". In practice the predicted values can be divided by 2 and rounded up or down to match the original input scale. In these experiments we have assumed a value of 6.0 or higher for the behavioural intent to represent a mostly positive attitude towards adoption and would say that households for which the model predicts the number is lower do not have a positive intent to purchase and adopt the technology.

In the initial situation, when the model is run simply using the survey data as input and without any additional scenarios or changes, the average behaviour intent is 6.27. This means the majority of the households have a positive attitude towards the technology. This matches the findings from the survey, which on average also had a slightly more positive perspective. Figure 2A (see below) shows a histogram showing the spread of different ratings for the entire population in the initial simulation.

We then define and run experiments for three scenarios based on the following questions:

Marketing communication question 1: What happens if consumers lose their motivation at a certain point once they have optimized their smart meter and consider these devices as commodities?

Marketing communication question 2: Because of a new update of certain kinds of smart meters, the devices are much easier to use. After what level of increase will a significant change in overall satisfaction occur for consumers who are currently dissatisfied?

Marketing communication question 3: We believe that customers are highly motivated at the start but after a few weeks they lose attention and they only want to know about their possible financial profit. Is this indeed the case?

These marketing and communication questions are then translated to the scenarios described below. In the discussion we reflect on the outcomes of the simulations.

[Scenario 1]

Location of uncertainty: consumers / level of uncertainty: moderate / variability uncertainty

Over time consumers get used to the smart home appliances and in a way developed a customized standard setting of their smart appliances. They are still content however, but their “Use depth” (i.e. to what degree are all functionalities of the technologies understood and used) and their attitude towards “Attitude towards knowledge function” (i.e. to what extent does the technology help to create new insights) decrease as they become less involved with the product. At what point does the overall attitude and adoption intention change to dissatisfaction?

Experiment: To answer this question we lowered the value of “use depth” over time, then the value of “Attitude towards knowledge function” and afterwards we tested what happens in a combination. We stopped the simulation when the average view changed from positive to negative and recorded the new situation.

When changing only “use depth” it required a drop of 45% compared to the initial views of the respondents to turn the average adoption intention to negative and when only adjusting “Attitude towards knowledge function” this was 25%. When testing for the combination, as suggested by the marketing and communication question, it was shown that a mere 15% decrease is sufficient to turn the positive view into a negative one. Figure 2A-2D shows the resulting histograms for this population.

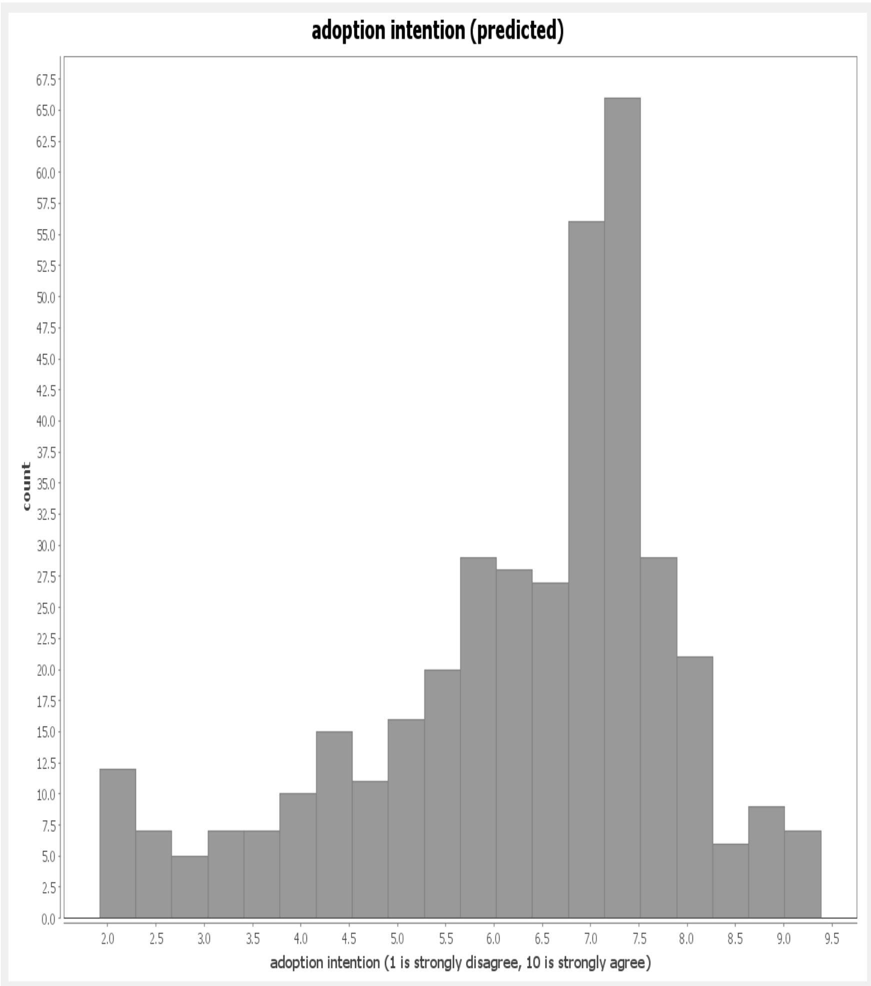

Figure 2A. *Initial state: average adoption intention 6.27*.

