The Value of a Smart Meter

Or a methodology to align actors using the value of different configurations

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Management summary

Smart meters are being implemented in different settings all over the world. Smart meters are also implemented in the Netherlands in different trials and projects. The local contingencies in which these meters are being implemented differ from each other. Also the smart meter systems that are being implemented differ from each other. What exactly the smart meter system is, which components it has and how it functions changes from project to project; the smart meter system is redefined each instance the smart meter is being implemented. The actors involved in the implementation and their respective costs and benefits also seem to differ in each single project. The smart meter system is therefore a distinct case of a configurational rather than a conventional, generic system as described by Fleck (1993).

Configurational systems are characterized by specific implementation barriers which stem from the configurational character of these systems, while the objective of the development of an innovation is the actual implementation of the innovation. The absence of a generic off-the-shelf system which can be implemented in different local contingencies hampers the implementation in several ways. One is the absence of a fixed revenue mechanism. As the configuration implemented in different local contingencies differs between settings, the components, their function, their relations and the overall function of the system also differ between instances. This leads to different costs and benefits and thus different revenue mechanisms for the respective actors in these different instances. This creates both insecurity on the overall effect of the implementation of the configurational technology on the actors involved, as well as leading to alignment problems as costs and benefits can be distributed unevenly over the actors involved in the implementation of a specific configuration. Additionally the configurations create additional benefits or additional value in different configurations and different local contingencies.

Conventional methodologies used to assess the profitability of an innovation for an actor, or methodologies used to assess the distribution of the value of an innovation over different actors, such as a business case, social return on investment or societal cost benefit analysis, are unable to discover or identify the additional value of a the implementation of a configuration in a specific setting as their scope is limited to financial costs and benefits or their scope is limited to one actor rather than the interaction between actors. Also these methodologies are unable to assess the distribution of these effects over the actors involved in the implementation of the configurational system and finally the methodologies do not provide guidance on how to capture the additional benefits into business models in order to propel the implementation of the configurational innovation.

This study uses the case of the implementation of smart meters to develop a methodology capable of assessing the value of a configurational system and to discover additional benefits to facilitate the implementation of configurational systems. Also the methodology will facilitate the incorporation of qualitative benefits into new revenue mechanisms which can further propel the implementation phase.

By combining the quantification and monetization aspects of social return on investment and societal cost benefit analysis methodologies with the recently composed fundamental principles of the value case methodology of Hoorik and Bomhof (2010), a value case methodology can be

compiled which is capable of discovering additional benefits from the implementation of a configurational system in a given setting. Also this methodology provides guidance as to how to incorporate the newly identified benefits into business models, even when these benefits are qualitative upon discovery, this in order to remove implementation barriers of the configurational innovation and to gain momentum during the implementation phase.

The methodology is based on the principle that when an innovation is beneficial for all the crucial actors involved in the implementation of the innovation, in other words if the actors are aligned, the innovation will indeed be implemented. The methodology thus aims at aligning the actors. This is done in several steps, as shown in Figure 1. The process starts with a conventional business case. If the outcome of the business case, which is an assessment method aimed at quantitative financial costs and benefits, does not align the actors, qualitative effects are being added to the case. These effects include profit effects, but also people and planet effects in order to broaden the scope of the search for additional benefits. The overview of the additional benefits to the business case is presented to the actors and in case this also does lead to an alignment of the actors, the next step is taken. This next step concerns the quantification of several or all quantitative effects. As some of the qualitative effects do not concern profit, but people or planet effects, the outcome of this process does not lead to a different financial outcome of the case. Once again the outcome of this process is used to align the actors involved and if no alignment is reached, the following step can be undertaken. This fourth step concerns the monetization of several or all quantitative effects. This does result in a different financial outcome of the case for the separate actors involved in the implementation of the innovation. Again as some effects stem from people or planet effects, it is possible that these monetized effects cannot directly be incorporated by existing business models. Therefore if the actors are not aligned after this step, the next step is to develop new business models to capture the monetized value of the additionally identified benefits.

In the case of the smart meter systems, this study provides an overview of the qualitative value case with an impetus for the quantification and monetization of several qualitative effects as well as a step towards new business models to capture the additional value of smart meters in the case studied in this research. This leads to the qualitative overview of effects summarized in Figure 2 and the investigation into the legal possibilities of one new business model by one of the actors involved in the implementation of smart meter systems.

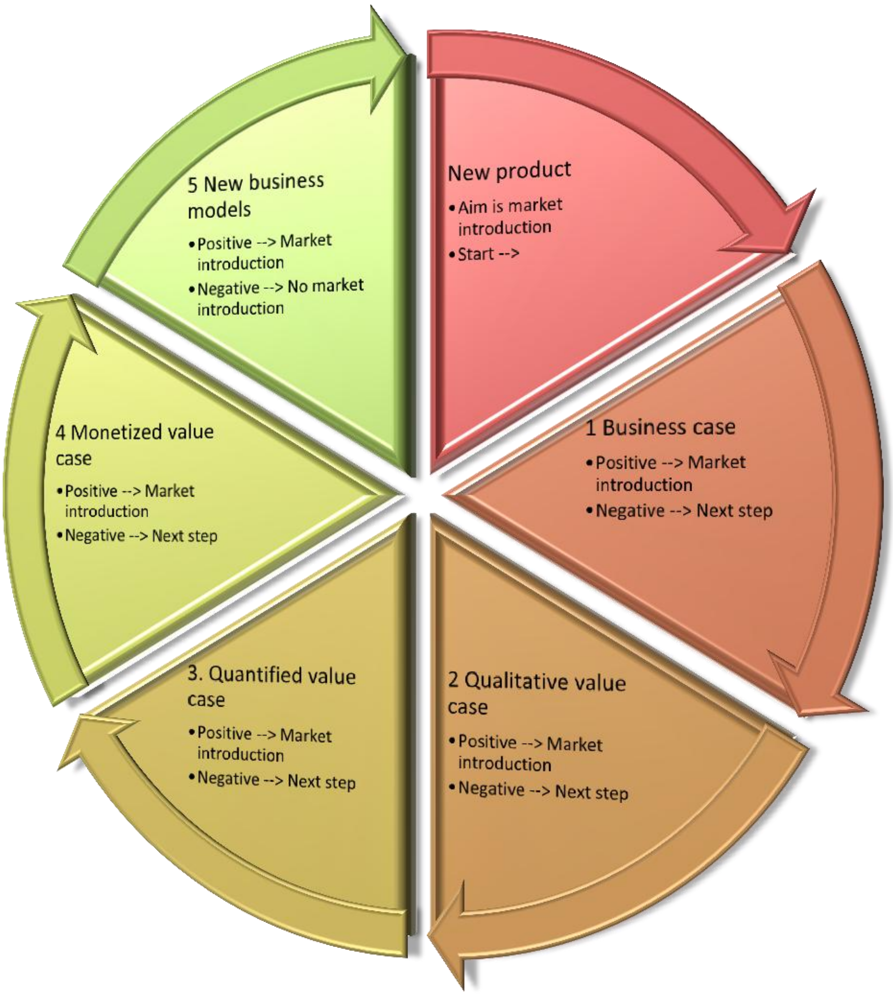

Figure 1, Value case process cycle.

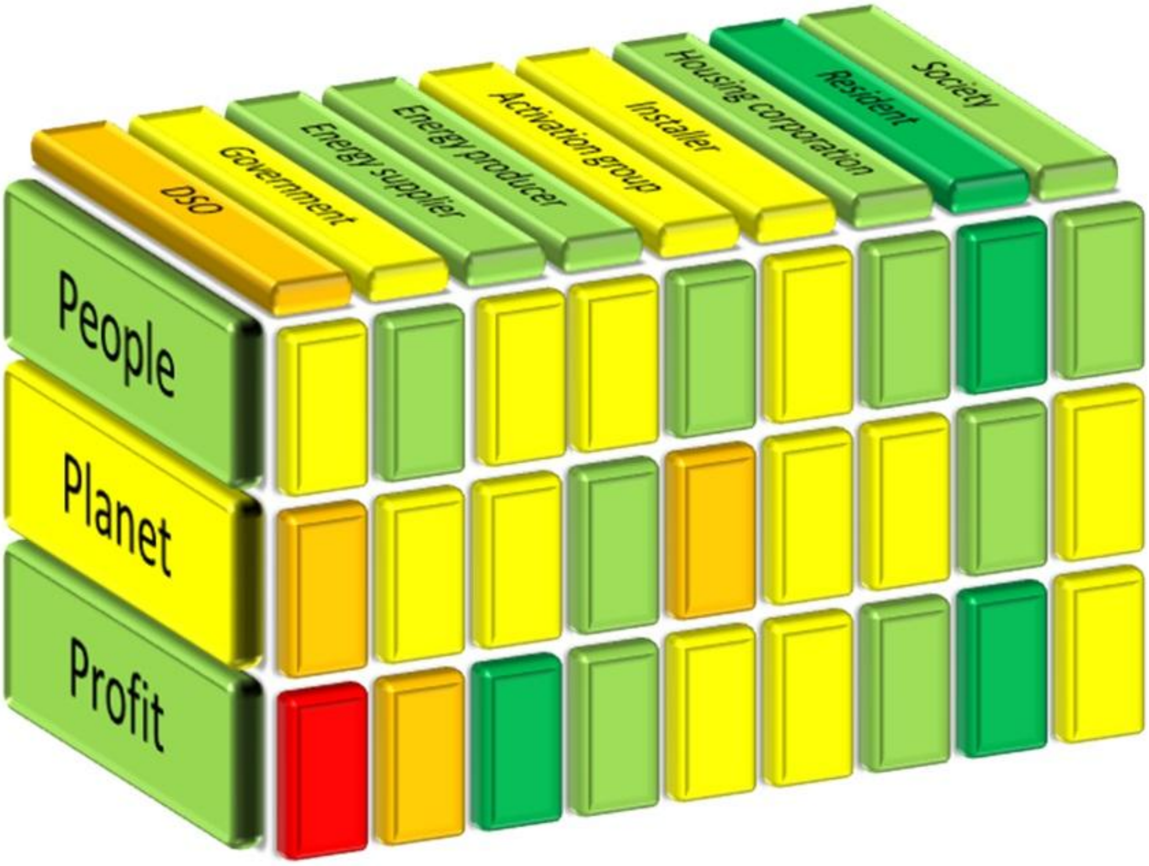

Figure 2, Effect summary.

Acknowledgement

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This project has led me to several valuable insights, of which one is conspicuously expressed by Albert Einstein:

“You cannot solve a problem using the same thought process that created it.”

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1. Introduction

All over the world, smart meters are being introduced (Chan et al, 2009). Smart meter trials are conducted ranging from large scale network preservation programs in Massachusetts, USA, to small scale energy savings programs in Amsterdam, the Netherlands (Chan et al, 2008; ASC, 2009; Faruqui et al, 2010b). Smart meters are considered a promising technology, enabling benefits including the previously mentioned network preservation and energy savings as well as other benefits. These benefits stem from the unique position of the smart meter as a 'bridge' between smart grids and smart homes, enabling these two systems to interact (Beard, 2010). The basic function of the smart meter is the same in each situation: detailed energy consumption measuring and data transfer. However the settings in which smart meters are implemented differ from each other; smart meters are thus implemented in different local contingencies.

Unlike standardized innovations where one technology, system or product is used in these different local contingencies, this innovation is implemented in different configurations. For example in Massachusetts smart meters are combined with peak shifting infrastructure, while in Amsterdam smart meters are installed in combination with in home energy feedback displays (Chan et al, 2008; ASC, 2009; Faruqui et al, 2010b). These configurations differ from each other "*beyond tweaking a few parameters*" (Fleck, 1993, p. 34) and can therefore be described with the configurations theory of Fleck (1993).

Each configuration of the smart meter comes with specific costs and specific benefits. The distribution of these costs and benefits over actors involved in smart meter development and implementation induces incentives and barriers to implement. With the Massachusetts trial the firm responsible for the energy distribution system, or distribution system operator (DSO), invested in smart meters, creating the benefits of cost reduction in network expansions. Costs and benefits are allocated to the same actor, inducing incentives for this actor to implement smart meters. For the Netherlands a business case, a calculation and overview methodology for financial costs and benefits of an innovation or intervention, of the KEMA (2010) has shown costs and benefits to be distributed over several actors; with DSOs being responsible for the installation of smart meters and their infrastructure and residents receiving the benefits of lower energy costs as shown in Figure 3 and Table 1. Based on the business case, the DSOs, who are responsible for smart meter implementation, lack incentives to invest in this innovation while the implementation of smart meters would overall have a positive outcome. An alignment problem of actors is thus present. To further complicate the problem, there is no owner of the problem. The only actor with significant benefits from this innovation is the one actor who does not play an active part in the implementation of the smart meter: the residents.

In order to induce smart meter implementation by DSOs, the Dutch government has imposed legislation stating that 80% of households in the Netherlands must have a smart meter installed by 2020 (KEMA, 2008; Staver, 2010). Without this government intervention, it is likely the innovation would not be implemented on this large scale in the Netherlands by DSOs: the current business models cannot cope with this disproportionate distribution of the value of an innovation over several actors. This inspires the question whether there are other ways to align these actors in case of an alignment problem, besides government intervention.

Simply changing the business models for the DSOs to charge actors who benefit from the innovation seems most obvious. In this case this would mean increasing the fee residents are charged by DSOs for the infrastructure. However this is not possible as the government does not only imposes the implementation of smart meters; the annual fee residents have to pay DSOs for the infrastructure, including the energy meters is also determined by the government in the form of regulations from the Dutch Competition Authority (NMa) (NMa, 2011).

Another possible direction leads to value propositioning (Peine, 2009). Different value propositioning might lead to the discovery of additional benefits which can be an incentive for the DSOs to implement this innovation. These benefits should be searched for outside the current framework of business cases. A different methodology is thus needed to identify costs and benefits in and beyond the current, monetized value focussed business case. Elkington (1997) states that not only money, or the profit dimension, should be an incentive for the direction of a company, but also the impact on people and planet dimensions must be assessed. This aspect can be used to identify more costs and benefits beyond the current scope. Hoorik and Bomhof (2010) have suggested the use of a value case rather than a business case as a methodology to identify positive and negative effects for people, planet and profit dimensions of complex ICT driven innovations. The results of this value case methodology, which has not been fully developed yet, are likely to contain qualitative costs and benefits, the methodology must be able to handle both quantitative and qualitative aspects of an innovation. This mixture of impacts could persuade actors to support the implementation of an innovation as the smart meter. However if the actors only respond to financial incentives, the qualitative effects of the innovation must be monetized and new business models are required for firms to obtain this value.

I argue that smart meter systems are configurational systems rather than off-the-shelf products and that configurational systems require a different methodology to gain insights in the value of the innovation. This, as more traditional methodologies are unable to provide this insight with configurational technologies. Furthermore I argue that the value case methodology of Hoorik and Bomhof (2010) can be adapted to provide these insights and to propel the implementation of complex configurational innovations, for example when this is hampered by an alignment problem between actors.

This leads to the research question, assuming value case methodology can in fact be used to resolve alignment problems: What must the value case methodology look like in order to provide insight in the value of an innovation in the implementation phase of complex configurational technology?

To find the answer to this question, the smart meter case in Amsterdam is studied. The DSO, in this case Liander N.V. finances the project (ASC, 2009). The smart meter is implemented in the configuration of the smart meter with the addition of an energy feedback display. The residents are expected to save energy as a result of the display. The same alignment problem from the KEMA (2010) study is thus also present in the Amsterdam Smart City project in Geuzenveld. The study of this project can therefore be considered exemplary for the Netherlands.

The next chapter will provide more detailed information on the difference between innovation models based on conventional, off-the-shelf, generic systems and the notion of configuration systems of Fleck (1993). This is followed by a chapter describing the technology of smart meters, explaining why smart meters are configurational rather than generic systems. After the technology, the methodology developed during this study is described into detail, followed by a description of the method used to implement the methodology in the case at hand. The results from this method are described thereafter. This leads to the discussion and conclusion chapter, which concludes with proposals for further research.

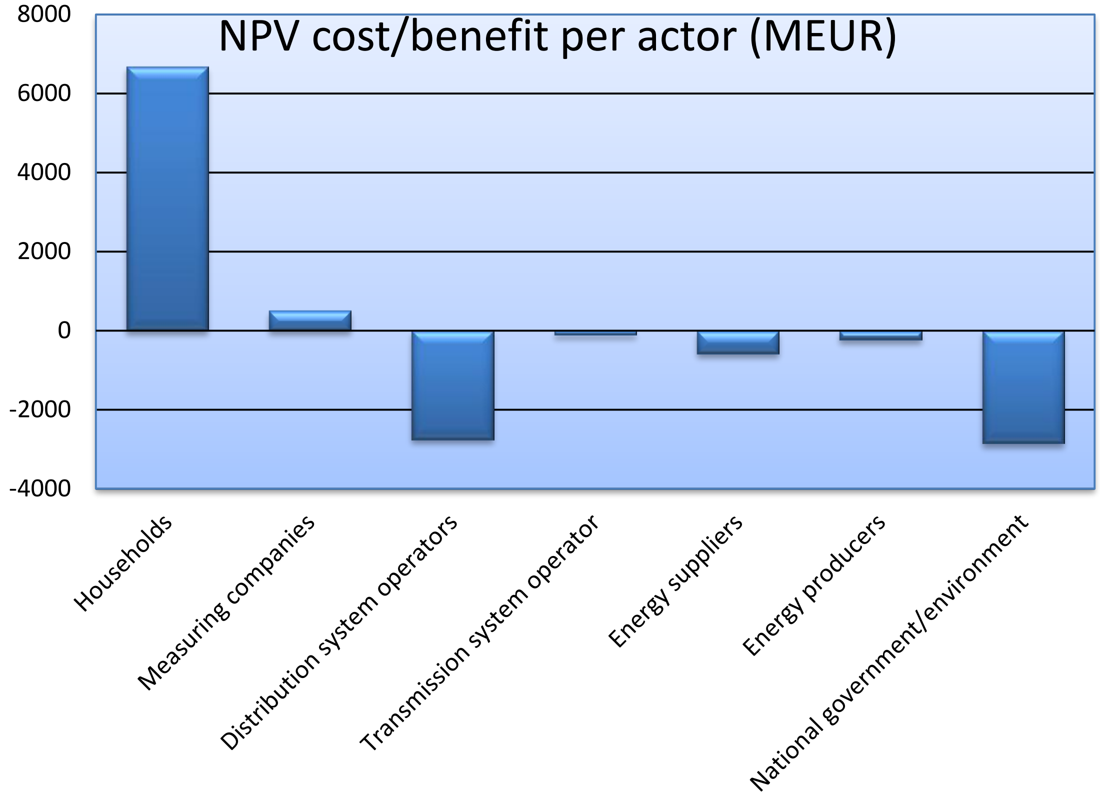


Figure 3, Allocation of costs and benefits of the KEMA business case (KEMA, 2010).

Table 1, NPV smart meter implementation per actor, derived from graph (KEMA, 2010).

	NPV cost/benefit per actor (BLN €)
Households	6,7
Measuring companies	0,5
Distribution system operators	-2,8
Transmission system operator	-0,1
Energy suppliers	-0,5
Energy producers	-0,2
National government/environment	-2,8

2. Theory

In this chapter the theory used in this study and the place of the configurational technologies theory of Fleck (1993) within, or perhaps opposed to, more conventional innovation theories is described.