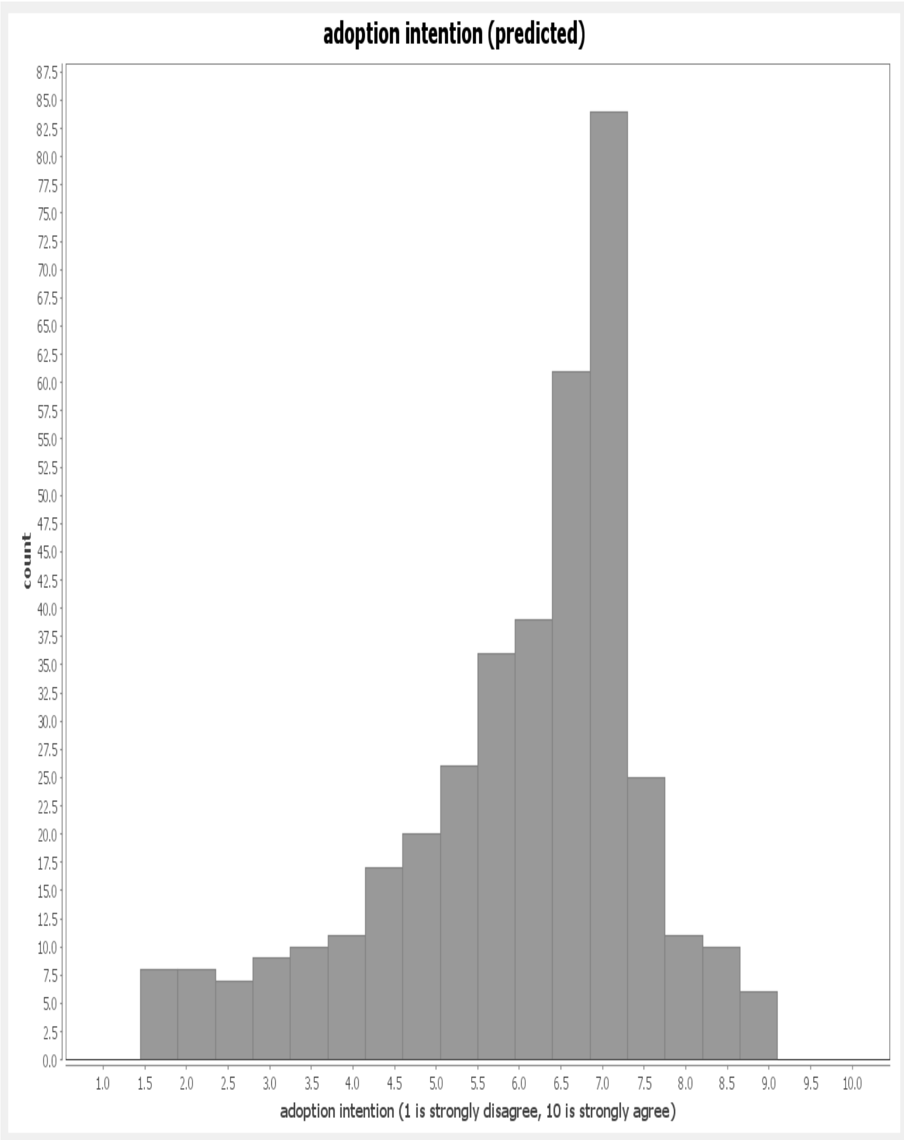

Figure 2B. *Use Depth 45% decrease: average adoption intention lower than 6.0, meaning that the larger part of consumers has a negative adoption intention.*

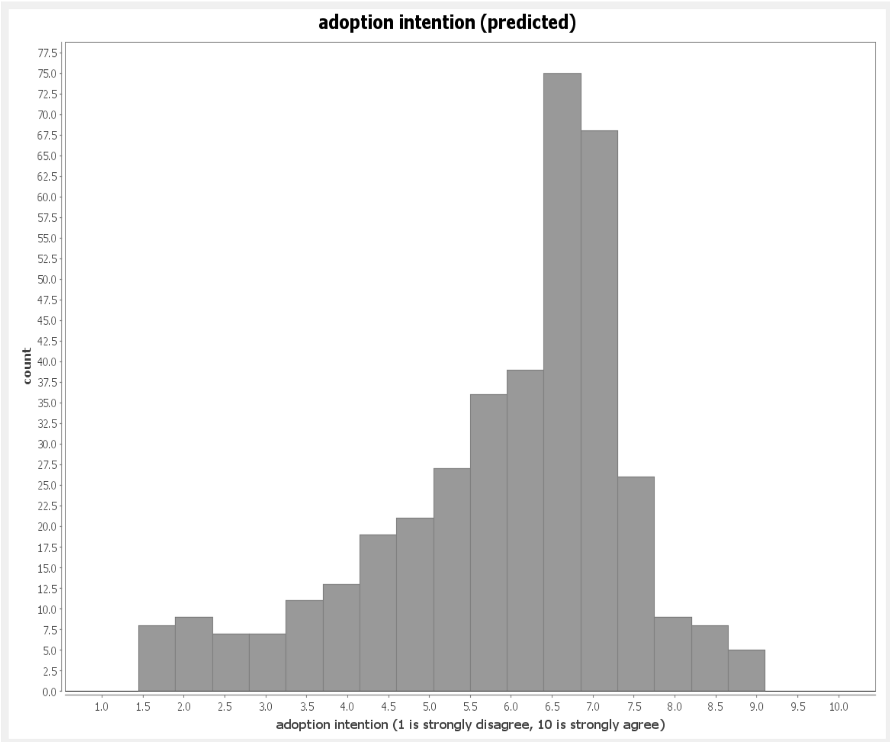

Figure 2C. *Attitude towards knowledge function 25% decrease: average adoption intention lower than 6.0, meaning that the larger part of consumers has a negative adoption intention. 'Only' 25% decrease reaches the same level whereas 45% decrease is needed for "Use Depth" (fig.2B).*

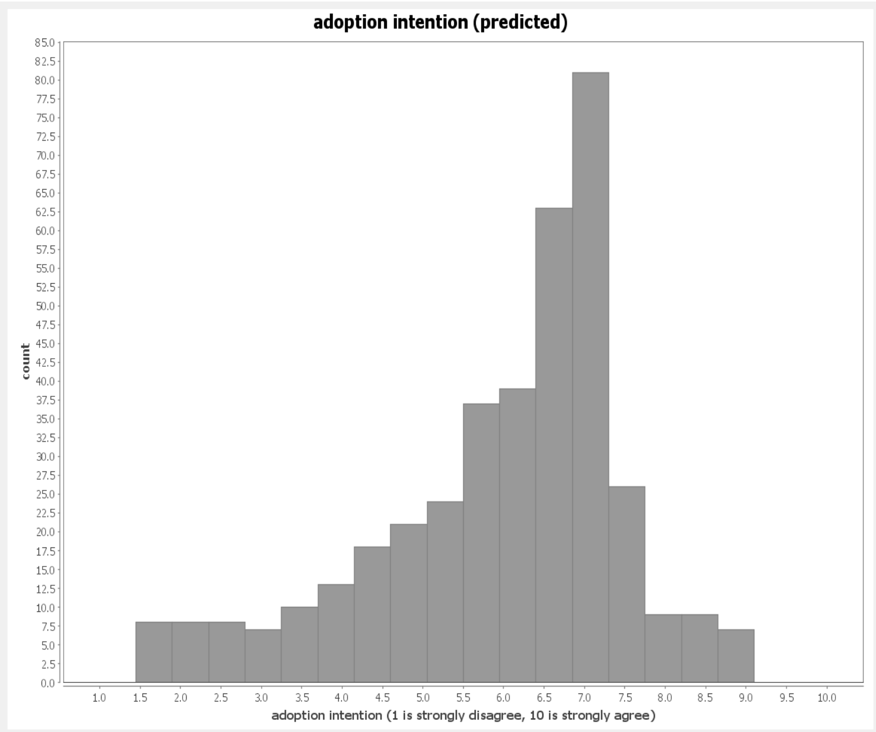

Figure 2D. *Use depth + Attitude towards knowledge function 15 % decrease: average adoption intention lower than 6.0, meaning that the larger part of consumers has a negative adoption intention. 'Only' 15 % decrease reaches the same level whereas 45% decrease is needed for "Use Depth" (fig.2B) and 25% decrease needed for "Attitude towards knowledge function"* (fig.2C).

[Scenario 2]

Location of uncertainty: consumers / level of uncertainty: high / variability uncertainty

When changes in the user interface are made or new capabilities of the technology are introduced this can often be sent to the users through an automatic update of the software. The installed hardware remains the same, but new software enables the new functionalities. How big do the changes need to be to significantly change the views of those users who are currently not satisfied?