2.1. Innovation Theories

Innovation theories try to explain and predict the success of an innovation through models, processes and frameworks, in order to make innovation manageable. The generic path of an innovation can be described by theories from Tidd et al (2005), Utterback (1994) and Rogers (2003) as shown in Figure 4. This path is not a linear process as steps can be made forwards and backwards, however it does provide insight in the bases which need to be covered when innovating. The innovation starts with the search for improvements or new products or services based on identified or expected needs or problems (Tidd et al, 2003). The most promising inventions are selected to be further developed in order to be implemented (Tidd et al, 2003). Prior to the large scale implementation, a dominant design emerges; one model or configuration which applies to a large number of local contingencies; a sort of one-size-fits-all artefact (Utterback, 1994). This dominant design facilitates the diffusion of the innovation as a standardized product is produced to meet the needs of large user groups (Utterback, 1994; Rogers, 2003). During or after this process of searching, selecting and implementing an innovation, a new cycle, or search for a new innovation will take place (Tidd et al, 2003). This generic innovation process applies to many innovations. However, these theories do not stroke with the notion of configurational technology as coined by Fleck (1993). He describes the implementation process of complex Information and Communication Technology (ICT) driven systems. Fleck (1993) characterizes these systems as lacking a clear dominant design as the innovation is implemented in different configurations, depending on local contingencies, making it difficult to understand or manage their innovation path with the theories of Tidd et al (2005), Utterback (1994) and Rogers (2003). To understand the differences between these theories and why configurational technologies theory best applies in this situation, the theories are explained in more detail below.

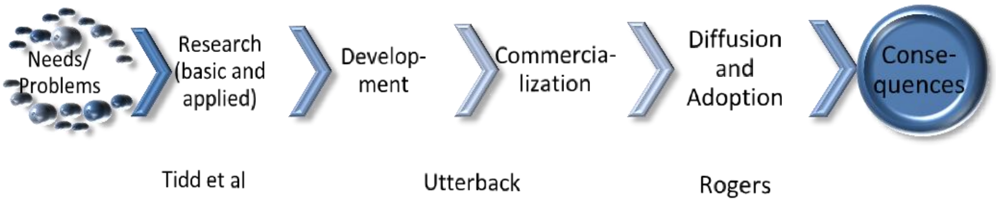


Figure 4, Six main stages in the innovation-decision process by Rogers (2003).

2.2. Innovation Process Model

Tidd, Bessant and Pavitt (2005) describe the main generics the first stages of an innovation process. They describe an innovation to mature through the three phases of their innovation process model: the search, select and implement phases. This model aims primarily on processes firms have to undertake in the form of routines, in order for them to be able to create a successful innovation. However this model can also be used as a view on how innovations mature throughout the phases and what is needed from actors to do so. The phases of this innovation funnel of Tidd et al (2005) are the search phase, the select phase and the implement phase as shown in Figure 5 where the funnel shape indicates the reduction in the number of potential innovations

The search and select phases in innovation concern the ability of actors to identify potential for change. This can be new technological opportunities, or changed needs from the markets, or legislative changes. Some innovations are based on market pull and some are the result of technology push, but most innovations result from a combination of these potentials for change. Actors require routines for identifying, processing and selecting information from the turbulent environment which provides a wide range of signals. Actors focus their search routines to the places where they expect to find useful information. This focus of the search routines increases the actor's ability to search, process and select useful information, however it can also create a barrier to more radical forms of innovation as the information leading to this, is not found within the scope of the search. Tidd et al (2005) state that a key challenge for actors relates to the understanding of what factors influence the boundaries of the selected environment and the development of strategies to ensure the boundaries of this selected environment are stretched.

The third phase of the innovation process model of Tidd et al (2005) concerns the implementation of an innovation, in which the potential ideas from the previous phases are converted into some sort of reality. Throughout this phase, knowledge is acquired on the feasibility of an innovation in terms of technological possibility and demand for the innovation. This is done by a continuing thread of problem-finding and problem-solving to fine tune the product to fit into the intended context. Eventually the innovation has a stabilized form, which can be launched on a large scale. Tidd et al (2005) describe three core elements of the implementation phase: acquiring knowledge resources, executing the project and launching and sustaining the innovation.

Acquiring knowledge resources concerns combining new and existing knowledge or ideas to propose a concept. This concept is developed to either cope with the changing environment or to take advantage of the identified opportunities. The knowledge can be acquired by an actor through the creation of knowledge such as research and development, as well as being acquired through technology transfer between actors. The initial combination of ideas, or invention, is likely to change considerably in the further development towards to the final innovation.

Executing the project concerns the transition from strategic concepts and initial ideals for realizing the concept to both a developed innovation and a prepared market, ready for launch. This is a challenge for an actor in terms of project management under uncertain conditions. It is during this part of the trajectory that most of the time, costs and commitment are incurred as problem-solving loops are run through in order to deal with expected and unexpected problems with respect to the technology and the market formation.

When the implementation-ready innovation is developed, the innovation can be launched. For this launching of the innovation, actors need to apply a set of activities associated with preparing the market in which the innovation will be launched. The fundament is the collection of information on customer needs and feeding this to the development process of the innovation to make sure the innovation will match with these needs. Tidd et al (2005) state that understanding the needs of users always has been a critical determinant of innovation success as a better match of the innovation with user needs or local contingencies strongly increases the chance of success of an innovation. Von Hippel (1988) underpins this notion that meeting the needs of users, for example by involving them in early stages of the innovation process, leads to a higher quality innovation and a better adoption. Overall following this innovation trajectory of Tidd et all (2005) should increase the chances of success of an innovation, for example in terms of profit, market share or the overall level of the diffusion of the innovation.

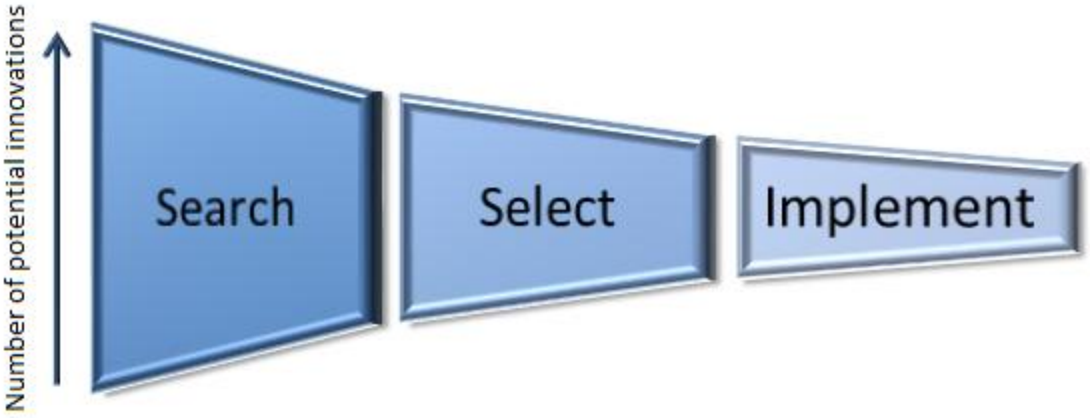


Figure 5, Innovation process model of Tidd et al (2005), the funnel shape indicates the reduction from the number of original ideas to the number of implemented innovations.

2.3. Dominant Design

In order for an innovation to be implemented and diffused successfully, more aspects come in play then only following the innovation process model of Tidd et al (2005). Utterback (1994) describes the success of innovations to be related to the dominance of the design of the innovation. The dominant design is the design that wins the allegiance of the marketplace; it defines how an artefact is supposed to look and operate in the mind of the users as well as the producers. A dominant design meets the requirements of many different groups of users, even though it may not meet the exact needs of separate groups as much as specialized designs would. The emergence of a dominant design is not predetermined; rather it is the outcome of institutional dynamics constrained by economic and technical possibilities (Tushman & Murmann, 1998). The concept of the dominant design is broader than technical competition. Other factors also influence the dominance of a design, such as collateral assets, industry regulation and government intervention, strategic manoeuvring by actors and communication between users and producers (Utterback, 1994).

Collateral assets such as market channels, brand image and customer switching costs can assist actors in enforcing a design to become the dominant design (Teece, 1986; Utterback, 1994). Also when an actor has well developed collateral assets, competitors and markets will form to the design pushed by this actor.

Regulators for industries often have the power to impose binding regulations in the form of standards (Utterback, 1994). By doing so, these regulators actually define dominant designs. Besides the regulators for industries, governments also have the power to impose binding regulations, for example to impose standards which either favour or undermine the interests of their domestic producers. Governments therefore often involve themselves in the process of defining international standards.

The strategy chosen by an actor when implementing an innovation may also influence the dominance of the implemented product design (Utterback, 1994). This strategy can involve the forming of alliances or contracts with other actors, creating a broader momentum supporting the product design. On the other side, a strategy can also aim at exclusivity of the design, leading to popularity and therefore possible dominance of the design.

Like Tidd et al (2005) and Von Hippel (1988) above, Utterback (1994) also emphasises the importance of involving users in the innovation process. Utterback indicates that involving users to develop the product can provide insights into which features of the product design are important to users. Also the interaction between users and producers can assist actors into determining how the product is being used, which can feed the development of the product design to one that meets the needs of the users.

These theories describe factors influencing the success of the implementation of an innovation; however the diffusion and adoption process of an innovation itself is not part of these theories.

2.4. Diffusion of Innovation

This diffusion of innovation is the part of the innovation process specifically described by Rogers (2003). He defines diffusion as follows:

"Diffusion is the process by which an innovation is communicated through certain channels over time among member of a social system" (Rogers, 2003 p. 5)

Adoption of an innovation, the decision to accept, purchase or use an innovation, follows this diffusion of an innovation; how an innovation is communicated, through which communication channels, over which period of time and in which social systems influences the adoption rate and thus the success of the implementation of an innovation. The four aspects of the definition of diffusion of Rogers (2003) contribute to the understanding of the diffusion of innovation. These four aspects are the innovation, communication channels, time and a social system. With the term innovation Rogers (2003) refers to the newly developed artefact of which the characteristics and development process have been described in the previous paragraphs. The other three aspects will be explained in more detail.

For an innovation to be diffused throughout a large part of a potential market, communication channels are needed to share knowledge or experience concerning the innovation between individuals or units of adoption. Communication channels are thus means by which messages get from one individual to another. Rogers (2003) makes a distinction between two types of communication channels: mass media channels and interpersonal channels. Mass media channels involve all those means of transmitting a message that involve a mass medium such as radio and television, which enable one individual to reach an audience of many. These channels are also characterized by concerning monologues. Opposite to these channels are the interpersonal channels. These involve a face-to-face interaction between two or more individuals. While a smaller audience is reached, the persuasion of the audience is more effective with the interpersonal channels. Rogers (2003) notes emerging of a third type of channel: the internet. However on the internet, both mass media and interpersonal channels can be distinguished as on site advertisements can be considered mass media channels and forums or social network can be seen as interpersonal channels, leaving the initial distinction of these two channels as the main communication channels for the diffusion of innovation unchanged. Diffusion is being described by Rogers (2003) as a very social process as individuals base their decision to adopt on the information provided to them through the different communication channels. However *"the subjective evaluation of an innovation that is conveyed to them from other individuals like themselves who have already adopted the innovation"* (Rogers, 2003 pp 18-19) has more influence on their decision to adopt. In other terms; when users of an innovation suggest the innovation will be beneficial to an equal individual, that individual is more likely to adopt the innovation; emphasizing the notion that interpersonal communication channels more effectively persuade their reached audience.

The next element in the diffusion process is time. This dimension is involved in diffusion as the time between in which an individual passes from first knowledge of an innovation through its adoption or rejection differs per individual. This period in influenced by the innovativeness of individuals or other units of adoption. Rogers (2003) identifies five main steps in the process between first knowledge and adoption or rejection of an innovation by an individual. These steps are: knowledge, persuasion, decision, implementation and confirmation. Knowledge is gained by individuals when they learn of the existence of an innovation and when they gain some understanding of how the innovation functions. The persuasion takes place when an opinion or favourable or unfavourable attitude towards an innovation. Next the decision occurs as an individual engages in activities that lead to a choice to either adopt or reject an innovation. This is followed by the implementation; the innovation is put to use or rejected. After this process, individuals seek conformation on their choices, which can lead to either reinforcement of the decision or reversing the adopt or reject decision, depending on the information received by the individual. Rogers (2003) describes an exception for some individuals under some conditions to the usual sequence of these five steps; the decisions stage can precede the persuasion stage when individuals are ordered to adopt an innovation by some authority figure.

The process of diffusion and adoption takes place in a social system. Rogers (2003 p 23) defines social systems as *"a set of interrelated units that are engaged in joint problem solving to accomplish a common goal."* The members or units of a social system may be individuals, informal groups, organizations and subsystems. The members of the social system cooperate at least to the extent of trying to solve a common problem in order to reach a mutual goal. These members can influence the decision of other members of the social system to adopt or reject an innovation. The decisions to adopt an innovation in the end determine the successfulness of the implementation of the innovation and thus the overall success of the innovation.

2.5. Configurations

Not all innovations follow the paths described in the previous theories by Tidd et al (2005), Utterback (1994) and Rogers (2003). One distinct group of innovations that are unlike the described innovations are configurational systems, as delineated by Fleck (1993). Configurational systems are described by Fleck (1993) as one of the two subgroups of systems with the other subgroup being generic systems. This distinguishing is not a fixed categorization; rather the characteristics of a system determine whether a system is more generic or more configurational. These two types of systems, their characteristics and their differences are being described in the following paragraphs to create an understanding of what a configurational system is and how these configurational systems differ from innovations following the conventional innovation paths.

Generic systems

Fleck (1993) characterizes the generic systems as systems having a generic identity, systematicity and a system dynamic. Systems with a generic identity are systems that possess a similar identity in different situations meaning the same system fulfils the same function in the same way in different settings. Voss et al (2010) add to this that generic systems are being delivered and installed as preconfigured systems in a given setting and that their function and how the system functions does not depend on the local contingencies in which the generic system is installed. This is related to the systematicity of generic systems as the systematicity represents the underlying coherence of how components are related and integrated, thus the same components are used in a similar combination, with similar relations between the components in the different situations in which the generic system is implemented. This can be retrieved to the existence of dominant designs with generic systems, based on standardized components being arranged in a standardized combination, functioning in a generalized manner. These components, their functions, their relations and the overall function of the system can change over time. This change will in the case of generic systems follow an inherent logic that strongly structures this development over time. This is referred to by Fleck (1993) as the system dynamics of generic systems.

For the generic system, system dynamics guide the development through incremental innovations as the focus of development is to improve system performance without altering the function of the system components and the operation of the system as a whole, as this is subjective to the standardization. These innovations take place in somewhat defined natural trajectories where there is a clear view of what will be the next incremental innovation based on the logics of the function of the generic system (Fleck, 1993). These incremental innovations, combined with the clear consensus on the design and function of the components, their relations and the overall function of the generic system will pave the way for the emerging of a dominant design or an off-the-shelf-product. In turn, the dominant design makes the generic systems suited for large scale implementation and thus diffusion on mass markets, following the diffusion of innovations path described by Rogers (2003). The generic systems thus follow the conventional path described before.

Configurational systems

Configurations are closely related to systems. When considering individual operating units, configurations are systems as they are a complex functioning entity. However systems can be classified in terms of the relation between the system and their constitutive components and the patterns in which they develop. In these terms, configurations can be identified as a specific subgroup of systems distinguishable from the more coherent generic systems.

Peine (2009) defines configurational systems with the characterization that configurations are systemic, specific and cumulative. Configurations are systemic as, similar to generic systems, components are assembled into systems. The components that make up the configurational system can have fixed design rules, however the configurational systems do possess the fixed design rules on how these components are assembled to build up the system like the generic systems do.

Configurations are specific as they form after local contingencies (Peine, 2009). Voss et al (2010) describe this as configurations always requiring a context in which they are deployed in order for them to even function at all. How configurational systems function as a whole and how they develop over time, arises from the requirements and needs or the exigencies of the intended application

(Fleck, 1993; Peine, 2009). The configurations depend on local contingencies, when the local settings differ, the configuration is different. And not just in the fashion of a few changed or tweaked parameters to better function in the local contingencies, rather entire components are added or left out of the configuration, their function as a whole can be different and the aim of the configuration can differ between configurations whilst they are still provided with the same system name and they are still regarded as similar systems. Configurational systems are not off-the-shelf-products, there is no one-size-fits-all system for all circumstances, rather the system has to be build up from individual components, based on how which combination of components best fits the given setting. This can lead to similar components having different roles or functioning different in configurational systems in different local contingencies. Voss et al (2010) stresses the importance of knowledge on the local contingencies in order to be able to implement and innovation. Williams et al (2005) add to this that emerging inter-operability standards support the use of configurations as different components can more easy be knit together in conjunction with customized components to meet the requirements of the particular circumstances of use, despite the lack of explicit system standards or dominant designs (Fleck, 1993). There is no clear system dynamic that guides the innovation in a specific direction or indicates how the components should integrate and work together, as this can be differ between situations. Configurations offer great opportunities for innovation at the level of the whole configuration itself, rather than only in terms of incremental innovations as the development of configuration is highly uncertain resulting from their subjectivity to local contingencies. From this it follows that configurations are cumulative as technological fields can be recognized in which several components are repeatedly configured. As they are configured repeatedly, learning takes place by which the configurations become more generic, thus shifting on the configurational-generic continuum. This characterization leads to configurations being more open to the contingencies of the application of the system compared to generic systems. A direct result from this distinction is the greater necessity for user involvement in the development of configurations (Fleck, 1993).

The innovation path of configurational systems differs from the conventional path of generic systems, models described by Tidd et al (2005), Utterback (1994) and Rogers (2003), based on the previously described characteristics of generic and configurational systems. For configurations it holds that first part of the innovation models is similar; needs and problems are detected and possible solutions in the form of new systems are identified. The difference lies in the specificity of the problems or needs, rather than one need or problem addressed by one solution, several configurations are required to meet needs or problems which are similar to each other. During the development of the innovation, the local contingencies rather than the development of standards determines the shape of the innovation and the existence of several configurations to meet the needs or solve the problems in different local settings. This also results in the absence of a dominant design or an off-the-shelf system. This has partly to do with the technology used to construct the innovation or configurations, the other part stems from the market as dominant design emerge on mass markets (Utterback, 1994) and configurations are specific for local contingencies and thus do not have a mass market as such. The total of all configurations could be recognized as a mass market, which can be an incentive to formalize and standardize configurations in order to have them develop into more generic systems to meet the heterogeneity of the markets and reform them into one mass market. However more likely are more generic configurations to be implemented in similar local contingencies rather than the development of a one-size-fits-all artefact. Finally the diffusion and adoption process does not follow the steps described by Rogers (2003). When an individual or unit of adoption gain knowledge on the innovation, the regular persuasion does not directly lead to a decision to adopt or reject the innovation as the problem, needs or specific requirements differ between the units of adoption. Rather the steps of persuasion, decision and implementation are replaced by a dynamic process. First the configurational technology must persuade the individual or unit of adoption that it can be made to fit in the local contingencies. Next the configuration is implemented and adjusted to the situation at hand. This step in which the configuration is matched to the local contingencies is more important than the other stages as the fit into local contingencies determines the functioning, usefulness and consequently the successfulness of the configuration. After this step, through learning by trying to implement the configuration, during the confirmation stage the final decision on whether to use this configuration or reverse the adoption of the configuration is made. Especially information and configuration technologies (ICT) fit the characteristic description of configurations and can therefore be considered configurational technologies (Fleck, 1993; Peine, 2009; Williams et al, 2005).

From this it follows that the value propositioning of configurations is utmost important. By determining the suitability of a given configuration in a given local setting, the value of that configuration can be determined ex ante, rather than the current learning by trying ex post method. This value then determines whether this configuration will be implemented in the given local contingencies. A procedural tool should be used to assist in this process.