Experiment: For this scenario we adjust the value for "ease of use" and test how many system iterations it takes to see a significant change in overall satisfaction.
Because we are only interested in those users who are currently not happy (assuming that those who are already satisfied will only be more satisfied with the new

functionalities being offered) this might not always be the case when people see changes to what they were familiar with, but we assume these are genuine improvements) a subset of those households for which the model predicted a negative view in the initial situation is taken. This subset contains 135 agents.

Increasing the value for "ease of use" by 10% from the initial value results in 3% of this group to change their views to a positive balance. It requires three such steps (i.e. new updates) to convince over 10% of this group and after six steps over 25% has now a positive behavioural intent to adoption. It is up to the user to determine how realistic the impact of consecutive updates is, but it is clear it can have a positive impact in the long run. See figure 3 A-C.

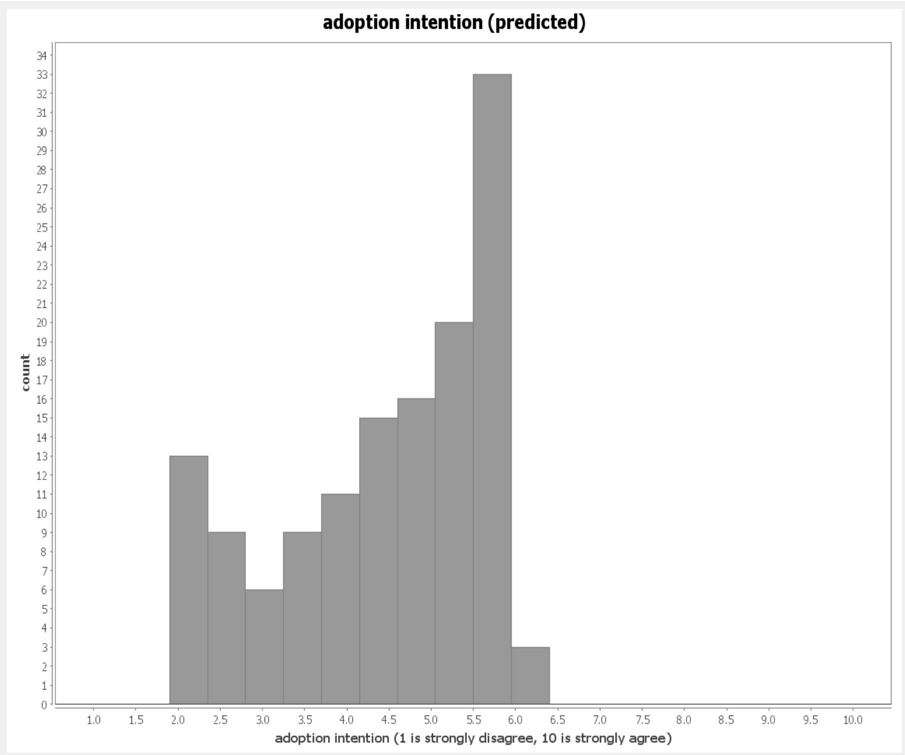

Figure 3A. *Initial state (N=135). Average adoption intention 4.43.*

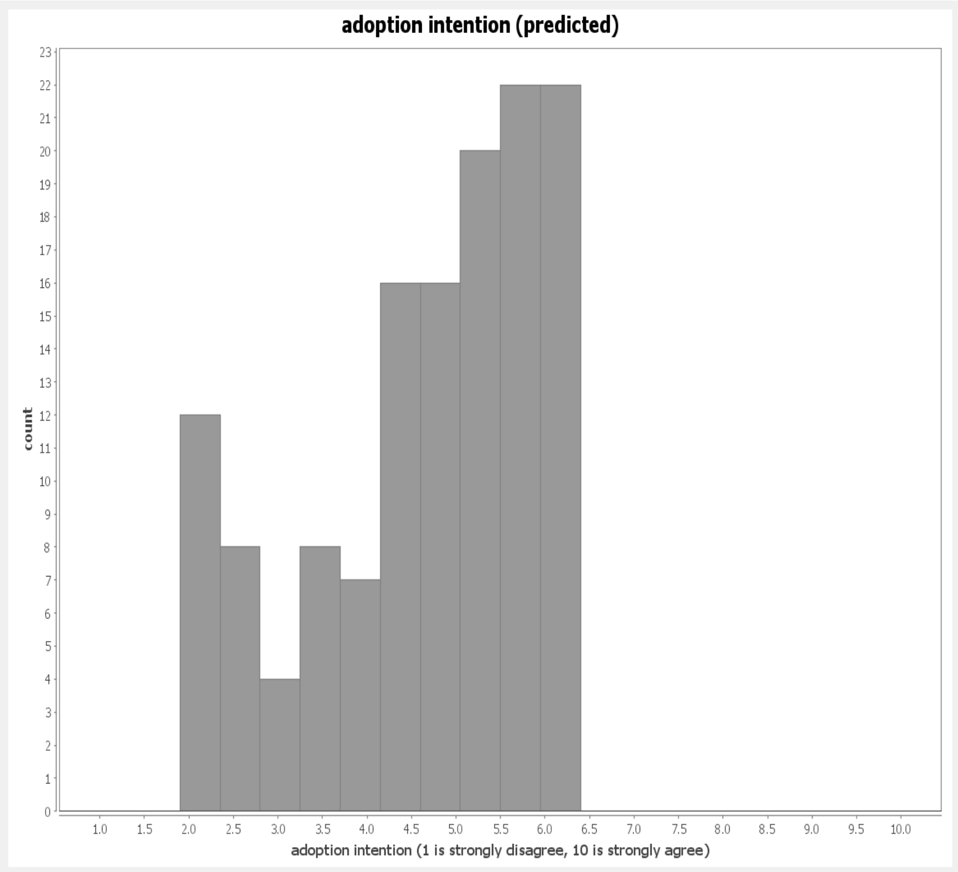

Figure 3B. *Improvement "Ease of use" after 3 steps (N=135). Average adoption intention 4.58.*

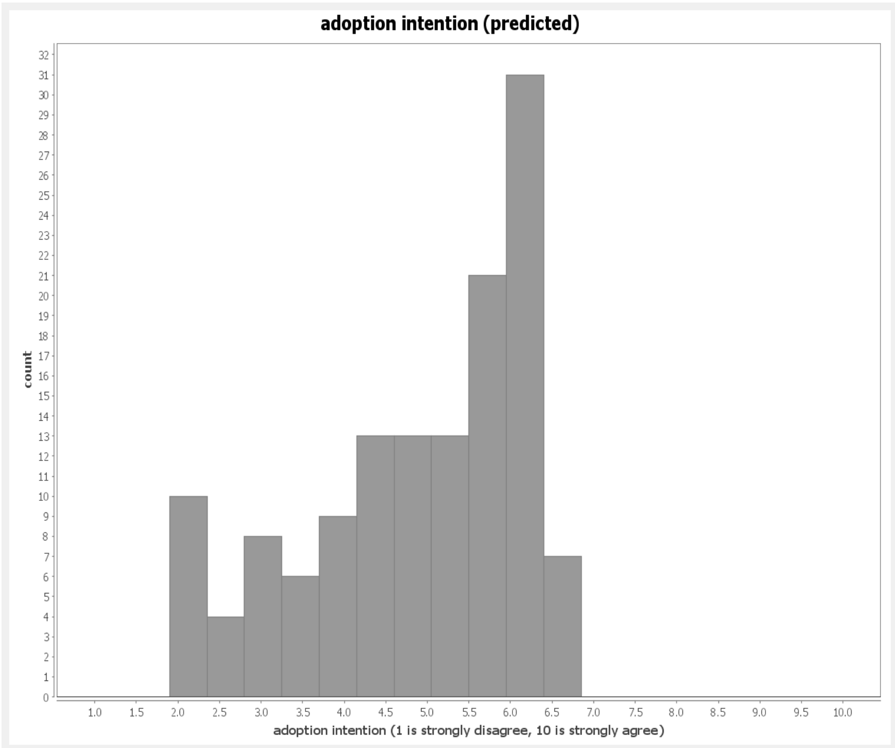

Figure 3C. *Improvement "Ease of use" after 6 steps (N=135). Average adoption intention 4.79.*

[Scenario 3]

Location of uncertainty: consumers / level of uncertainty: moderate/variability uncertainty

Customers may be highly motivated when they start using smart energy systems in their home, but literature shows that this effect often does not last for a very long time and may not cause permanent behavioural change based on the new insights offered by the tool. It is often assumed that when this happens the user is still, and perhaps only, interested in their possible financial profit.

Experiment: To test this hypothesis, we lower the values for "Attitude towards knowledge function" (i.e. does the technology offer new insights in energy use) as well as "Information satisfaction" (i.e. to what extend is the user happy with the information presented to him or her through the smart energy technology) and then experiment with increasing levels of "Financial motivation" to see if this can undo the drop in motivation. Because the hypothesis is that there is a situation where the input is so low that financial motivations become more relevant we allow the values for "Attitude towards knowledge function" and "information satisfaction" to decrease to 0, at which point they no longer influence the final behaviour intent. Afterwards we raise the value for financial motivation (i.e. the degree to which the household acts more sustainable in order to save money and keep control of energy bills) in small steps from the initial values as stated in the survey to the maximum threshold where all households completely agree with the statement that they want to lower their bills.

However, this does not appear to have any noticeable effect: after the drop in "Attitude towards knowledge function" and "information satisfaction" resulted in the average view dropping to negative, not a single household is predicted to change this to a positive value through the increase in financial motivation.

Discussion and conclusion

The scenarios and results presented above were based on actual questions that are relevant to C&M professionals. Other questions and hypotheses may be generated and tested in a similar way. We have shown that from the various strategic C&M management scenarios we can simulate the expected response in the population, within the framework of assumptions set and given the case study and available knowledge and intuition about the domain. This knowledge is made explicit in the simulation. The results provide input for the decision maker and can result in more effective choices and C&M efforts. Furthermore, the results may trigger additional surveys or literature studies or additional surveys to be performed so that the confidence level increases.

The described uncertainty is for all three scenarios more or less the same. However, one can imagine when aspects as socialization and network are included, as discussed before in the 'related work' section. In a network of people communicating, in which aspects of bonding and bridging play a role in the process of sharing willingness to share knowledge or experiences (Pieron, 2012). The locus of uncertainty then switches to network or group which increases the level of uncertainty. The description of uncertainties should be seen as an uncertainty indicator instead of an absolute value. In a future interface this might be visualized by colouring the histogram bars from green (relative low uncertainty) to red (relative high uncertainty) in the C&M communication dashboard.

Some results may be surprising to the C&M professional, which can help re-think some of the underlying concepts and uncertainties. Again, it should be stressed that the outcomes are only valid under the assumptions built into the model, but the modeller and professional (i.e. the user) can work together to redefine these and make adjustments to the simulation based on initial findings. As from a decision support point of view they can 'play' with various scenarios, and discover the dynamics (flexibility and plasticity) of the target audience they are facing on a daily basis, without executing expensive surveys. It could be insightful to compare the simulation outcomes with the daily consumer use log data if available.

Regarding the three questions posed and addressed in the previous section, we can say the following. The first scenario shows that the system is indeed sensitive to user habits that, after a while, result in the user interacting less with the technology. What exactly the numbers means and how realistic the stated 15% change is, is up to the domain expert to judge and evaluate, but it certainly appears that it is not an unlikely situation and one which the stakeholders may wish to address at an early stage. The second scenario only addressed a smaller group of households and particularly looked at how the changes could affect them. This is a critical group and a number of updates which are appreciated by the user could convince a number of them to change their overall views. The user of the tool may want to evaluate the expected costs of implementing such changes and comparing them with other system interventions to see if it is an effective way to change the experience of the user. The relatively high importance of ease of use, especially when compared with concepts such as the environmental responsibility and environmental concern, suggest that it could be worth exploring.

The third scenario showed that the hypothesis stated does not hold in the simulation. It should be stressed, however, that we only experimented with the values of the constructs and not their relative importance (i.e., we did not change the coefficients themselves but only the construct upon which they act). It might be possible that the relative impact of items changes over time. However, the questionnaire did not address such dynamic aspects and therefore it is up to the professional and domain experts to assess how likely it is that this is indeed the case. Perhaps literature can be found with evidence from other domains that indeed the user can change their views on what is important. Having said that, it does appear that the financial rewards play a very minor role in the decision making process and that other aspects are much more important, at least at the beginning. One possible reason for this is that financial rewards are important to everybody already and as such are not a good predictor for wanting to adopt and invest in a home energy management system. This is an interesting result because in practice C&M about smart energy systems actually often stresses the energy savings and consequently lower energy bills as an advantage for the end user, while the results of this study suggest that addressing other factors would have a much bigger impact.

Concerning future research, in addition to all kinds of scenarios the complex adaptive behaviour of consumers and the influence on target audience segmentation might be of interest. Due to differences in speed of adoption intention changes and its specific individual character (e.g. consumer group A is triggered by Use Depth, whereas consumer group B is mostly triggered by being overall satisfied) various consumers refit to different target groups, or even new target groups concerning smart meters. This possibly means that, for example, a mass media campaign targeting a large group of 'classical-segmented' consumers appears no longer to be effective and a more customized approach is needed, i.e. a social media approach. Simulation then might show a tipping point when C&M professionals might consider to switch from classical media to social media.

Having said that, an important next step is a validation of the simulation by using a second survey to test if the simulated data are in range of real occurrences of consumer adoption intention. Then one can calculate the new regression coefficients and see how the internal behaviour of the model changes over time.