3. Technology

In this chapter, the smart meter and the systems surrounding the smart meter are being introduced before providing an explanation of the smart meter systems being configurational. Subsequently an overview of the smart meter case studied in this research, the Amsterdam Smart City project in Geuzenveld, is provided.

3.1. Smart Meter

The definition of a smart meter is not a singular one (Parsons, 2007). A smart meter can be described as an energy meter which interacts with a Smart Grid to provide better insight in demand and distribution needs for utility companies (Parsons, 2007). One can also be described as an energy meter providing real-time or near real-time feedback to the occupants on their energy consumption (Parsons, 2007). A third description of a smart meter can be an energy meter which interacts with the Smart Home to provide input in the smart home system to decide what appliances to run autonomously based on interaction with the smart grid on energy demand and supply. These definitions all describe the function of a smart meter, and they are all different from each other as other components of a larger smart meter system differ from each other. The definition of the function of a smart meter thus depends on the system where it is a part of.

Besides defining a smart meter, a description of a smart meter can be provided. The description of a smart meter as used in this study is a technical description of generic features of a smart meter, based on the Smart Meter Requirements as described by KEMA (2008). This description is currently being used by the Dutch government to standardize smart meter interfaces. The document of KEMA (2008) proposes a smart electricity meter with three standardized interfaces (as shown in Figure 6): The P1 connection is the interface which can be used to provide the residents with detailed information on their energy use; P2 can be used to connect gas and water meters to the main smart meter; With P3 the smart meter can interact with the DSOs, either through the electricity lines themselves, through wireless communication as 3G networks or through broadband home networks (KEMA, 2008). Both P2 and P3 are capable of two-way communication; the P1 interface only provides a one-way flow of information from the meter to the residents. Additionally data retrieved from the smart meter by DSOs can be provided do third party firms, like energy producers, energy suppliers and other firms, through an additional P4 interface. The Dutch government is currently in the process of standardizing the interfaces (KEMA, 2008).

The smart meter itself is thus not really that smart, it can only measure energy use in more detail compared to conventional energy meters and it has the ability to communicate with external devices. The smart meter requires a larger system, such as a smart grid or a smart home, in order to be able to communicate and become smart. The other components in the smart meter system, how they are arranged, how they function and what need or problem they address thus define what the smart meter is. This is where the numerous definitions of smart meters stem from: the numerous possible combinations of components into systems addressing specific needs or problems, rather than one generic system addressing all needs and problems. The following paragraph will describe two streams of systems surrounding the smart meter: the smart grid and the smart home; this in order to display the lack of one off-the-shelf smart meter system.

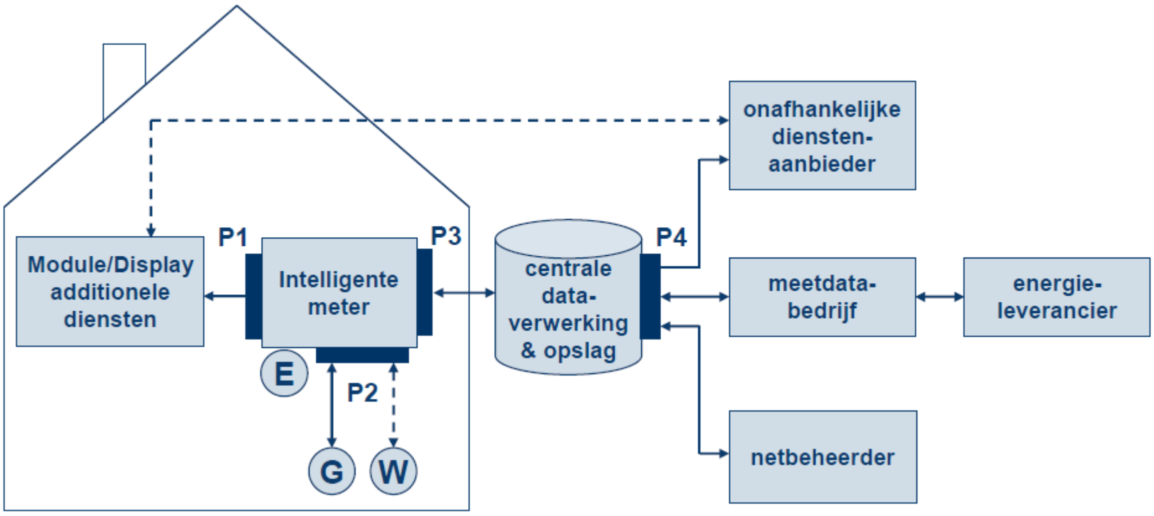


Figure 6, Smart meter interfaces (KEMA, 2010).

3.2. Smart Grid

The term smart grid is an umbrella term for energy networks that use communication technologies to operate more intelligent than conventional energy grids. This ranges from energy networks where only the final energy consumption is measured remotely to networks where supply and demand of energy is managed fully autonomous. The addition of communication technologies enables the grid operators to improve the efficiency, reliability and safety of power delivery and use (Beard, 2010). Figure 7 provides insight in the basic structure of the electric system, showing the possibility of communication between the parts of the smart grid and the actors involved namely energy producers, very high voltage transmission system operators (TSOs), medium and high voltage distribution system operators (DSOs) and the low voltage home of the final consumers. The addition of two-way communication between components, advanced sensors, and distributed computers can assist the system operators to better manage their network. There are many combinations of components available to address needs and problems in the different situations. A more conventional energy network where energy is produced in centralized locations and is distributed to end users over transmission and distribution lines requires different components to measure energy flows, energy supply and energy use compared to a situation where electricity is also produced decentralized, i.e. by end users. Local settings thus determine which combination of components is best suited to fulfil a specific function of the smart grid. As there are numerous functions the smart grid can fulfil and also many different local settings, both in technical terms, as well as in economic, legal and social contexts. The possibilities are so numerous that almost every project concerning smart grids uses different components in also a different composition. With the differences between the smart grids, the function of the smart meter also differences between smart grid projects. Thus concerning the grid-side of smart meters the function of the smart meter depends on the settings in which the smart grid is placed.

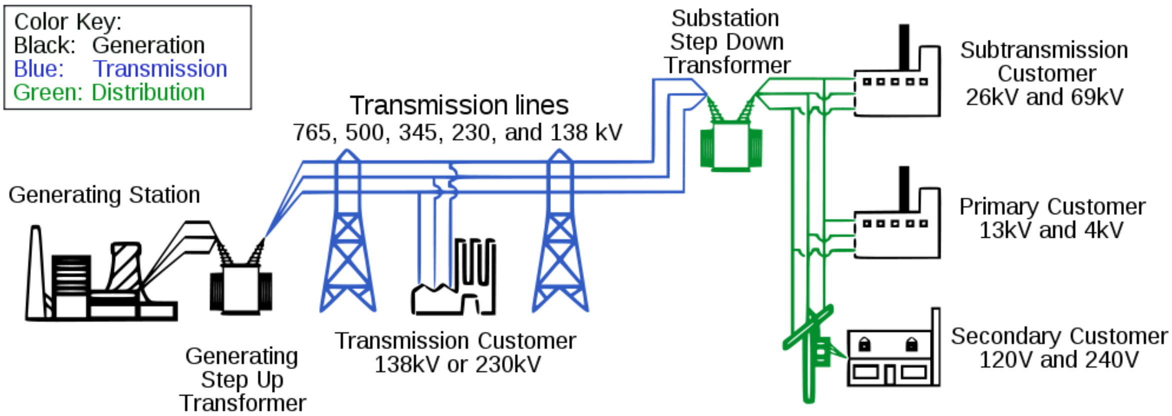


Figure 7, Basic structure of the electric system (USDoE, 2004).

3.3. Smart Home

On the other side of the smart meter, the systems of a smart home are being developed. A smart home is a home in which systems (appliances, lighting, heating, air-conditioning, and so on) are connected and remotely controlled to save energy and improve comfort, safety, and convenience for the occupants (Beard, 2010). A more general description is the one provided by Peine (2009, p. 398): *"… using ICT in the home to facilitate interoperability of household products and services."* Some smart home systems are not very complex, for example an in home energy use display connected to plug-in power meters (meters that measure the energy used for each socket). Others are more complex and autonomously control several devices. Most of these systems do not make use of a smart meter yet to measure energy use or as a variable to determine which appliances to control. An exception to this is the Smart Appliance system of LG (LG, 2011). This system will be able to use information on energy consumption and energy pricing from a smart meter to determine which appliances to run. When the energy price rises, only appliances which will be turned on. When energy prices drop due to reduced overall energy demands by all consumers, the appliances with a lower priority are also turned on by the system. Also this system will run diagnostics on the system components to solve problems directly or to inform customer service with detailed information on the problem, making it easier and faster to solve the problem. The consumer will in all cases be able to control all devices and monitor the energy use through mobile devices like mobile phones or a tablet pc (LG, 2011). Such autonomous systems should lead to a reduction of energy use, peak shaving and reduced costs for customer service and repairs. The autonomous systems are the type of smart home that will be referred to as smart home with energy management system (EMS) in this study. An overview of smart home functions related to smart meters is provided by Xcell Energy (2008) in Figure 8.

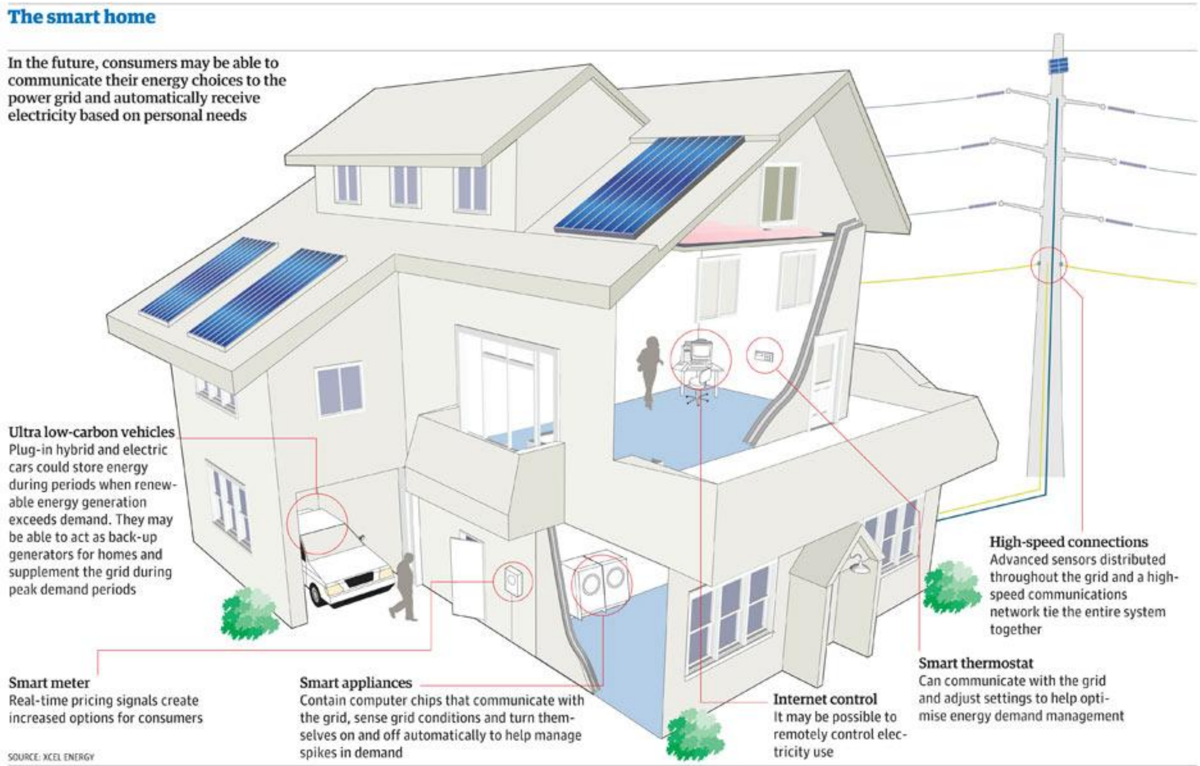


Figure 8, Basic smart home functionality (Xcel Energy, 2008).

3.4. Configurational Nature of Smart Meter Systems

Determine whether the smart meter systems are more configurational or more generic according to the definitions of Fleck (1993) can be done by reviewing the previous technology paragraphs and comparing them with the characteristics of generic and configurational systems described in the theory chapter.

Several aspects of smart meters contribute to the notion of smart meter systems being configurational systems. There are currently no standardized smart meter systems. The smart meter itself is being standardized to reduce implementation barriers in different configurations. At this moment no mass market for smart meter systems; Dam et al (2010) explain this as there is no one-size-fits-all configuration for smart meter systems, rather the actors responsible for the energy infrastructure experiment with smart meter systems on a learning-by-trying base in trials.

This leads to many combinations of smart meters and additional systems being configured in different trials (Faruqui & Sergici, 2010; Dam et al, 2010; Darby, 2010; ASC, 2011). An overview of several projects is provided in the appendix. Between these trials there are differences in the issues addressed by the smart meter systems. In some cases the smart meter system is used by DSOs to remotely measure energy use by residents in order to comply with new legislation. In other projects, the smart meter system is being used to manage energy supply and consumption autonomous. The components composing the smart meter system, as well as the composition of the components differ between the trials addressing different issues. This contributes to the argument of smart meter systems being configurational systems.

When considering one configuration: a smart energy meter with an energy feedback display, or power cost monitor, the energy savings of the participants in the projects vary between 0% and 6,7%. This stipulates to significant importance of local contingencies in determining the effect of a specific configuration, thus stipulating to the configurational nature of smart meter systems.

Also the smart meter systems are characterized by the lack of a generic diffusion process as there is no dominant design or off-the-shelf system. This results into a lack of momentum and support caused by lack of alignment between actors involved in smart meter development. As costs and benefits are distributed unevenly over the actors, some will strongly support and push the implementation of specific configurations as they will strongly benefit from this, while other actors will lack support as they will indulge huge cost to facilitate such systems. Combined with the uncertainty of the effect of smart meter systems in different local contingencies, this leads to lack of momentum to implement smart meter configurations on a larger scale. More insight in the fit of specific smart meter configurations in specific local settings, as well as more insights in the effects of these systems and how these effects are distributed over the actors involved could potentially align the actors.

In general, the implementation of configurational systems is more complex compared to the diffusion of generic systems. The generic systems have an off-the-shelf system which is ready to be implemented in numerous different situations. This dominant design ensures the presence of a generic revenue mechanism. This simplifies the decision made by the actors involved to either implement the generic system or not as the system which will be used in a particular situation is known, the function of the system is known, the components, their composition and their functions are known and the revenue mechanisms are known. This while with configurational technology, for a particular situation the system has to be determined, the function of the system has to be determined, the components, their composition and their functions have to be determined and the revenue mechanisms are unknown. The local contingencies determine which configuration is best suited to be implemented in a given situation. The most important question concerning the implementation of configurational systems in new situations is thus how to assess and manage the fit of configurations in local contingencies? This methodology can be used to determine the fit of a configuration of a smart meter system to be implemented in a local setting, providing input in the decision making process of actors involved in the implementation of smart meter systems, which in turn can create momentum to implement smart meters on a larger scale.

The next chapter will discuss which methodology is best suited to assess and manage the fit of configurations in local contingencies. This methodology will be used to assess the fit of a smart meter system in one smart meter project in Amsterdam and to provide guidance to align the actors in that project. This project will be introduced into more detail in the next paragraph.

3.5. The Amsterdam Smart City Case Geuzenveld

In Amsterdam, DSO Liander and the municipality of Amsterdam have performed a project to test several technologies and methods to reduce energy consumption in cities. The aim of this project called Amsterdam Smart City was to show how it is possible to save energy now and in the future (ASC, 2011). For this matter, sixteen small scale projects were launched in four areas: living, working, mobility and public space. Each small scale project had their aim, their actors and their technology. Three projects in the living division used some sort of smart meter configuration. These projects are:

Geuzenveld, West Orange and eManagement Haarlem. These projects will be shortly described next.

The smart meter configuration in Geuzenveld contained the smart meter and smart meter infrastructure in the Geuzenveld neighbourhood for 541 households with the addition of an energy feedback display for 60 of these households. In addition to these technologies, a user participation program enabled neighbours to interact with each other by discussing sustainability topics. The eManagement project in Haarlem also involved smart meters; however the configuration in this project did not contain an energy feedback display, but an energy management system through which appliances could be controlled autonomous through time schedules or via remote control. The West Orange project used a combination of both configurations with an energy feedback display and remote control of the thermostat and other appliances.

To research the value of configurations, of these three projects the Geuzenveld project has been chosen to study the effects of this smart meter configuration into detail as this project had the clearest structure of the actors involved. Also the aim of this project was more focussed on the effects of the implemented technology rather than testing the technological feasibility of the technology itself.

4. Methodology

In this chapter the value case methodology will be described. From this methodology, the actual method used in this study will be derived.

4.1. Methodology on Configurations

A methodology on the fit of configurations must meet a number of criteria in order to be an effective tool. As configurations concern complex systems, multiple actors will be involved in throughout the innovation process, causing potential alignment problems between the actors. In order for any methodology to solve such and other problems hampering the implementation of an innovation, the methodology must be able to handle a multiple-actor situation. The methodology must incorporate the points of view of the separate actors, include the impact the actors generate and the impact the innovation has on the separate actors. These impacts must also be aggregated to provide an overview of the overall impact, and thus the desirability, of a configuration. The impacts or effects of the configuration can include financial or quantified costs and benefits, but also non-financial or qualitative effects. The methodology must incorporate both quantitative and qualitative effects in order to provide a complete overview of the impact of an innovation on the actors. Also as the configurational innovation concerns complex systems, the methodology have a broad scope on effects throughout the system, rather than limiting the incorporated effects to the innovation itself. This should again provide more insight in the effect of the configuration on the actors involved. Also this could lead to identifying more actors involved in the innovation, which could influence the support for a configuration. Due to the complexity of the requirements of the methodology, the methodology should be multi-disciplinary, this to ensure the broadest and most open view of the configuration, the system and the effects. And finally, as the aim of the tool is to contribute to decision making processes concerning the implementation of specific configurations, the methodology must provide an outcome which can be used to base decisions upon. This looks trivial; however it is an important aspect of methodology which concerns both quantitative and qualitative data. In several cases the qualitative effects must be quantified in order to be taken into account in the decision making process of actors. Therefore the option to quantify qualitative affects must be part of the methodology.

Several methodologies are able to reduce the uncertainty of the implementation of an innovation ex ante, such as social cost benefit analysis (SCBA), business case and social return on investment (SROI). Social cost benefits analysis methodology as described by Newberry and Pollit (1997) *"would involve carefully identifying who gained, who lost, by how much, and at what social value, comparing the historical and predicted future evolution"*. This is in line with the required methodology for configurational technology as the impact on multiple actors is being analysed. SCBA provides an overview of both financial and non-financial effects. The outcome of the SCBA however focuses on monetized values. This requires the monetization of non-financial effects using one of the following four methods (Boer & Larsen, 2010):

- Revealed preference: Monetizing value using prices observed on a (derivative) market.
- Stated preference: Monetizing value using surveys on what people state they are prepared to spend on a matter.
- Avoidance cost: Monetizing value using the amount of money required to avoid an effect.
- Key figures: Monetizing value using standardized figures from earlier studies on similar

matters.

If effects are not monetized, they are still mentioned in the outcome, but the focus lies with the monetized effects: the qualitative effects do not play a part in the assessment of the outcome, contrasting to what is required for a methodology on configurational technology.