We have shown that from the various strategic C&M management scenarios we can simulate the expected response in the population, within the framework of a set of assumptions given the case study and the available knowledge and intuition about the domain. This knowledge is made explicit in the simulation. We have demonstrated the concept of consumer simulation based on agent-based modeling as a promising experimental method in C&M and shown how it can result in relevant insights in C&M management of rather complex and adaptive changes in social-psychological constructs, for example for the roll out of smart energy meters.

Future research should focus on the development of a C&M management dashboard that contains this kind of simulation modules to make consumer data insightful and useful in discussions amongst C&M colleagues and the company board.

Acknowledgements

The authors would like to thank Enexis for providing anonymous consumer data and the communication & marketing professionals who provide us with real communication & marketing scenarios.

Koen H. van Dam works on the Digital City Exchange project funded by Research Councils UK's Digital Economy Programme (EPSRC Grant No. EP/I038837/1).

References

Abrahamse, W., & Steg, L. (2009) How do socio-demographic and psychological factors relate to household's direct and indirect energy use and savings? *Journal of Economic Psychology*, *30*, 711-720.

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2005). A review of intervention studies aimed at household energy conservation. *Journal of Economic Psychology*, *30*, 273-291.

Allcott, H. (2011). Social norms and energy conservation. *Journal of Public Economics*, *95*, 1082-1095.

Bailey, K.D. (1994). *Sociology and the new systems theory. Toward a theoretical synthesis.* New York, USA: State University of New York Press.

Balmer, J.M.T., & Stuart, H. (2004). British Airways and Balmer's AC3ID Test of Corporate Brand Management, *Working Paper No 04/26, Working Paper Series, Bradford University School of Management*, July 2004.

Brown, S. A., & Venkatesh, V. (2005). A Model of Adoption of Technology in the Household: A Baseline Model Test and Extension Incorporating Household Life Cycle. *Management Information Systems Quarterly*, *29(3),* 4.

Caeiro, S., Ramos, T.B., & Huisingh, D.(2012). Procedures and criteria to develop and evaluate household sustainable consumption indicators. *Journal of Cleaner Production*, *27*, 72-91.

Clastres, C., (2011). Smart grids: Another step towards competition, energy security and climate change objectives. *Energy Policy*, *39*, 5399-5408.

Dam, K.H. van, Nikolic, I., & Lukszo, Z. (Eds) (2013). *Agent-Based modelling of Socio-Technical Systems*. Dordrecht, The Netherlands: Springer.

Darby, S. (2006). Social learning and public policy: lessons from an energy-conscious village. *Energy Policy*, *34*, 2929-2940.

Dijkema, G.P.J., Lukszo, Z., & Weijnen, M.P.C. (2013*)*. Introduction. In K.H. van Dam, I. Nikolic & Z. Lukszo. *Agent-based modelling of socio-technical systems,*. Dordrecht: Springer.

Fisher, C. (2008). Feedback on household electricity consumption: a tool for saving energy. *Energy efficiency*, *1*, 79-104.

Flipse, S.M., & Sanden, M.C.A. van der (2013). Setting up spaces for collaboration in industry between researchers from natural and social sciences. *Science Engineering & Ethics*. Doi 10.1007/s11948-013-9434-7.

Grawal, R., Mehta, R., & Kardes, R. (2004). The timing of repeat purchase of consumer durable goods: the role of functional basis of consumer attitudes. *Journal of Marketing Research*, *41*, 101-115.

Gruenfeld, D.H. (1998). Cognitive flexibility, communication strategy, and integrative complexity in groups: public versus private reactions to majority and minority status. *Journal of Experimental Social Psychology*, *34*, 202-206.

Jager, W. (2006). Stimulating the diffusion of photovoltaic systems: a behavioural perspective. *Energy Policy*, *34*, 1935-1943.

Jager, W., & Janssen (2012). An updated conceptual framework for integrated modeling of human decision making: the consumant II. *Paper for workshop complexity in the real world*, ECCS 2012, Brussels, 5-6 September 2012.

Jennings, N. (2000). On agent-based software engineering. *Artificial Intelligence*, *117(2),* 277– 296.

Jones, B.D. (1999). Bounden rationality. *Annual Review of Political Science*, *2*, 297-321.

Kahneman, D. (2003). Maps of bounded rationality: psychology for behavioral economics. *The American Economic Review, 93(5), 1449-1475*.

Karjalainen, S. (2011). Consumer preferences for feedback on household electricity. *Energy and Buildings*, *43*, 548-467.

Kobus, C.B.A., Mugge, R., & Schoormans, J.P.L. (2012). Washing when the sun is shining! How users interact with a household energy management system. *Ergonomics*. Doi:10.1080/00140139.2012.721522.