Another methodology is the business case. With a business case, the efficiency of invested resources to support a specific business need is being evaluated. This methodology also looks at the effects of an innovation, calculating what the impact will be on a specific actor. Performing a number of business cases for the separate actors should provide a full overview of the impact of an innovation. As with SCBA, a business case should provide an overview of both quantitative and qualitative effects. However as the business case methodology has a strong focus on financial effects for businesses, the qualitative effects which currently cannot be monetized by firms are not taken into account in the assessment. Therefore also this methodology does not match the needs in this case.

The third methodology is the social return on investment (SROI) methodology. This methodology *"captures the economic value of social benefits by translating social objectives into financial measures of benefit"* (Wright et al, 2009 p463). By comparing this economic value of social benefits with the financial investments made by an actor, their social return on investment is calculated. This methodology focuses on the social effects of an intervention, however also economic, environmental and financial value is included in the analysis (Wright et al, 2009). The outcome of an SROI analysis should not be restricted to one number, but provide insight in the social impact of an intervention, in which monetization plays *"an important but not an exclusive role"* (Wright et al, 2009 p463). The limitation of this methodology is that it is aimed at providing information to stakeholders on the returns of their investment, rather than providing an overview of costs and benefits for all the actors involved. As such, the SROI methodology does not provide the full overview of the impact of an innovation to solve alignment problems between actors.

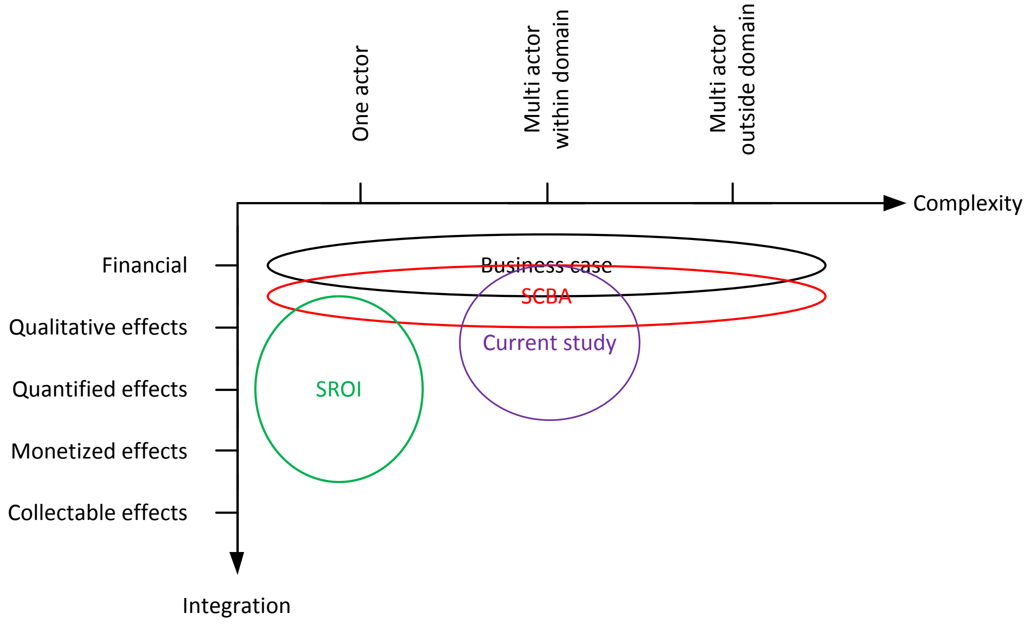


Figure 9, Methodology positioning and current study positioning.

As described in the section above, none of the mentioned methodologies fully meets the demanded characteristics by configurational technology value determination. These methods are suited for generic systems following conventional innovation paths, but they do not match with the specificity required for configurational systems. Figure 9 provides an overview of the relative positioning of the methodologies described above, the gap they leave in the spectrum and the type of methodology required for this study. Several aspects of the separate methodologies do provide guidance for a methodology which does meet all the requirements. Therefore a new methodology is proposed in the next paragraphs with features from the previously described methodologies.

4.2. Existing Components for Value Case Methodology

To meet the requirements of a methodology capable of assessing configurational systems, the value case methodology of Hoorik and Bomhof (2010) can be combined with several components of the previously described methodologies, to form a basis for an extended value case methodology to deal with the unique characteristics of the implementation of configurational technology.

The value case methodology proposed by Hoorik and Bomhof (2010) is a tool used to determine the value of an intervention by assessing the value of the effects caused by the intervention beyond a normal business case. The scope of a value case is broadened through the inclusion of not only financial effects of an innovation, but also the impact of an innovation on people and the environment. This is based on the principle of the triple bottom line of Elkington (1997) which states that the impact on people, planet and profit dimensions should be assessed. Hoorik and Bomhof (2010) combine the triple bottom line with a categorization of effects based on their relatedness to the intervention. Their categorization contains the categories direct effects, indirect effects and system effects. By implementing an intervention, direct effects are caused by the existence and use of the intervention. For example the development and of the intervention requires resources. Indirect effects are the effects caused by the impact of the usage of the intervention on its environment. For example the intervention influences the system output quality or peoples comfort. System effects are the less related and behavioural effects, such as rebound effects or dematerialisation. These direct, indirect and system types of effects are combined with the triple bottom line to create the framework as presented in Figure 10.

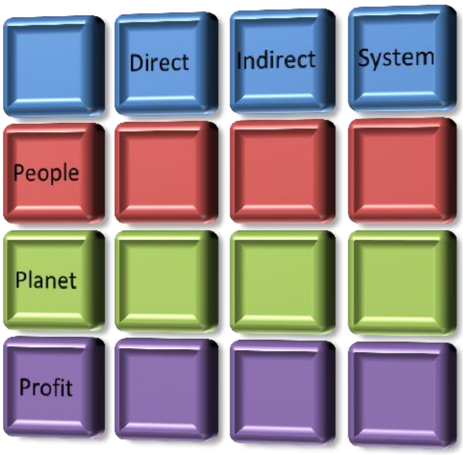
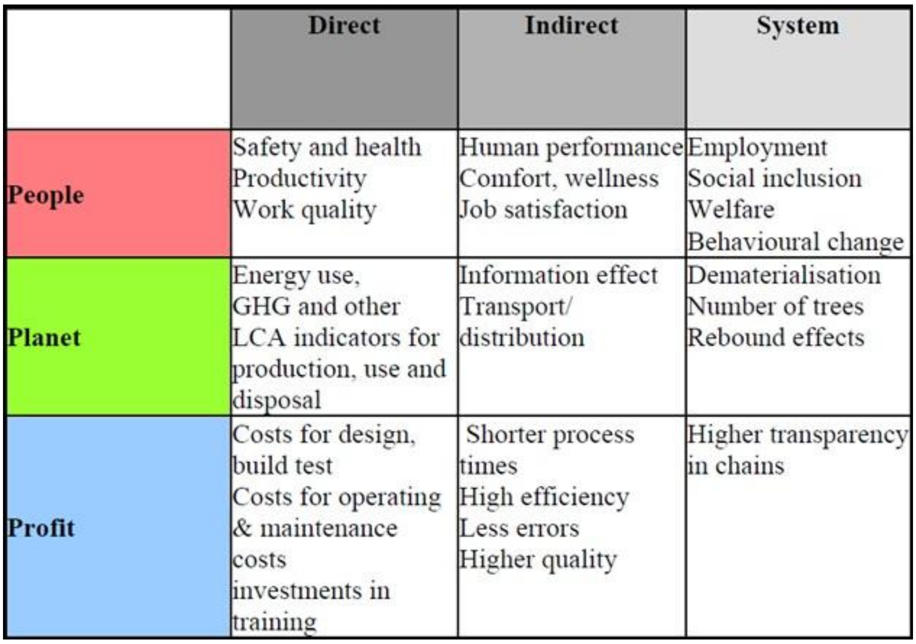


Figure 10, People, planet, profit vs. direct, indirect, system (Hoorik & Bomhof, 2010).

Hoorik and Bomhof (2010) use this framework to draft effect categories in order to be able to categorize qualitative effects in their e-invoice case, as displayed in Figure 11. The framework is thus used to create an overview of both quantitative and qualitative effects of one actor on people, planet and profit dimensions. However if this framework is combined with quantification and monetization methods of the SROI methodology, as described in the previous paragraph, the framework no longer only provides an overview of effects. The combination of these methodologies can provide an actor with the opportunity to create more revenue mechanisms, or new business models, from an intervention; thus leading to a more positive outcome of the case for that actor. Also the value case methodology described by Hoorik and Bomhof (2010) is aimed at finding the effects of one actor. By combining the value case methodology with multi-actor methodologies such as the SCBA methodology described in the previous paragraph, the value case methodology could be used in multi-actor situations. The aggregation of these methodologies into an extended value case methodology as well as a detailed overview of this value case methodology is described in the next paragraph.



	Direct	**Indirect**	**System**
People	Safety and health Productivity Work quality	Human performance Comfort, wellness Job satisfaction	Employment Social inclusion Welfare Behavioural change
Planet	Energy use, GHG and other LCA indicators for production, use and disposal	Information effect Transport/ distribution	Dematerialisation Number of trees Rebound effects
Profit	Costs for design, build test Costs for operating & maintenance costs investments in training	Shorter process times High efficiency Less errors Higher quality	Higher transparency in chains

Figure 11, Effect categories of e-invoice case (Hoorik & Bomhof, 2010).

4.3. Aggregation to Value Case Methodology

The first part of the value case methodology is very generic. Most effect study methodologies use the same build up from determining the research object, configuration, or intervention as it will be referred to in this methodology, to the point where effects are being identified. The second part is where methodologies differ as different effects are incorporated in the research and these effects are handled differently.

First the research object must be determined. This intervention can be a new technology, a new component, new legislation or another change which alters an action or development (Heritage, 2009). When the research object, or intervention is determined, the boundaries of the system or the group or combination of interrelated, interdependent, or interacting elements which form a collective entity; a methodical or coordinated assemblage of parts, facts, concepts etcetera (Collins,

2009) must be determined. This identifying of the system is an important step as a different system boundary will result in a different value of the intervention. For example, limiting the system surrounding the smart meter to the smart grid will automatically exclude the value a smart meter will enable in smart homes. On the other hand, a too broad system boundary will include a number of effects which is too many to process as shown in the design tree in Figure 13. System boundaries are also debatable; therefore the choice of boundaries must well argued. When the system is identified, the actors who are related to the system can be identified. This includes actors who produce or control components of the system, as well as actors who use the system, for example users of the final product or service. These actors all have activities in relation to the system prior to, during and after the implementation of the intervention. Some activities might be discontinued as a result of the intervention, some might be changed and some activities might be new. These activities can be identified and listed. From these changed activities, the effects resulting from the intervention can be identified.

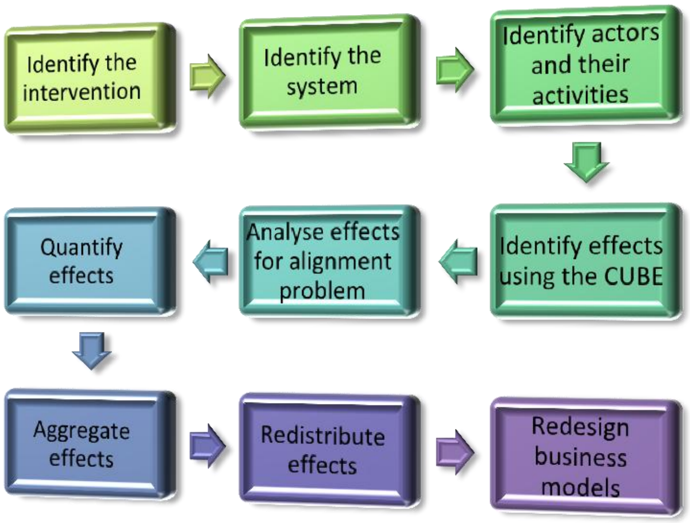


Figure 12, Value Case Methodology Roadmap.

A specific framework is used to identify, or generate, the effects of information and communication systems (ICT's). The foundation of this framework was laid by Hoorik and Bomhof (2010), using three types of effects; direct, indirect and system effects and combining them with the triple bottom line of Elkington (1997), as described in the previous paragraph. This creates the framework as presented in Figure 10.

The triple bottom line of Elkington (1997) demands a broader view of the effect a business has, extending the scope of impact analysis beyond the profit dimension, including people and planet dimensions. The profit dimension concerns the financial effects of an innovation; how much money is required to implement an innovation, how much money is made on the implementation of the innovation and by whom. The people dimension concerns the effect of an innovation on people. The global reporting initiative (GRI) provides subdivisions of people effects to help define what these effects are. These subdivisions are: Labour practices and decent work; Human rights; Society and customers; Ethical behaviour (GRI, 2011). Thus effects that can be allocated to these categories are considered people effects. The planet dimension concerns environmental effects of an innovation. Again the sustainability reporting guidelines of the GRI (2011) provides a subdivision which aids in determining what should be taken into consideration with the planet dimension. The categories are: Materials; Energy; Water; Biodiversity; Emissions, effluents and waste (GRI, 2011). Thus effects that can be allocated to these categories are considered planet effects.

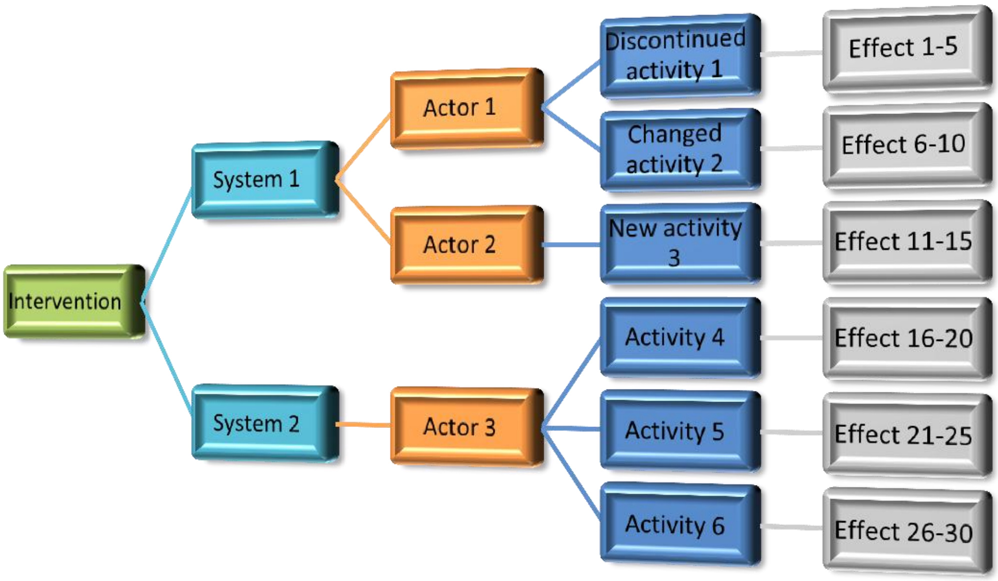


Figure 13, Design tree from intervention to effects.

The application of this framework will lead to identifying many effects. Several effects will be observed on the short term, while others will be induced or become apparent on the long term. This division of effects in terms of time is not included in the current framework. Adding this dimension to the model would emphasize the importance of identifying both short term as well as long term effects, as stipulated for the case at hand by Dam et al. (2010). This additional dimension would convert the table in Figure 10 to the DiCE in Figure 14.

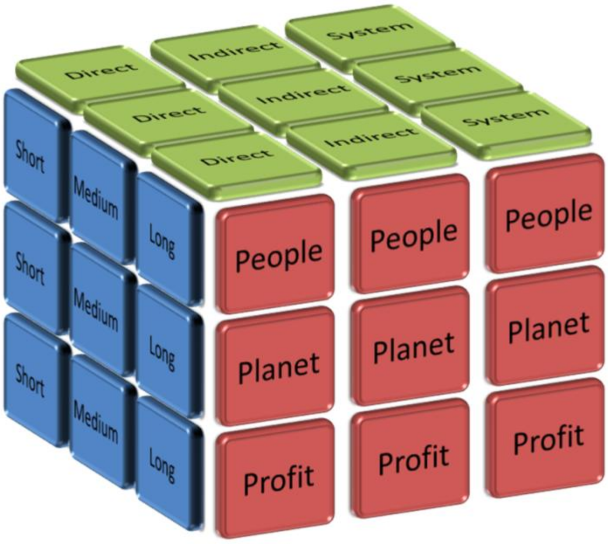


Figure 14, The Dimensions Cube of Effects (DiCE).

This DiCE can be used in many methods to identify the effects. Examples are interviews with actors where the DiCE can assist to broaden the view of the interviewee. This will result in more effects being identified by actors and therefore by the research. Also the DiCE framework can be used by researchers to draft effect categories which in turn can be used in again for example interviews with actors to steer them to relevant effects.

Once the long list of effects is formed, the effects can be analysed. First a summation of quantitative effects can be conducted on actor level to identify any alignment problems if present. In the case of an alignment problem, there is a problem with the integration or harmonization of aims, practices etcetera within a group of actors (Collins, 2009). For example one or more actors have no incentive to invest in an intervention while the intervention overall will be beneficial, for example for society. Or different actors have incentives to pursuit different interventions. This can lead to a suboptimal outcome of the interventions.

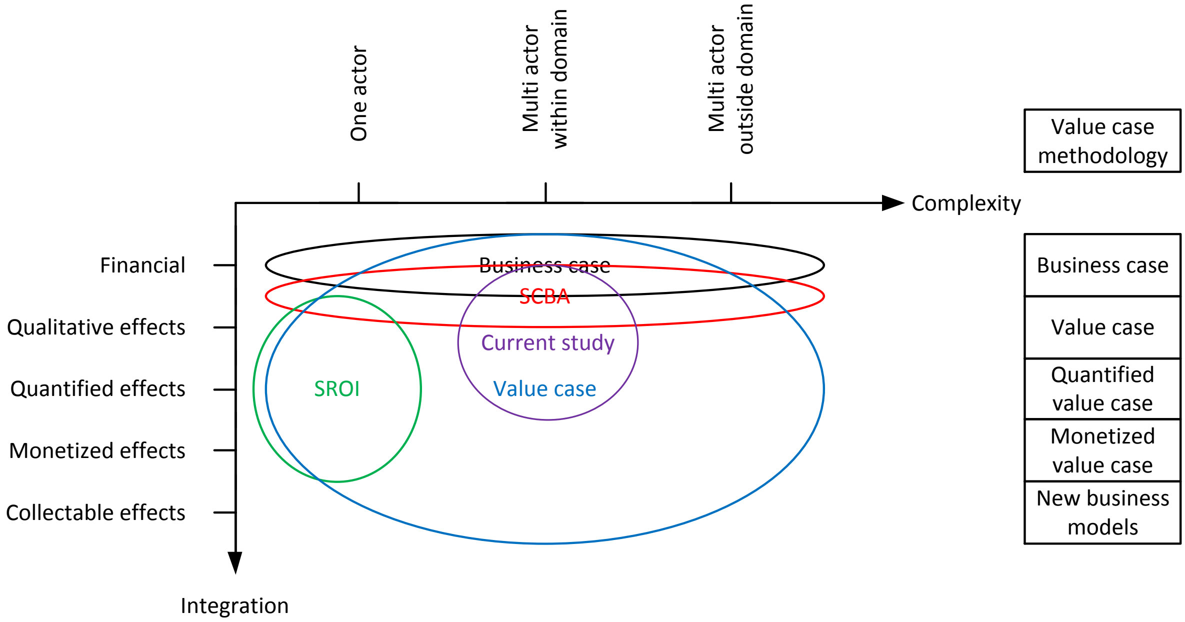


Figure 15, Value case methodology positioning and current study positioning.

If there is an alignment problem present based on the outcome of the analysis of the quantitative effects, the qualitative effects become involved to harmonize the aims of the actors towards the most desirable outcome. This can be in a simple form: as qualitative mitigating effects which align the actors to a harmonized aim. Or in a more complex form: as quantified interchangeable or at least comparable effects. For the simple form the qualitative effects need to be presented in a form which supports the decidability of the results. This presentation form depends on the effects at hand. When the actors are not aligned by the qualitative effects as such, effects have to be quantified. After using an appropriate quantification method for the effect at hand, the now quantitative effects can be aggregated with the other quantitative effects. This will provide the overall value of the intervention as determined by a value case. A part of this value is already distributed over the actors what resulted in the alignment problem. The remainder of this value, the value added by the qualitative effects, can be redistributed over the actors to align them. As the value stems from qualitative sources, current business models are likely to be unable to incorporate this value. Thus the current business models have to be redesigned or new business models have to be created in order to capture this added value, which is currently a public value.

This process results in a presentation of the effects on actor level, providing them insights in what the value of the intervention will be for them, where that value lies and how they are able to capture this value, thus providing the actors with incentives to harmonize their aim to the most desirable outcome. This most desirable outcome can be one specific configuration; several coexisting configurations, for example for several situations; or not implementing any of the proposed configurations as not enough value is generated by the configuration. The process of steps to reach alignment between actors is described in the value case process cycle in Figure 16. After each step in the cycle, the actors can review the outcome and determine their alignment. When alignment is reached between actors, they can act on their alignment; otherwise the next step can be taken to reach the alignment. When no alignment is reached after the last step, the actors supporting the configurational innovation should either revise the product or abandon the product and pursuit another development, which in turn can be taken through the process cycle. The position of this value case methodology compared to earlier described methodologies is presented in Figure 15.

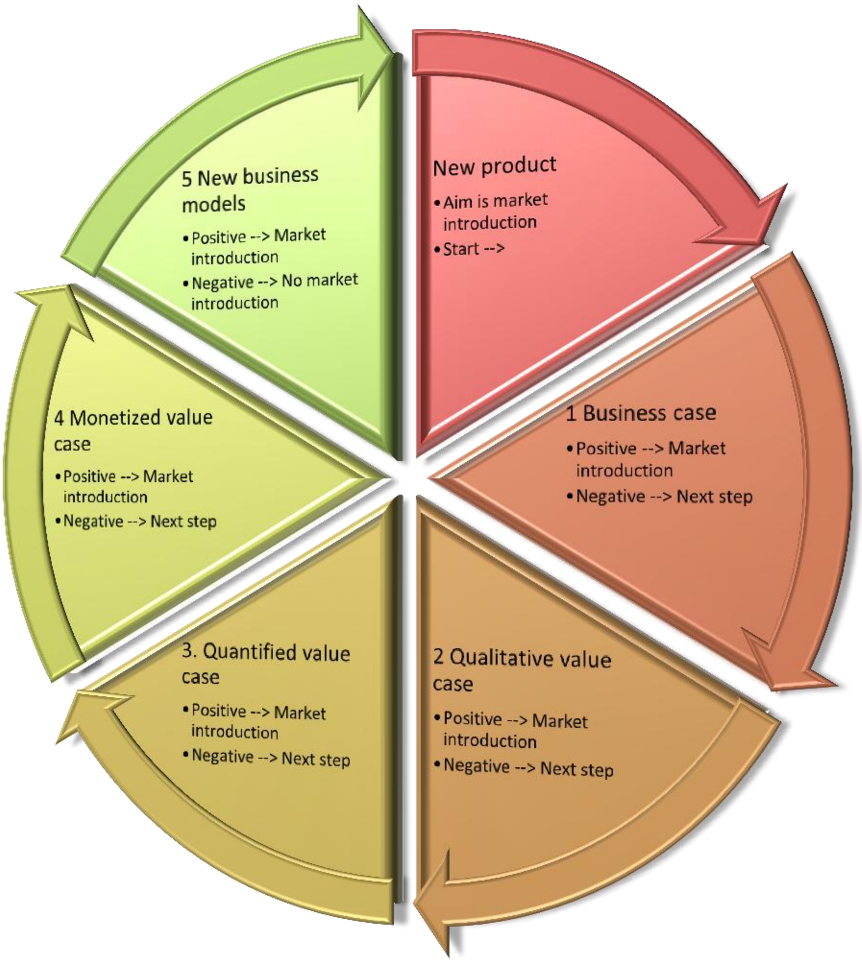


Figure 16, Value case process cycle, what the next step is if the previous yields negative results.

4.4. Method

The methodology described above is tested in the Amsterdam Smart City project of Geuzenveld to determine the fit of the smart meter configuration of a smart meter with an energy feedback display in the local contingencies of the Geuzenveld neighbourhood. During the process of executing the methodology, a number of choices had to be made. These choices are described and explained in this paragraph.

First of all the case has been selected from a number of possible cases to investigate in the Amsterdam Smart City project. This selection was based on both functional as well as practical arguments. The functional argument is that this case provides a more clear structure of the actors. It is clear what the roles of the actors are and which actors are directly and indirectly involved in this project. This is also the first practical argument as the new methodology might be tested first in a more simplistic rather than a more complex situation. Furthermore configuration used in this particular case has been subject of earlier trials, as shown in the list of earlier trials in the appendix. This led to the functional argument of the case being more focussed on the effect of the configuration rather than the technological feasibility, as similar technology had already been used in earlier trials. This also holds the practical argument that less technological setbacks are expected to occur during this trial.

After the selection of the case, a literature study was performed to provide background knowledge on which actors are usually involved in such a trial and what the outcome of these trials are. For this literature study, several online sources were used to find articles describing comparable cases. The outcome of this search is the list of trials in the appendix. The effects of the earlier trials were later used in the interaction with the actors of the project in Geuzenveld.

The actors actively involved in the Geuzenveld project were interviewed to retrieve the effects of the smart meter configuration used in the project. Two types of interaction methods were used: a group workshop and individual interviews. During the interactive group workshop, the actors in the project were asked to describe the roles of the actors in the project and how they are related to each other and to implementation of the smart meter configuration. Also they were asked to describe the activities of the actors in relation to the project and the smart meter configuration. Besides the actors involved in the project, there are more actors who play a role in or who are affected by smart meter implementation. This ranges from the company responsible for mining the raw materials required for smart meter production up to society as a whole. In this case a selection is made for the most important actors based on effects identified through the interviews with project partners. The selection of actors does not signify the unimportance of other actors or mean that other actors are not affect by smart meters. Only in this study they were ranked with less importance compared to the actors included in the study based on the information gathered in this study.

The group session was followed by individual interviews at a later stage of this study. Three rounds of interviews were conducted. The first round was used to verify the role of the actor, their relation with the project and the smart meter and the activities mentioned in the group workshop. Also the interviewees were asked what the effects of these activities would be. At first the interviewees were not guided in their search for effects. Later in the interview, the DiCE from Figure 14, the effect categories of the e-invoice case from Figure 11 and an overview of effects mentioned in the literature from the literature study were presented to the interviewees to stimulate them to find more effects. Also actors who were interviewed later were asked to review the effects mentioned by the earlier interviewees. During the second round of interviews, the actors were asked to respond to the list of effects compiled from the literature study and the first round of interviews. This was all done in order to create the most accurate and complete list of effects.

Besides the qualitative data gathered through the interviews, the case also yielded quantitative information in terms of financial data and energy consumption data. The energy usage data has been statistically researched to determine both the overall outcome of the data on energy consumption as well as the significance of this outcome. The data made available to this research concerned the overall energy consumption in terms of natural gas and electricity of 32 households over 2010 as well as the detailed daily energy consumption of these households over the first 6 months of 2011. From both time periods, the average daily energy consumption has been derived and compared using a paired sample test. Even though this test does not provide much information, it is best suited to compare the paired consumption statistics per household and determine whether the average daily energy consumption in 2010 differs from the average daily consumption per household in the first six months of 2011 based on the available data. The outcomes of the used method are described in the following chapter.

5. Results

In this chapter the results of the used method are presented. This includes the findings of first steps of the methodology in detail as well as an overview of the redistribution over actors of the effects for the smart meter project in Geuzenveld. As the results of the project in Haarlem were remarkably similar to the results of the project in Geuzenveld, only a short overview of the additional or different effects of the project in Haarlem is provided subsequently.

5.1. Actors

An inventory of the partners actively involved in the smart meter project in Geuzenveld provides the overview of actor roles and the specific partners in the project in Table 2.

Table 2, Actors in Geuzenveld project.

Actors in project	
Project management [i]	Amsterdam Smart City
DSO	Liander
Government	Municipality of Amsterdam
Activation group	Favela Fabric
Housing corporation	Far West (De Key)
Meter and display installer	BAM Infra
Residents	Residents of Geuzenveld

i. Project management is a separate actor in the Geuzenveld project, however in general this actor is a part of the DSOs which are responsible for smart meter implementation.

Besides the actors involved in the project, there are more actors who play a role in or who are affected by smart meter implementation. They are listed in Table 3. In this research, the effects perceived to be most important, did affect the actors in Table 2 and Table 3. Therefore these actors were used in the remainder of this analysis.

Table 3, Additional actors.

Additional actors, not in project
Energy producers
Energy suppliers
Society

5.2. Activities

The next step is to identify the changed activities per actor. From interviews with the actors in Amsterdam Smart City in Geuzenveld, a list of changed activities is compiled. This list is provided in the appendix. The activities differ per actor as also their role in the implementation of smart meters differs. The DSO for example is responsible for the preservation of the energy grid, thus their activities include the maintenance and balancing of the grid. The DSO is also responsible for measuring the energy consumption. Therefore the activities of the DSO include energy usage data gathering as well as storage of that data. And as the DSO is responsible for the implementation of smart meters, the activities of project management are also listed under the DSO. This includes, among other activities; stakeholder management and being present at public meetings. The government has limited involvement in this project. The main activities of the government are enabling the implementation of the smart meters and enabling smart energy services. During the project an activation group was involved to educate residents on the functionality of the smart meter as well as providing them means with which they could reduce their energy consumption in combination with the smart meter. The activities of the activation group therefore include the provision of means to reduce energy consumption with gifts and tokens, creating energy awareness and community building. The housing corporation was responsible for determining which houses were used in the project as well as the communication with residents. The latter activity was chosen by the project members as the brand of the housing corporation was most respected by residents. In the future the housing corporation can choose to implement smart home functionality based on the smart meter to gain additional benefits from the system. Therefore the activities of the housing corporation include communication with residents, making houses available for the project and implementing smart home features. The metering and display installers are responsible for installing the smart meters in the households as well as upgrading the grid, both as commissioned by the DSO. The residents are different in this project as they do not have specific responsibilities with respect to the implementation of smart meters. However they do have activities that can change as a result of the smart meter such as their normal habits which cause energy consumption. Also the residents can participate in the activation sessions.

The additional actors also have changed activities. The energy producer for example currently produce energy based on estimations of the energy demand. These estimates can be based on more accurate consumption data as a result of the smart meter. Therefore the energy production can change. The energy supplier buys the energy produced by energy producers and sells this to residents. Again as a result of more accurate usage data, the energy supplier can more accurately buy the required energy. Also the smart meter enables different pricing schemes. Furthermore the energy suppliers can use the detailed consumption data to provide the residents with bills based on accurate, current consumption. The activities derived from this can thus change.

5.3. Quantitative Effects

From these changed activities, the actual effects of the smart meter can be identified; starting with the quantitative effects. The qualitative effects will be presented in the next paragraph. First the savings data from the Geuzenveld project will be analysed. Following this, the effects will be displayed per dimension of people, planet and profit.

Data analysis of the Geuzenveld Project

The data of the Geuzenveld project concerned a database with 32 addresses and their overall energy consumption over 2010 and detailed daily energy consumption figures over the first six months of 2011. Both data on the natural gas consumption as well as the electricity consumption were provided. From this data, the graphs in Figure 17 and Figure 18 were compiled, showing the daily energy consumption of all 32 households in the first six months of 2011.

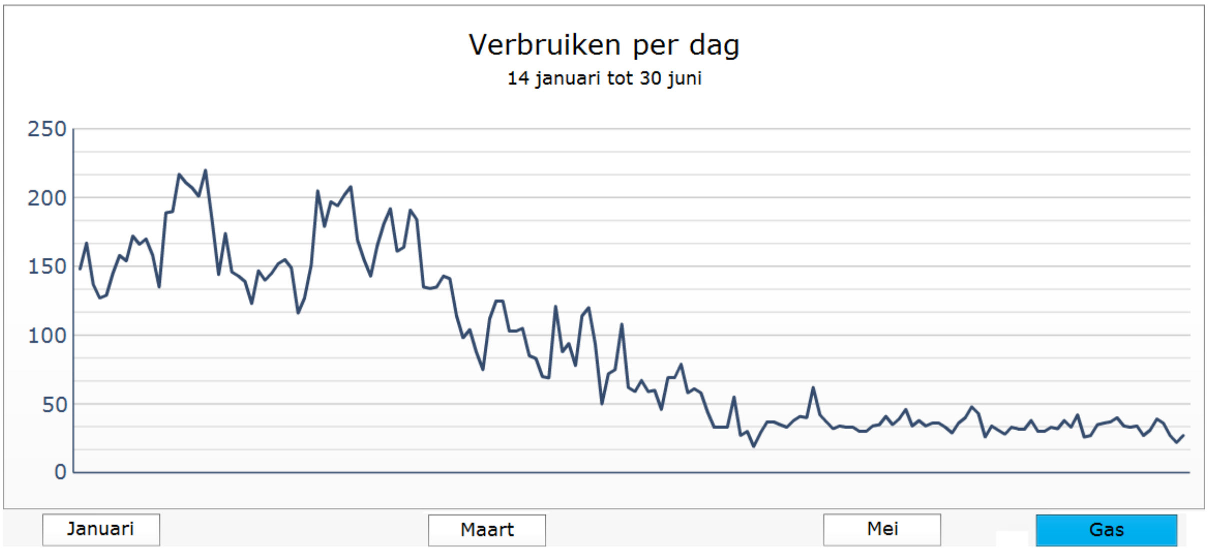


Figure 17, Aggregated gas consumption Geuzenveld over 2011.

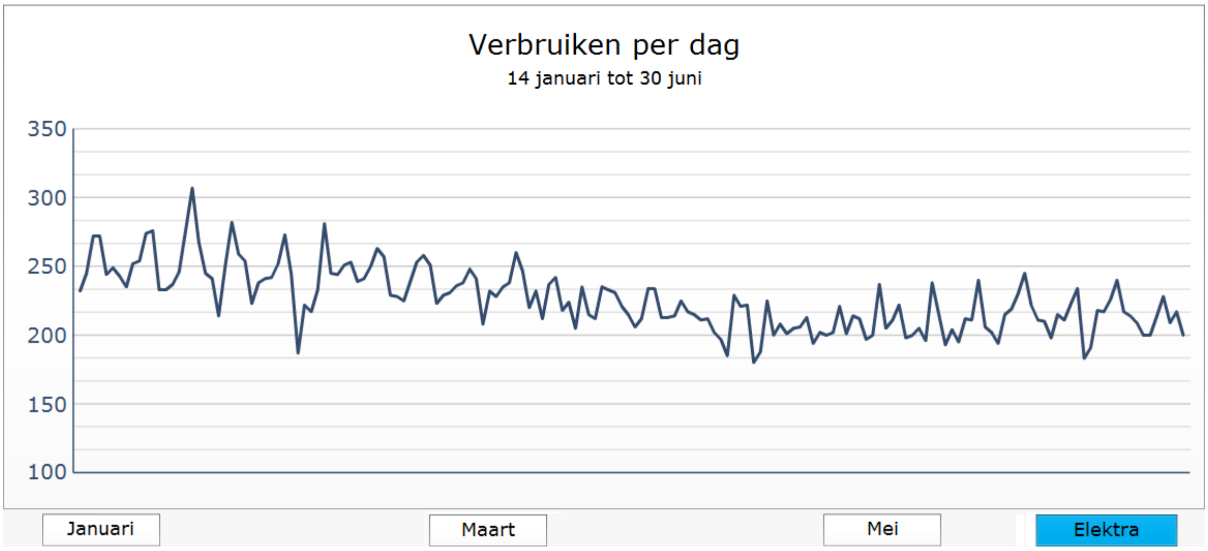


Figure 18, Aggregated electricity consumption Geuzenveld over 2011.

Both graphs show a decline in energy consumption of the households over the trial period. However in order to be able to accredit the reduction in energy consumption to the smart meter configuration, first the seasonal influence must be eliminated. As winters are cold and summers warm, space heating increases natural gas consumption during the winter. Also people spend more time indoors as a result of both the lower temperatures and the shorter periods of daylight; resulting in slightly increased electricity consumption during winters. To find whether the reduction in energy consumption must be accredited to seasonal influence or the smart meter configuration, the energy consumption is compared to the 2010 average consumption for both the participants of the project as well as for the Netherlands in general, based on information of the CBS (2011a). The relative daily electricity consumption of 2011 is shown in Figure 19.

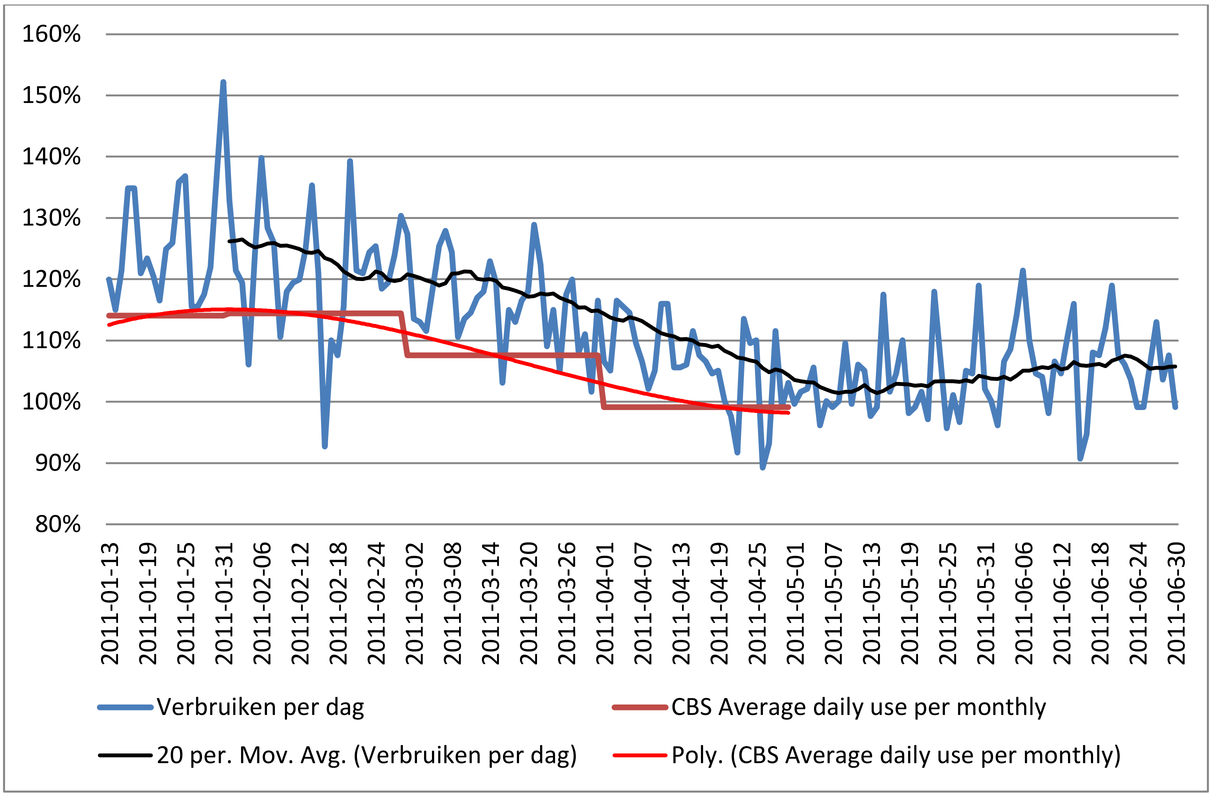


Figure 19, Relative electricity consumption of 2011 compared to 2010 average for both Geuzenveld as the Netherlands (CBS, 2011a).