Kowatsch, T., & Maass, W. (2010). In-store behavior: how mobile recommendation agents influence usage intentions, product purchases, and store preferences. *Computers in Human Behaviour*, *16*, 697-704.

Krischnamurti, T., Schwartz, D., Davis, A., Fischhoff, B., Bruine de Bruin, W., Lave, L., & Wang, J. (2012). Preparing for smart grid technologies: a behavioural decision approach to understanding consumer expectations about smart meters. *Energy Policy*, 41, 790-797.

Kulvivat, S., Bruner II, G.C., Kumar, A., Nasco, S.A., & Clark, T. (2007). Toward a unified theory of consumer acceptance of technology. *Psychology & Marketing*, *24*, 1059-1084.

Littejohn, S.W., & Foss, K.A. (2008). *Theories of human communication*. Boston, USA: Wadsworth Cengage Learning.

Mägi, A.W. (2003). Share of wallet in retailing: the effects of customer satisfaction, loyalty cards and shopper characteristics. *Journal of Retailing*, *79*, 97-106.

Meuter, M.L., Bitner, M.J., Ostrom., A.L., & Brown, S.W. (2005). Choosing among alternative service delivery modes: an investigation of customer trial of self-service technologies. *Journal of Marketing*, *69(2)*, 61-83.

Momoh, J.A. (2009). Smart Grid Design for Efficient and Flexible Power Networks Operation and Control. *IEEE Power Systems Conference and Exposition, 2009. PSCE '09*.

Peffer, T., Pritoni, P., Meier, A., Aragon, C., & Perry, D, (2011). How people use thermostats in homes: a review. *Building Environment*, *46*, 2529-2541.

Pieron, M. (2012). *Bonding & Bridging in capacity building*. Thesis, Delft University of Technology.

Pommeranz, A. (2012). *Designing human-centered systems for reflective decision making*. PhD Thesis, Delft University of Technology.

Riel, C.B.M., & Fombrun, C.J. (2007). *Essentials of corporate communication. Implementing practices for effective reputation management*. New York: Routledge.

Ruler, B. (2013). *Communicatie: grootboek van het communicatievak*. Amsterdam: AdformatieGroep BV.

Sanden, M.C.A. van der, Dam, K.H. van., & Stragier. J. (2013). Professionalization of organizational communication by means of decision support systems and simulation. *Etmaal van de Communicatie*, Rotterdam, February 2013.

Sanden, M.C.A. van der, & Dam, K.H. van. (2010). Towards an ontology of consumer acceptance in socio-technical energy systems. *Proceedings of the 3rd International Conference on Infrastructure Systems and Services: Next Generation Infrastructure Systems for Eco-Cities (INFRA)*, Shenzhen, China, November 2010.

Sanden, M.C.A. van der, & Meijman, F.J. (2012). A step-by-step approach for science communication practitioners: a design perspective. *Journal of Science Communication, 11(02)*, 2012A03

Sanden, M.C.A. van der, & Osseweijer, P. (2011). Effectively embedding science communication in academia: a second paradigm shift? In D.J. Benett & R.C. Jennings. *Successful science communication: telling like it is*. Cambridge:Cambridge University Press.

Schindler, J. (2012). Rethinking the tragedy of the commons: the integration of socio-psychological dispositions. *Journal of Artificial Societies and Social Simulations*, *15(1)*, 1-15.

Schoemaker, P.J.H. (1995). Scenario planning: a tool for strategic thinking. *Sloan Management Review, Winter 1995*, 25-40.

Stragier, J., Hauttekeete, L., & De Marez, L. (2010). Introducing smart grids in residential contexts: consumers' perception of smart household appliances. *Proceedings IEEE 2010 IEEE Conference on Innovative Technologies for an Efficient and Reliable Energy Supply,* Boston.

Sycara, K.P., Zeng, D., & Decker, K. (1998). Intelligent agents in portfolio management. In Jennings, N.R., & Wooldridge, M.J. *Agent Technology. Foundations, applications, and markets*. Heidelberg: Springer.

Vringer, K., Aalbers, T., & Blok, K. (2007). Household energy requirement and value patterns. *Energy Policy*, *35*, 553-566.

Walker, W.E., Harremoes, P., Rotmans, J., Sluijs, J.P. Van Der, Asselt, M.B.A. Van, Janssen, P., & Krayer Von Kraus, M.P. (2003). Defining uncertainty. A conceptual basis for uncertainty management in model-based decision support. *Integrated Assessment, 4(1)*, 5-17.

Wehrmann, C. and Sanden, M.C.A. van der (2007). Communication spectrum: useful instrument in the science communication practice? The necessity of combining theory and practice. *Tijdschrift voor Communicatiewetenschap*, *35(1)*, 79-98.