In order to make a visible comparison between the daily statistics of Geuzenveld and the monthly statistics of the CBS, two lines are added to the graph. The black line shows the twenty days advancing average of the 32 participants in Geuzenveld. The red line is a third order polynomial of the average daily electricity consumption of residents in the Netherlands over the first four months of 2011, calculated by the CBS as daily averages for each month, compared to the 2010 average daily electricity consumption of households in the Netherlands.

The graph shows a great resemblance between the average for the Netherlands and average for the participants of the Geuzenveld project in terms of the decline in consumption during the first four months of 2011. The main difference is that the line for Geuzenveld is much higher compared to the national average. This is stipulated when comparing the data from Geuzenveld with the monthly averages for household electricity consumption over the last sixteen years in Figure 20. The same holds for the gas consumption. Thus the data from Geuzenveld does not show energy savings but increased energy consumption. In order to find whether this increased energy consumption is significant or whether it can be ascribed to normal variance in energy consumption in the Netherlands, the data has been analysed using SPSS statistical analysis software. A paired sample test was performed to compare 2010 average energy consumption with the average energy consumption in the first six months of 2011, adjusted for the national average increase in energy consumption. The analysis yielded the significance of the difference between the paired samples to be 0.239 for electricity and 0.369 for natural gas. With a 95% confidence interval it can now be determined that the increased energy consumption in Geuzenveld does not differ significantly from the national average increase in energy consumption. The detailed outcome of the statistical analysis is provided in the appendix.

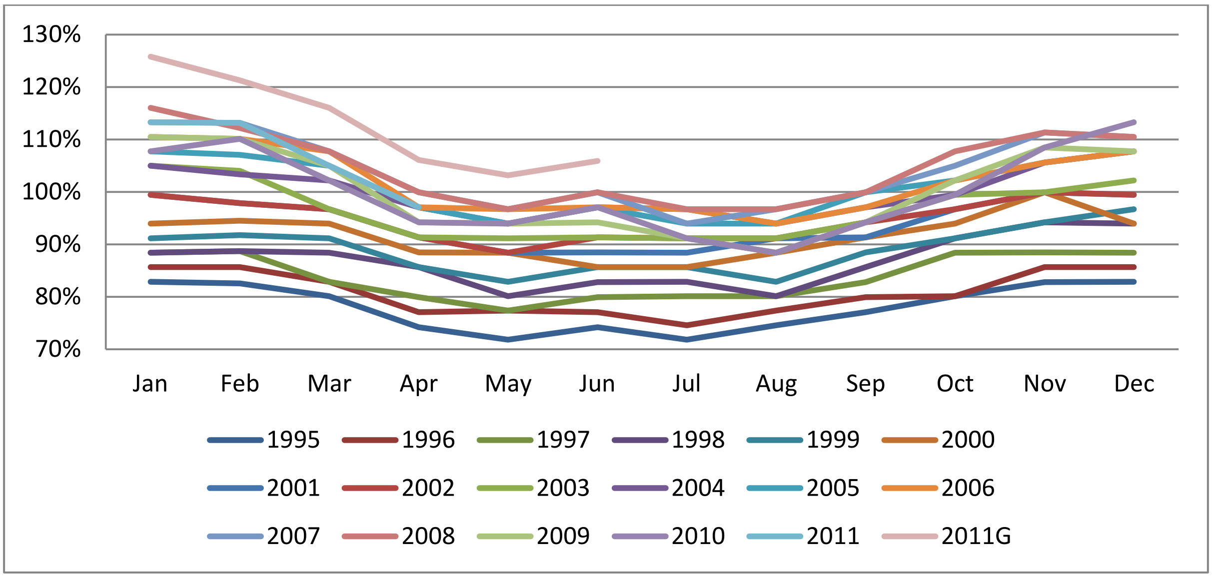


Figure 20, Monthly electricity consumption for the Netherlands 1995-2011 (CBS, 2011a) and Geuzenveld 2011, both compared to the 2010 average.

Several factors can also explain the increase in energy consumption compared to the national average trend. Geuzenveld is a somewhat deprived area in Amsterdam. It is very much possible that the residents are catching up with the national average when it comes to appliances in their households, such as large screen televisions, automatic coffee machines and computers. Also the small sample group and the lack of a control group make it difficult to find the reasons behind the deviation in energy consumption. Finally the trial only included the energy consumption in the first months of the year. During this period, energy consumption always declines. It is possible that residents felt they were doing a good job reducing their energy consumption when in fact they did not. The effect of the smart meter on the energy consumption of the residents in Geuzenveld is therefore inconclusive and the outcome of the data from the trial will not be used in the remainder of this research.

Profit Effects

The effects in the profit dimension provided quantitative data. This data can be aggregated. The remaining qualitative effects cannot be aggregated. These effects are therefore handled separately.

The quantitative profit dimension can be compared to a business case, such as the business case of KEMA (2010) as described in the introduction as the starting point of this value case. From the effects identified through the activities, the quantitative financial effects have been aggregated to an overview of the cost of the project and the benefits per year of smart meters with energy feedback displays. These figures have been scaled up for smart meter implementation in the Netherlands. For this scaling effect, several assumptions were made. The most important assumptions are an implementation of smart meters in 100% of Dutch households and implementation of 11% energy feedback displays in households, in accordance with the adoption grade in the project in Geuzenveld. Also the costs of implementing a smart meter or a display for a household in the Netherlands are assumed to be similar to the cost of implementing a smart meter for a household in Geuzenveld. Finally the costs of project management and activation of residents to reduce energy consumption are assumed to be similar for a household in Geuzenveld and a household in the Netherlands. The costs of smart meter implementation consist of the smart meter itself, the cost of installing the smart meter and in investments in the required infrastructure. Additionally the costs of energy feedback displays consist of the display itself as well as the installation of the display. Furthermore there are cost for the project management and the activation of residents to reduce their energy consumption. An overview of these costs is provided in Table 4 and an overview of all assumptions underlying the costs and benefits is given in the appendix.

Table 4, Smart meter and energy feedback display implementation cost.

Costs	Project (€)	Netherlands (mln€)
Smart meter + infrastructure	1.300.000	17.072
Display (display + installation) (11% diffusion)	3.000	39
Project management + activation	347.000	4.557
Total investment	**1.650.000**	**21.668**

Besides these costs of smart meters, annual quantified benefits are also calculated. These benefits vary from reduced cost for distribution system operators to balance the grid to the reduced cost from emission trading for energy producers. An overview of the annual benefits from smart meter implementation is provided in Table 5. These benefits are based on a number of assumptions. The most important assumptions are 70% reduction in grid losses; 80% less cost from energy fraud as fraud detection is improved with smart meters; 80% reduction in cost from grid failure as DSOs are able to notice and respond to grid failure in a shorter time; 90% reduction in data gathering cost from remote meter readings. These reduction percentages are based on the study of Faruqui et al. (2010a) of the Italian smart grid. It is assumed that the same reduction percentages can be achieved with smart meter implementation in the Netherlands. The energy savings assumed to be feasible in the Geuzenveld project are estimated at 3,9% electrical energy savings, based on earlier trials of the DSO involved in the project (ASC, 2011). The actual electrical energy consumption of the residents in the Geuzenveld project who agreed to have their energy consumption being used in this research has in fact increased by 12% compared to the same time period last year. Despite these results from the project, this research assumes the earlier mentioned 3,9% electrical energy savings to be reasonably achievable on average in the Netherlands.

Table 5, Smart meter and energy feedback display annual benefits.

Benefits (€/year)	Project (€)	Netherlands (mln€)
From grid losses	13.450	177
From energy fraud	10.661	140
From grid failures	1.298	17
From data gathering	6.548	86
From electric vehicle grid investment	11.091	146
From energy savings	19.720	259
-Of which energy taxes	7.923	104
From emission trading	529	7
Total savings potential	**63.297**	**831**

The qualitative effect less investment in grid reinforcement by DSOs for electric vehicle charging as a result of the smart meter is incorporated in these benefits. This required the quantification of this effect. Hoorik and Westerga (2011) describes a project of DSO Liander in combination with TNO and Cogen Projects where current average household electricity profiles were used to quantify the benefits of several technologies, such as managed electric vehicle charging. By modelling the energy demand for a typical neighbourhood, which is representative for the Netherlands, demand volumes and energy cost were analysed. This provided insights in the peak load from electric vehicles charging without managed charging and the potential load shifting from this managed charging. Load shifting results in a reduced peak energy demand. In turn this requires less grid reinforcements. If 25% of the residents have electric vehicles and charge them with this system, the benefit of less grid reinforcements are € 10 per electric vehicle per year. Besides this reduced peak load, the load shifting from peak to off-peak hours results in lower costs for the energy required to charge the electric vehicles. Hoorik and Westerga (2011) calculated this benefit to be on average € 18 per household per year, for both households with and without electric vehicles.

To provide insight in the relative sources contributing to the benefits, they can be presented in a stack diagram such as in Figure 21.

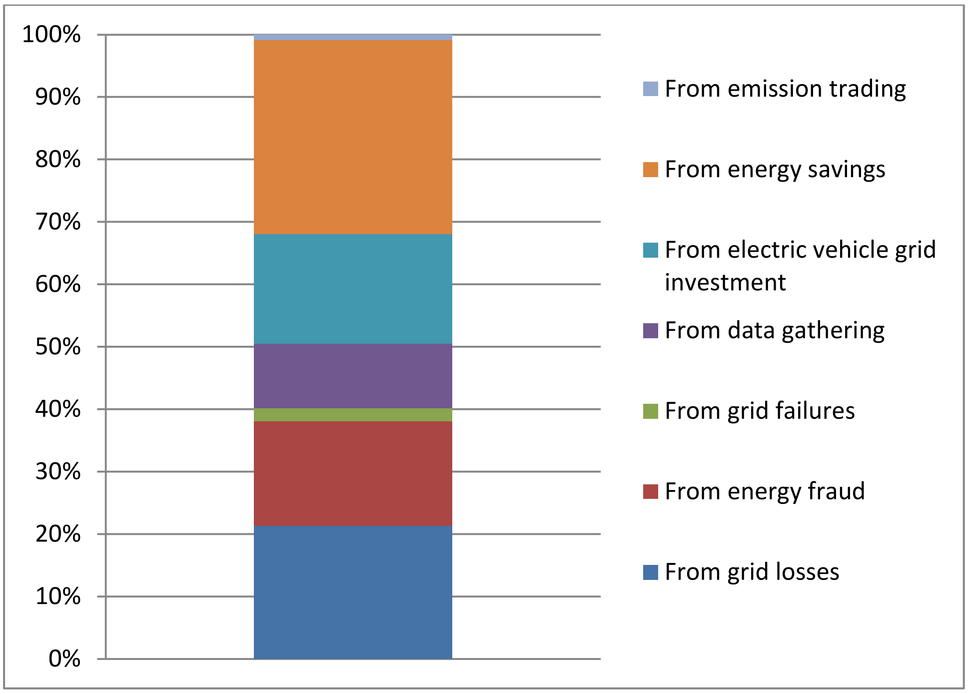


Figure 21, Smart meter and energy feedback display annual benefits relative to source.

When these quantified costs and benefits are distributed over the actors, the profits and losses presented in Table 6 are made. These figures are based on the available quantified numbers, assuming an implementation period of 8 years and a total of 40 years of returns before the smart meters are being replaced. The table shows the net present value of the smart meter using a discount rate of 5%. This discount rate lies between the common discount rate for social cost benefit analysis of 5,5% for government projects and the recently approved discount rate of 4% for irreversible external effects for the same social cost benefit analysis methodology (Koopmans, 2010). The smart meter implementation is imposed on DSOs by the government and some of the quantified effects are related to irreversible effects such as emissions, therefore this discount rate is chosen. The outcomes based on this interest rate are robust as a sensitivity analysis of the interest rate shows that the interest rate has to double in order to change the outcome of the NPV with more than 10%.

Table 6, Net Present Value of quantitative costs and benefits.

Actors	NPV Netherlands after 40 years (bln€) [i]
DSO	-10
Government	-2
Activation group	Nil
Housing corporation	Nil
Energy suppliers	Nil
Society	Nil
Meter and display installer	Nil
Energy producers	+0,1
Residents	+7

i. This study did not quantify the qualitative profit effects for the following actors: activation group, housing corporation, energy suppliers, society and meter and display installers.

This data can also be presented in a figure providing insights in the positive or negative outcome for this specific dimension for each actor. The same method of presenting results can be used to display the qualitative results.

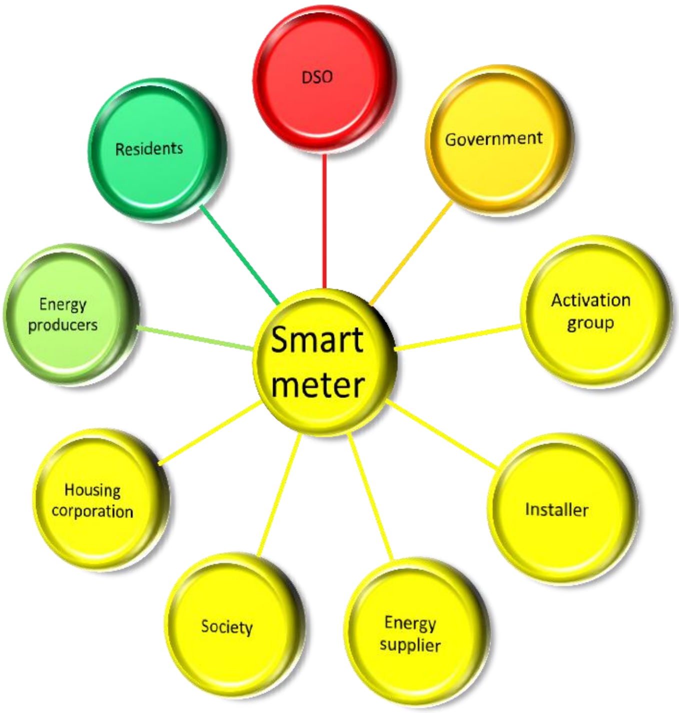


Figure 22, Aggregated quantitative profit effects per actor.

This figure provides a quick overview of how costs and benefits are distributed; showing in one instance which actor has incentives to pursuit the intervention and which actor has incentives to not pursuit the intervention, regardless whether the overall outcome of the business case is positive as calculated by the KEMA (2010) or negative according to this case. This difference stems from differences in implementation cost, which are significantly higher in this case compared to the assumption of the KEMA (2010).

5.4. Qualitative Effects

Profit

Besides the quantitative and quantified effects, this study found a list of qualitative profit effects which have not been assigned a monetary value. Some of these effects have a positive (+) effect on one or more actors, some have an unknown effect (?) and some have a negative (-) effect on actors or are potential risks. An overview of these effects, ranked by perceived magnitude of their impact, is provided in Table 7. A few actors have no effects listed. This implies that no effects were found on this dimension for the specific actor in this study. It must be noted that effects can always be found by arguing extensively. However the relevance of the found effect will decrease the more extensive arguing is needed to connect the effect to the intervention. Deciding where to stop further arguing for effects is subjective. In this study this point is determined through the interviews by what the actors indicate as reasonably related and not reasonably related effects. Several effects are self-explanatory; others will be explained into detail below. Also the effects have been numbered on the rank of the perceived magnitude of their impact. The ranking of the qualitative effects is rather subjective and can only be stipulated by conducting interviews with the actors, as was the procedure during this study; by interviewing experts or by quantifying all the effects.

Table 7, Qualitative profit effects per actor.

Actors	Effects
DSO	+ 1 Stable grid from 10% peak shifting + 2 Energy services ? 1 Decentralized energy production - 1 Not reaching remote locations - 2 Increased energy consumption from the behaviour of residents - 3 Smart meters redundant after hack - 4 Data theft
Government	+ 1 Sustainable image (asset value) + 2 Conforming to EU legislation
Activation group	+ 1 Efficiency from learning - 1 Lost knowledge
Housing corporation	+ 1 Smart home functions for comfort and/or elderly + 2 Less maintenance + 3 Increased property value from smart home functionality - 1 Mismatch between functions and resident needs
Meter and display installer	-
Residents	+ 1 Reduced energy cost from peak shifting schemes + 2 Reduced energy cost from switching supplier + 3 Increased housing value from smart home functionality
Energy producer	+ 1 More stable energy demand + 2 Avoid capacity shortfall - 1 Decentralized energy production

Energy supplier	+ 1 Less short term power purchase on APX-ENDEX and spot markets + 2 More predictable energy flows - 1 Different pricing forms - 2 Decentralized production - 3 Frequent billing
Society	-

Smart meters enable different pricing schemes, creating an incentive for residents to shift their energy use from peak to off-peak hours. This creates less income for energy suppliers; however a more stable grid load also decreases their cost for short term power purchase on the APX-ENDEX market, this is the market where energy suppliers have to purchase additional energy if the demand of their customers is larger than the amount of energy they had bought on the long term market for that period in time. Faruqui et al (2010a) have found 10% peak shifting to be well feasible from comparing several peak shifting projects. This results in a more stable grid load. This results in lower cost of grid balancing for DSOs. Energy services can also aid in balancing the grid as these services can control or manage the energy consumption of residents. Smart meters also allow for decentralized energy production as the smart meter, in contrast to current energy meters, can also measure the flow of energy from the household back to the grid. This can be a positive effect when this decentralized production is managed to meet the energy demand, further reducing the cost for DSOs to balance the grid. However if not managed properly, this can cause unbalance on the grid, increasing the cost for DSOs to balance the grid again. Costs caused by criminal activities, such as hacking meters or energy usage data theft negatively influences DSOs rather than end users as the DSOs are responsible for the safety of the meter. Also the costs to prevent mischief in the first place have to be paid by DSOs.

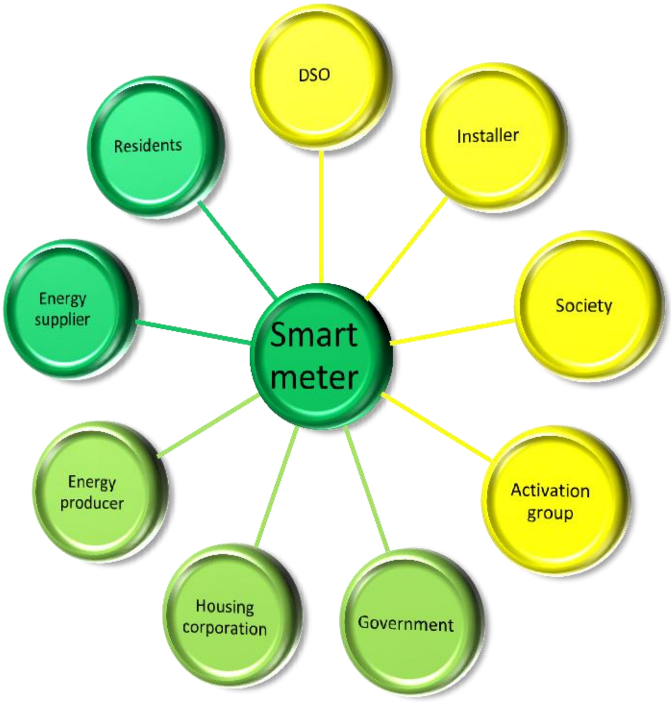


Figure 23, Aggregated qualitative profit effects per actor.

These qualitative effects can be presented by aggregating their impact. As the more objective quantified impact is unknown, they can only be aggregated with their subjective expected impact. A five point colour scale can be used as an aggregation tool. When the effects on an actor are all positive and expected to have a large impact, the actor is given a dark green colour. When the effects are overall expected to have a significant, negative impact, the actor will be displayed in a dark red coloured circle. Yellow is used for neutral aggregated effects and light green and orange are used to display the remaining 2 points of the five point scale accordingly. The qualitative profit effects aggregated on actor level are presented in Figure 23. As the figure shows, the aggregated qualitative profit effects are neutral for the DSO, the installer, society and the activation group. The other actors experience positive profit effects with energy suppliers and residents experiencing strongly positive effects. Therefore the overall aggregated qualitative profit effect of the smart meter is considered strongly positive.

People

As with the qualitative profit effects; a list can be compiled of the people effects affecting the separate actors. Again some of these effects have a positive (+) effect on one or more actors, some have an unknown effect (?) and some have a negative (-) effect on actors or are potential risks. The list of effects is presented in Table 8. Several effects are explained below.

Table 8, Qualitative people effects per actor.

Actors	Effects
DSO	+ 1 Increased number of ICT employees + 2 Temporary increased number of project management personnel ? 1 Changed job satisfaction from gasmen retraining - 1 Smart meters redundant after hack - 2 Data theft - 3 Reduced number of gasmen
Government	-
Activation group	+ 1 Increased number of personnel
Housing corporation	-
Meter and display installer	+ 1 Temporary increased number of installers
Residents	+ 1 Smart home functions for comfort + 2 Smart home appliances + 3 Feeling of control due to real-time meter readings + 4 Comfort of energy services + 5 Safety-check of energy lines during installation + 6 Comfort of receiving accurate bills + 7 Feeling of status from having smart meter/display + 8 Smart home functions for elderly + 9 Comfort of not having to stay home for gasmen + 10 Increased health from reduced shower time ? 1 Feeling due to energy consumption change from lifestyle changes - 1 Reverting to old habits after 4 months - 2 Mischief/data theft
Energy producer	-
Energy supplier	-
Society	+ 1 Supportive network in neighbourhood + 2 Energy aware community + 3 Social inclusion

This dimension provides mostly effects related to employment. However the DSOs have several risks related to safety. Of this category, data theft, smart meter hacks and other mischief affects both the profit of the DSO as described in the previous paragraph, as well as the productivity of DSO personnel and the safety of residents.

The increased health through reduced shower time is an example of what is brought up as reasonable related to the intervention according to the housing corporation. Assumed is that feedback on energy consumption influences energy use by residents. This should then include the energy used to shower. Participants in the project were also activated to spend less time in the shower to reduce energy consumption. This then leads to less humidity in homes and less humid living conditions increase the health of people according to the housing corporation.

The feeling of residents is also influenced by smart meters. This can be a positive feeling due to the increased control over energy consumption, cost and the feeling of contributing to a better living environment. However the lifestyle changes required to reduce energy consumption, the failure of being able to change habits or reverting to old habits after 4 months (Dam et al, 2010) can also have a negative impact on the minds of residents. When people are able to change their behaviour and promote their changed behaviour, an energy aware community with supportive local networks can emerge. This could result in a form of social inclusion. All the qualitative effects can be aggregated using the same 5 colour scale in Figure 24.

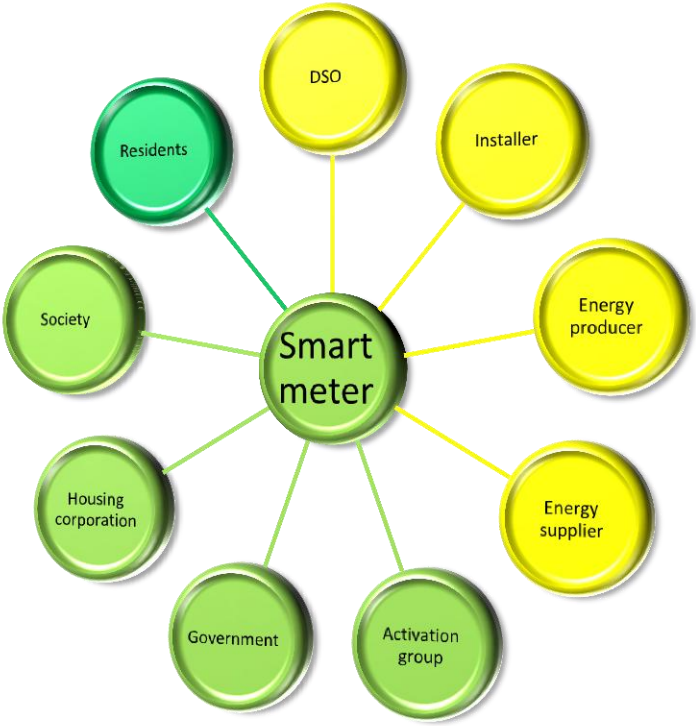


Figure 24, Aggregated qualitative people effects per actor.

From the aggregation it follows that the aggregated qualitative people effects are at least neutral for all actors. Most actors actually experience positive people effects, with as most positive actor the residents. Therefore the overall aggregated qualitative people effect is somewhat positive.

Planet

The planet dimension differentiates from the previous dimensions. With this dimension the effects do not affect the actors themselves, but the actors all affect the environment. A better or worse environment again affects most actors in one way or another, therefore the planet effects are listed by causer. Several effects have a positive impact on the environment (+), several have a negative impact (-) and the actual effect of some results is unknown (?), meaning this could be both positive and negative. Also several effects have a quantitative nature as they contain numbers on the magnitude of the effects. These effects are still seen as qualitative effects as they are not interchangeable with other effects. Some effects are listed both in this dimension as well as in other dimensions. An example is the energy use reduction. The saved energy can be displayed as both amount of energy and amount of money. While these two effects are interchangeable, this does not result in a double counting of the same effect, as the dimensions are analysed individually. Even when all effects are quantified into one interchangeable unit, the separate effects are needed as they provide insight in the performance of the intervention on the different dimensions. The actors can then decide what the weight of the separate dimensions is in their final decision.

An overview of the qualitative planet effects from smart meters equipped with in home energy feedback displays is provided in Table 9. As with the qualitative profit and people effects, several of the effects are explained in more detail below.

Table 9, Qualitative planet effects per actor.

Actors	Effects
DSO	+ 1 Less energy loss from: better grid balancing, less energy fraud and less network failure + 2 Less energy required for traveling gasmen - 1 Natural resources required for meter and display production - 2 Energy required for meters, remote reading and data storage - 3 Energy needed to recycle old meters - 4 Waste from recycling old meters - 5 Energy required display production (2,84*10^3MJ) and transport
Government	-
Activation group	- 1 Energy and resources required for activation and to save energy
Housing corporation	-
Meter and display installer	? 1 Temporary changed energy demand from travel
Residents	+ 1 -3,9% electricity use (4TWh/year) + 2 -419kTon CO_2/year + 3 -183kg nuclear waste/year ? 1 Changed resources needed from dematerialisation or re-materialisation (rebound effect) - 1 Energy use from rebound effect (more use of energy efficient appliances or purchase of more appliances)
Energy producer	+ 1 Reduced energy consumption from reduced energy production
Energy supplier	- 1 Resources required for frequent billing
Society	-

The temporary changed effect from meter and display installer can be both positive and negative.

This depends on the number of installers required, the distance they have to travel, whether this is more or less compared to when they did not have this assignment and how the installation is planned. For example bad planning results in travelling installation mechanics during their working hours while good planning keeps them working on one location throughout the day.

In Geuzenveld the electrical energy consumption is assumed to be reduced with 3,9% as a result of the project. A similar savings for the Netherlands as a whole would create energy savings of 4TWh per year based on 2006 energy consumption figures (CBS, 2009a). The reduced energy consumption reduces the energy production. Assumed is that the energy savings will not result in a reduction of the renewable energy production, but only in fossil fuel power plants. This reduced production in coal, natural gas and oil power plants in turn reduces the CO_2 emission of these power plants. Based on the energy label of Essent (2011), this accumulates to a total of 419kTon CO_2 emission reduction per year. In comparison, the energy sector is the largest emitter of CO_2 in the Netherlands with a total CO_2 emission of 48,7Mton, which is 58% of the national total emission (Energeia, 2011). The reduced carbon dioxide emission can be quantified using the actual price being paid by firms to emit CO_2 on the emission trading market. This part of the effect is presented in the profit dimension. Still the effect is also listed in this dimension as it has an environmental component. Besides this reduction in CO_2 emission, power production also comes from nuclear sources. The 3,9% national electrical energy reduction can result in a reduction of 183kg of nuclear waste per year, based on the energy label of Essent (2011). Even though the energy producers reduce their energy production, this effect is distributed to the residents as they are responsible for reducing their energy consumption. The effect is mentioned with energy producers as well; however as the less significant effect of reduced energy consumption of the energy production facilities themselves, as a result of reduced energy production of the facilities.

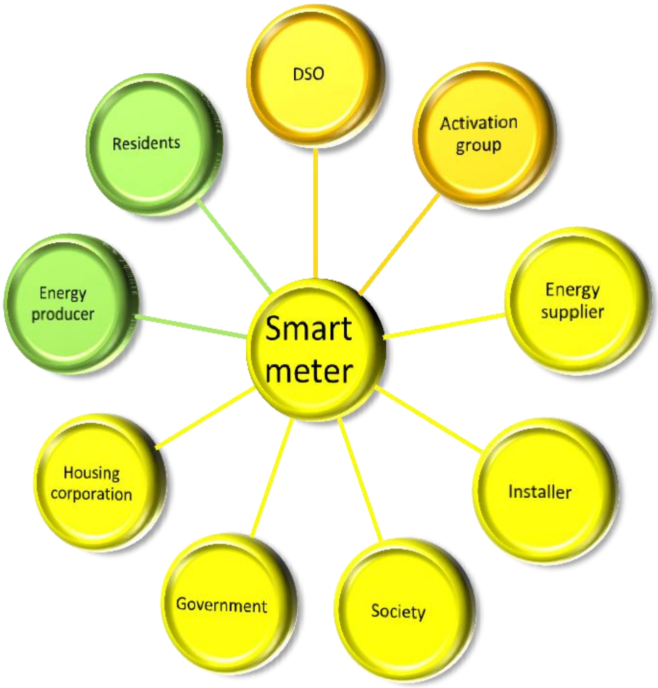


Figure 25, Aggregated qualitative planet effects per actor.

Figure 25 provides an overview of the aggregated qualitative planet effects per actor. The planet value of smart meters varies from slightly positive for residents and energy producers to slightly negative for DSOs and activation groups. Therefore the overall aggregated qualitative planet effect is neutral.

Effect summary

The effects can be summarized per dimension and per actor based on the DiCE model in Figure 14. For this matter the qualitative and quantitative profit dimensions need to be joined into one dimension. This provides the figure in Figure 26. This figure provides a simple overview of how the intervention will affect the actors per dimension. Based on this overview, the actors could be able to resolve their alignment problem either by being consentient on the desirability of the innovation or by agreeing to compensate the actors who are negatively impacted.

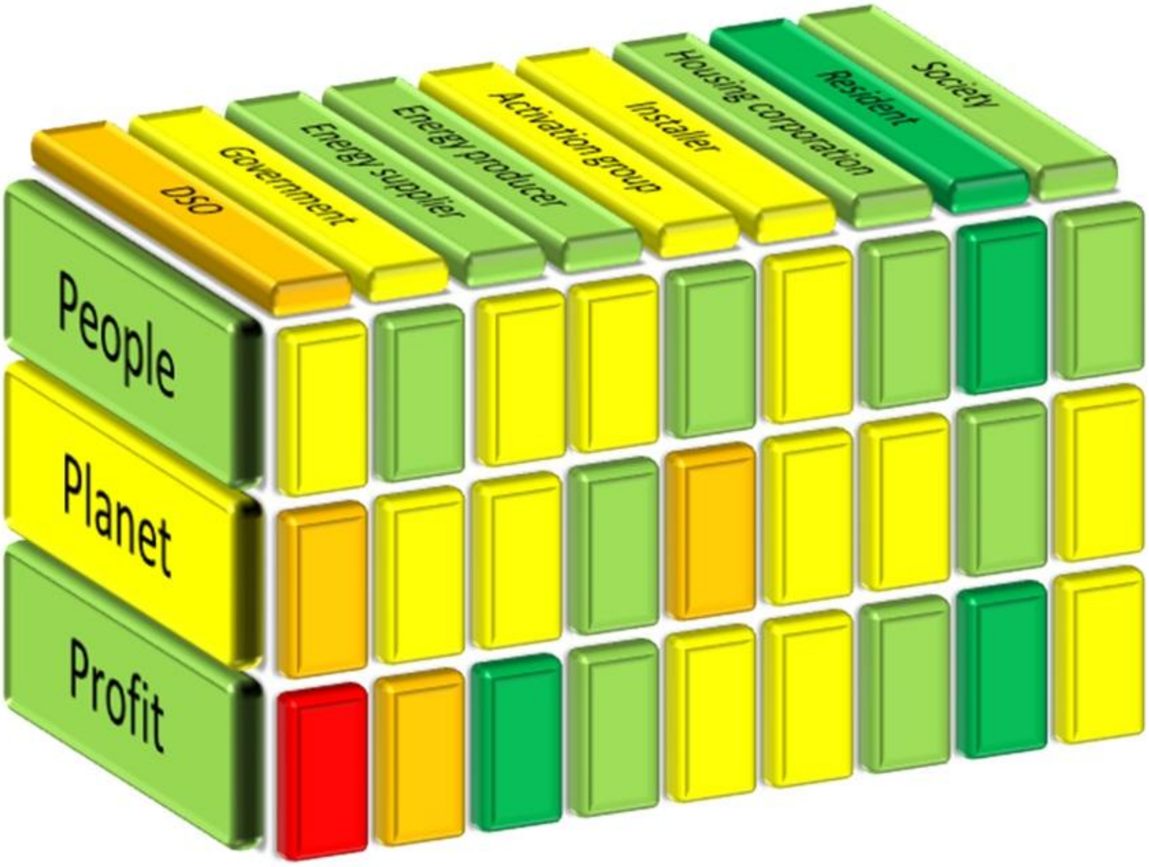


Figure 26, Effect summary.

The effect summary shows the overall neutral and positive impact of the smart meter on most actors and most dimensions. Only the DSO experiences negative impacts overall and strongly negative impact on the profit dimension. Due to the earlier mentioned regulation of the income of DSOs, the current business models cannot resolve this negative impact. New benefits to compensate the negative impact are required if the actors do not become consentient and the alignment problem remains present. These new benefits can be the quantification of qualitative positive effects. New business models are also required to provide the actors the possibility to scoop these new benefits. The new business models can also be used for compensation between actors. This in itself can resolve the alignment problem.

5.5. Quantification

When the previously introduced outcome of the value case process does not manage to align the actors, one, some or all qualitative effects can be quantified in order to provide a new outcome which can again be used to attempt to align the actors. It is recommended to first quantify the effects with the highest perceived impact as this is likely to influence the outcome and thus the possibility of alignment the most. Effects in the profit dimension are relative less complicated or subjective compared to effects from the other two dimensions. To quantify the effects in the profit dimension, data is needed as well as understanding of the relation between the intervention and the effect in order to calculate the effect. If either the data or the relation between the intervention and the effect are not available, these should be estimated. The qualitative effects of the other two dimensions can be quantified using either a method to calculate the economic value or by using one of the following four methods of the SCBA (Boer & Larsen, 2010):

- Revealed preference: Quantifying effects using prices observed on a (derivative) market.
- Stated preference: Quantifying effects using surveys on what people state they are prepared to spend on a matter.
- Avoidance cost: Quantifying effects using the amount of money required to avoid an effect.
- Key figures: Quantifying effects using standardized figures from earlier studies on similar matters.

For the smart meter case, an overview will be provided per dimension of suggested quantification methods for several qualitative effects which are perceived to impact the overall outcome of the value case.

Profit

Less short term purchases on APX-ENDEX and spot market for energy supplier: The profit for energy suppliers to better estimate energy use will become apparent in energy purchases on the APX-ENDEX and spot energy markets after the large scale implementation of smart meters. There are currently no estimates available for this effect based on prior research. However an estimate of the effect can be provided by modelling the impact of the information provided by the smart meter on the energy buying behaviour of energy suppliers. A method to model this impact is demonstrated with other interventions in the energy system by Hoorik and Westerga (2011). In their study, Hoorik and Westerga (2011) modelled the implementation of several decentralized energy technologies to determine the financial benefits per household. These benefits could be realized through peak shifting, delayed grid reinforcement, reduced grid losses and trading on APX-ENDEX and spot markets. Instead of using decentralized energy technologies to model differences in energy production and storage by consumers, such as heat pumps, electric vehicles and solar panels, the method could also be used to model the impact of detailed profiles of energy consumption on the trade on balancing markets as the APX-ENDEX and the spot market.

More stable grid from 10% peak shifting for DSO: As with the previous effect, better grid balancing from shifting 10% of peak energy demand to off-peak periods can be modelled by simulating the energy system. The peak shifting as a result of energy feedback from smart metering will reduce the operating cost of DSOs as grid reinforcements can be postponed. By modelling which grid reinforcements can be postponed, the benefits can be calculated.

People

Smart home functions for comfort of residents: For this effect, two of the four methods mentioned by Boer and Larsen (2010) could be used to quantify the effect: stated preference and revealed preference. When houses with comfort functionality are for sale on the housing market, the increased price offered for these houses can be used to reveal how much residents are willing to pay for these additional functions. Also if smart home comfort systems are on the market, the price being paid by customers should indicate what the function is worth to the user. As there currently is no market with significant product volumes and no data on houses sold with additional smart home comfort systems, the revealed preference method cannot be used at the moment. The stated preference method can be used by conducting a survey in which residents are asked which comfort systems they would appreciate as an addition to their home and what they are willing to pay for these additions.

Increased number of ICT personnel for DSO: The quantification of the effect of increased employment is more complex than the previous effects. The quantification does not aim at monetizing the cost of additional personnel for the DSO as that is already part of the operating cost. This effect concerns the employees themselves. Aim is thus to determine the value of the increased employment for the employees. Beckman and Houser already studied the perceived satisfactions and costs of employment in 1979. Their examined motivators for employment are: money, liking to work, fulfilling achievement needs, seeking intellectual stimulation and escaping the boredom of home. With a survey, the stated preference can be examined to valuate these dimensions of employment. By asking the unemployed people what they are willing to invest in order to gain the satisfiers of employment stated above, the value of employment can be approximated.

Planet

Reduced nuclear waste from reduced energy consumption by residents: The reduced nuclear waste from reduced energy consumption is already quantified into a number in this research by calculating the amount of nuclear waste reduction. This comes to 183 kg nuclear waste per year for the Netherlands in total. To monetize this reduced nuclear waste, two methods can be used. Either calculating the benefits of not having to process and store the nuclear waste or the stated preference of people on creating less nuclear waste. While the first method leads to a more accurate outcome of the cost, the second method can be used better in business models to stimulate the nuclear waste reduction. Calculating the avoided cost of the nuclear waste processing and storage provides an accurate number on the benefits and how these benefits can be collected by energy producers and through market mechanisms to residents. The second method of researching the stated preference of residents on how much they are willing to spend on reducing their stake in nuclear waste can provide more information than the perceived benefit of reducing the nuclear waste; it also provides input for business models which aim at reducing energy consumption and nuclear waste, paid for by residents; more on this in the next section.

It must be noted at this point that for different value cases, these methods must be determined based on the effects and the information at hand in the separate cases.

5.6. New business models

For actors to be able to compensate for the negative impact they occur on the profit dimension, new business models are required based on monetized qualitative effects. The monetization of effects follows the quantification of effects. This step is not performed in this study as only methodologies are proposed for quantifying qualitative effects. However Hubbard (2010) stipulates to the viability of monetization methods as he states everything can be measured and monetized. In this case, new business models are required to compensate the investment made by the DSOs for which they do not receive same size benefits. The benefits of better balancing the grid and more accurate fraud detection do not cover the expenses made by a DSO.

One new model can involve the data gathered and stored by the DSOs. The DSOs are required to provide energy suppliers with two monthly usage data as the energy suppliers are required to provide residents with two monthly bills based on current energy usage. The main benefit of smart meters for energy suppliers is not receiving two monthly data, but detailed consumption data which assists the energy suppliers in better estimating the amount of energy they have to purchase at a given time. DSOs could implement a model in which they provide the two monthly data to energy suppliers as regulated, but where the energy suppliers are charged a fee to receive more detailed energy usage data.

Another potential new business model involves the earlier mentioned reduced nuclear waste. DSOs could be involved in a price scheme to reduce the nuclear waste when this is a result from the detailed information on energy consumption by smart meters, for example energy usage feedback. Consumers can be given the choice to enter into a contract with the energy supplier, the DSO and perhaps an additional party. From this contract, the consumer receives means to reduce energy consumption in the form of a smart meter and an addition such as an energy feedback display or an energy management system. In return the consumer does not receive all the financial benefits of the reduced energy consumption as such; a part of the financial benefits are used to compensate the DSO while the final part is used to make sure the reduced energy of the consumer leads directly to reduced nuclear waste. This can be done by ensuring contractually that the reduced energy consumption leads to a reduction in nuclear power production, rather than a reduction of the energy production from other sources.

A third business model involves the additional smart home functionality for comfort. Based on the outcome of the stated preference on smart home systems on comfort, DSOs can perhaps receive more compensation for their investment in smart meters by combining the smart meter with additional smart home systems which increase the comfort of the residents. When the stated preference of customers reveals they are willing to spend more than implementation of the additional system will cost, combining this additional system with the smart meter installation will enable DSOs to recover more of their smart meter investment. For this matter, the DSO must be an active actor in this business model and find partners to build and market such systems.

6. Discussion and Conclusion

In this chapter the discussion paragraph starts with a subparagraph reviewing debatable topics concerning the methodology developed during this study and the used method. This is followed by a subparagraph discussing the empirical findings of this study in the light of the theories described in this thesis. This is followed by the conclusion in which the answer of the research question is provided. This chapter closes with proposals for further research.

6.1. Discussion

Methodology

On the methodology of the value case: the researcher is somewhat dependent on the knowledge of the interviewee. By increasing the number of interviews and the number of interviewees, more credible information can be collected on the activities and effects. Some information can be retrieved from a study of available literature. However in many cases, the implementation of configurations is relative new, therefore not much literature will be available on the activities and the effects related to the implementation of the innovation in that configuration. One other problem can be that interviewees do not reveal all the information they have as some information might be confidential and provides them with an edge over competitors.

On the case at hand it can be noted that the project did not include savings from natural gas, while the energy feedback display is capable of providing information on natural gas consumption. This is caused by interoperability issues between the smart meter and the energy feedback display. The outcome of the value case can be more positive if the interoperability issue is being resolved. This potential saving is left out of this study as there is no accurate data available on the natural gas savings from feedback in such a situation.

Also this study assumes smart meter implementation in 100% of the households. The regulations of the Dutch government state that smart meters must be implemented in 80% of households. DSOs also expect the smart meters to be implemented in just over 80% of the households as the costs of implementing smart meters in the remaining 20% is much more costly. The benefits are also affected with not implementing smart meters in these 20% of households. It is unknown what the exact effect will be of this. One can argue that the costs of the remaining 20% are more than 20% of the overall costs. However on can also argue that the benefits of the last 20% are also more than 20% of the total benefits, as for example the grid balancing becomes significantly more accurate when all households are being monitored, rather than 80% being monitored and 20% using an unknown amount of energy. The argument is thus that costs and benefits are both not linear with the implementation grade.

An extensive value case incorporates ‘upstream’ and ‘downstream’ research in value chains. Interviewing more actors in more parts of the value chain is needed to find the effects they foresee. The choice for limiting the actors depends on the scope or purpose of the value case. In this case, the scope has been limited to the actors directly involved in the smart meter implementation in smart grids and smart homes. One can argue that more actors are affected by smart meter implementation. The magnitude of the impact on them however is not likely to be of the same magnitude. For the matter of resolving alignment problems and identifying new business models, incorporating a larger scope can be beneficial as more actors and more benefits can be used to resolve an alignment problem.

Also besides the effects identified in this study, more effects can occur during and after the implementation of smart meters in different configurations. New products and services can be introduced based on the capabilities enabled by smart meter configurations. The effects and thus the value of these products and services are currently unknown. The value case, like for example a business case, should be updated on a regular base in order to remain accurate.

In this research, one configuration is being studies using a value case. Other configurations can include different actors and activities and will result in different costs and benefits. Even though the outcome of this study provides incentives to implement the smart meter using the configuration with en energy feedback display, this does not imply this is the configuration with the most support to be implemented in the Netherlands, or even in this situation. Other configurations have to be studied for this matter. However the outcome of the study on this configuration provides the insight that this configuration can be implemented successfully in this situation.

There is a different outcome between business case of KEMA (2010) and this case. This is caused by differences in implementation costs and expected energy savings potential (KEMA uses 5-15% while this study uses 3,9%). This difference can be understood by looking at several studies on smart meter effects, as provided in the appendix. The electrical energy savings in other studies varies even more as shown in the appendix. With the note that the larger the trial becomes, the smaller the energy savings are. This can partly be explained by the trial group. The smaller the number of households involved in the trial, the more likely these households have been selected based on their willingness to participate in the trial. This makes a bias in willingness to contribute to energy savings and the willingness to change energy consuming behaviour by the residents possible. Also assumed or expected savings based on earlier studies can be influenced by a possible publication bias as studies are more likely to promote their findings with publications when positive results have been achieved, while negative results will less likely be published, even though a negative result is as important as a positive result.

The proposed methodology with quantification, monetization and the capture of value in new business models suggest an interexchangeability of effects. Even though on paper this interexchangeability exists, in practice there are ethical objections to this notion. Compensating pollution or deforestation with economic value is supported by monetizing mechanisms; however the desirability of such processes should be questioned. One method to guide the desirability of the monetization of such effects lies in the discount rate used to determine the impact of an effect on the current decision making process. This issue is further addressed in the paragraph concerning further research.

Empirical Findings

The outcome of the smart meter case provides insight into what the value case methodology can contribute to configurational systems theory as described in the theory chapter. The configurations in which smart meter systems are being implemented differ between projects. There is no generic off-the-shelf smart meter system to implement in the different settings; rather the smart meter system is determined separately in each instance. Conventional methodologies do not provide insights in the additional benefits that are created by different configurations of smart meter systems in different settings. This leads to uncertainty and alignment problems during the implementation phase of smart meter configurations and thus to a hampering implementation of smart meter systems.

In general as local contingencies lead the configuration of the system implemented in a specific case, rather than a generic system which is being implemented in all local contingencies, not only the shape and function of the configurational system differs between implementations, also the revenue mechanisms and thus the value of the configurations differ between cases for actors involved in the implementation of configurational technology. The benefits that can be yielded by the implementation of configurational systems differ between instances, which make it difficult to discover all of these benefits. Conventional methodologies aim at providing insight in the recurring costs and benefits as is common with generic systems. However these methodologies are not able to discover the additional benefits created by different configurations in different local contingencies. This leads to a hampering implementation as the revenues for the actors are either unknown or an alignment problem between the actors exists. The case at hand is therefore exemplary for the problems of configurational systems, namely that configurational systems lack momentum as a result of more uncertainty during the implementation of a configuration caused by the exclusion of additional benefits in the assessment of the configuration. From this view, the findings in this study can apply to configurational systems in general.

The value case methodology developed during this study does provide insight in the additional benefits provided by configurational systems which are implemented in different local contingencies as it uses a broad scope to search for effects. The value case methodology does not only point out where additional benefits can be found, the methodology also provides guidance which steps have to be taken in order to be able to capture these often qualitative effects in business models. This makes the value case methodology a useful tool to create momentum for the implementation process of configurational systems.

6.2. Conclusion

This study set out to determine what a value case methodology must look like in order to resolve alignment problems in the implementation phase of complex configurational technology.

In order to determine the shape of the methodology, first the characteristics of configurational technologies were described. The main characteristics are the complex nature of configurations and their strong dependence on local contingencies during the implementation phase. The lack of insight into how local contingencies can best yield benefits, or additional benefits, across a range of crucial actors, leads to implementation barriers. As local contingencies differ from each other, different configurations are required to fit to the local settings. As a result, configurations, in contrast to conventional generic systems, do not follow the generic innovation trajectories characterized by dominant designs and generic diffusion curves. Rather individual cases where the actors learn which configuration fits into local contingencies lead to insights in the additional benefits of configurational technology on a learning by trying base. Conventional methodologies as business cases or social cost benefits analysis are unable to discover the costs and benefits and thus the value of a configurational technology due to their limited scope.

The value case methodology must thus be able to incorporate both the technological effects as well as the intermediate effect of the local settings on effects created by the implementation of the configurational system. This is done by the case study approach where the value case is performed for a specific situation. This provides insights in the effects of the proposed configuration in the local contingencies at hand. By performing several cases for several types of contingencies, the outcomes can be generalized to configurations with specific characteristics matching local contingencies with specific characteristics. From this, the benefits created by the implementation of a configuration in a local setting can be discovered and captured to create more support for the implementation of the configuration.

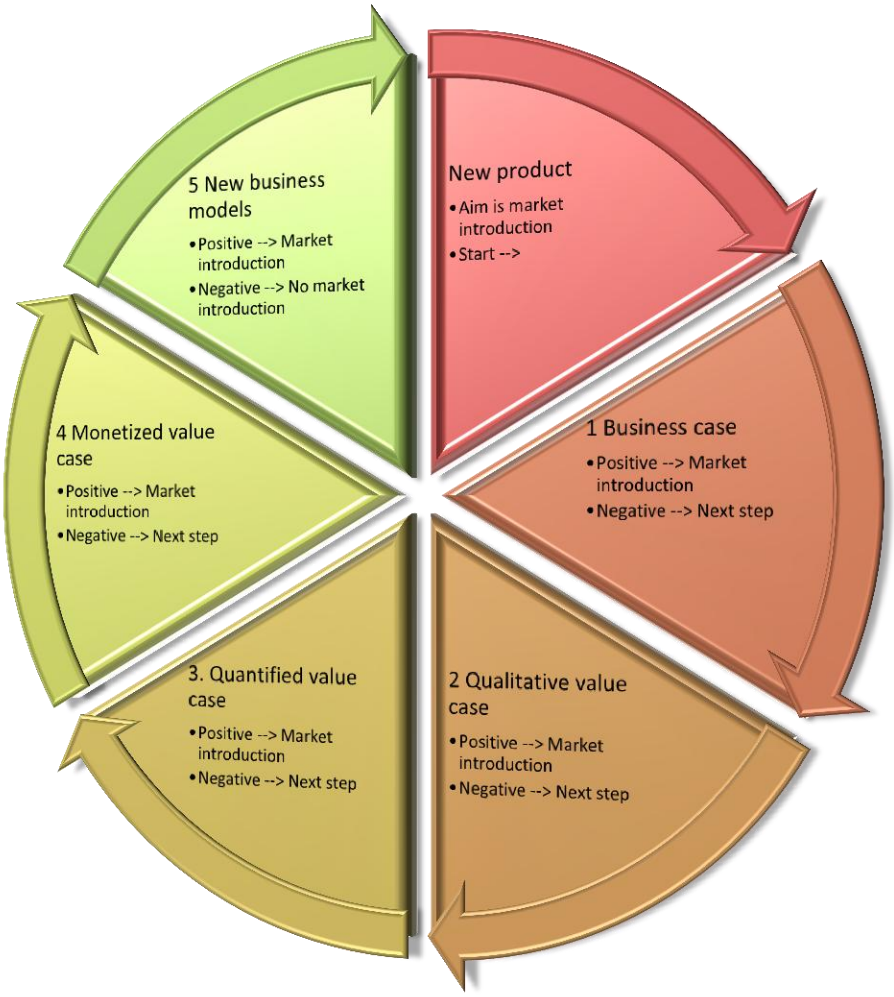


Figure 27, Value case process cycle.

Furthermore as configurations concern complex systems, in most cases a number of actors are involved in the implementation process, all with their own costs and benefits. In order to gain support and momentum for an innovation, these actors have to be aligned in their perception of the desirability and success of the implementation of a specific configuration in local contingencies. The value case must therefore be able to provide an outcome which can be used to align actors. For this matter, the value case provides a complete overview of the effects of the implementation of the configuration. This overview includes both quantitative and qualitative effects. The quantitative effects can provide insight in the alignment problem assumed to be present before conducting the value case. The qualitative effects can be used as starting points to align the actors. This alignment can be a result of the insight in the presence of the qualitative effects. However if this insight does not persuade the actors to align to each other, the qualitative effects can first be quantified, then monetized and finally captured in new business models, depending on what is needed to align the actors. This process is also shown graphically in the value case process cycle in Figure 27.

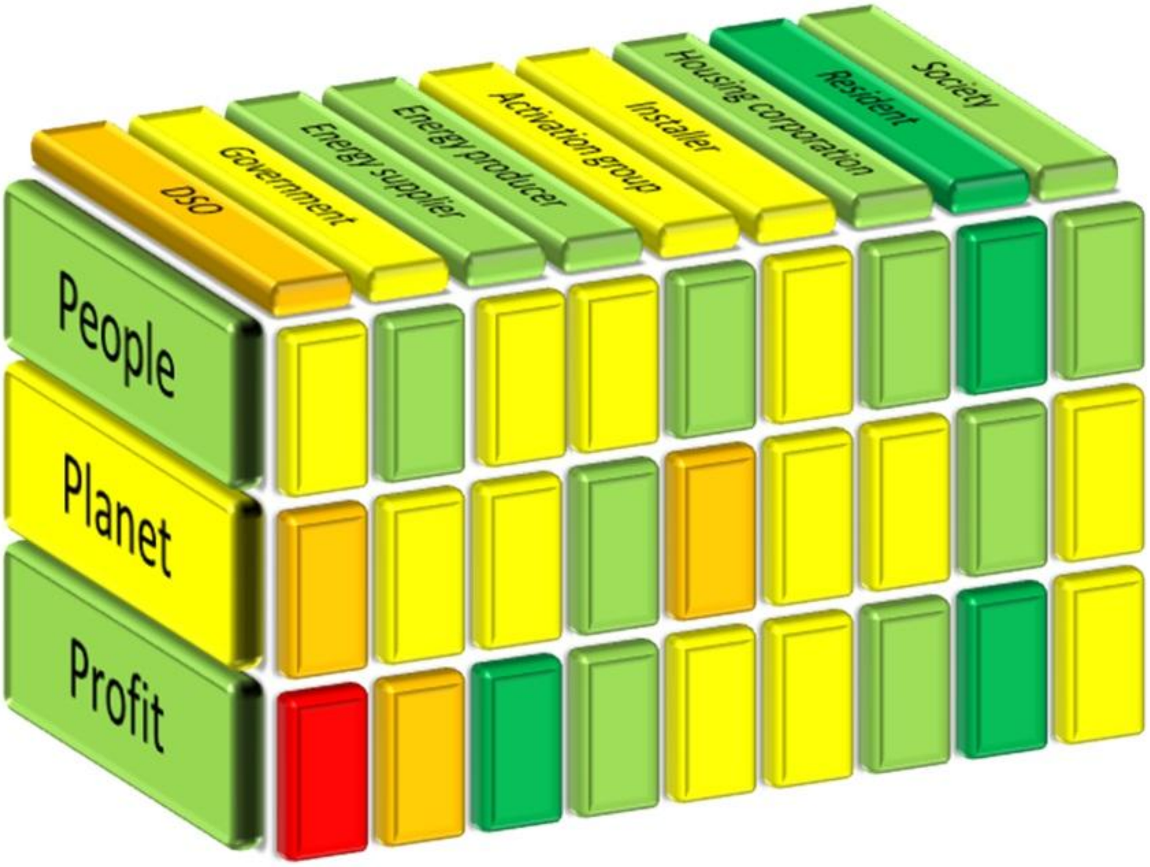


Figure 28, Effect summary.

The case studied in this study, the smart meter trial of Amsterdam Smart City in Geuzenveld shows the viability of the proposed value case methodology. In this case there is a clear alignment problem as the DSO experiences strong negative financial effects, while other actors experience strong positive effects in people, planet and profit dimensions, as shown in Figure 28. Also the viability of quantifying, monetizing and incorporating qualitative effects in new business models is underpinned by the Geuzenveld case. This study proposes a number of methods to quantify several qualitative effects. The viability of these methods and the monetization and new business model steps is underpinned the strongest by the initiative of the DSO to actively explore the possibilities to incorporate the value of the data collected from smart meters in a new business model where third parties are charged for detailed information from the energy consumption database of the DSO. This was one of the proposed new business models derived from the value case methodology.

6.3. Further research

Several aspects of this study raise more questions than they answer. These questions are the starting point of future research. Some suggested topics for further research are outlined here.

Several propositions for further research concern the methodology, to start with the methodology to identify the effects. The currently proposed methodology suggests a large number of effects being identified with the objective of creating an exhaustive list of effects. Several aspects could influence the number of effects found, for example the number of actors included in the research. This raises the question whether the number of found effects for and between the actors grows out of proportion when more actors are included in the research or when a case is studied where more actors are involved? Future studies could explore the usability of the value case methodology as proposed in this research in cases with more actors involved.

Related to this subject is methodology on which effects to include and which effects to exclude. During this research, effects were identified which differentiated in terms of their relatedness to the intervention and in terms of their perceived impact. Two methods to reduce the number of effects incorporated in the case can be proposed based on these distinctions. One is to reduce the number of effects by ranking them on importance and choose a cut-off point from which less important effects, or effects with less perceived impact. A second method is to reduce the number of effects based on their relatedness to the intervention, again with a chosen cut-off point to separate the related effects which become part of the study from the less related effects which are left out. A future study should be conducted on the feasibility of these measures to keep the number of effects from growing beyond a workable case.

An exact mechanism is needed to qualitatively assess the qualitative effects. In this study the qualitative effects have been ranked subjectively. A more objective method to assist in the ranking of the qualitative effects can significantly improve the perceived quality of the outcome of value case.

Furthermore, as the initial outcome of a value case, as presented in this study, does not align the actors, one, several or all qualitative effects can be quantified and monetized, albeit some more difficult than others. The quantification of an effect itself can be subject for further research; however the more interesting research topic in the light of this study is the question whether the outcome of the quantification process will align the actors. The same question holds for the new business models; do these new business models align the actors when the outcomes of previous stages of the value case do not manage to align them? Further research should attempt to answer this question by further developing this value case to include quantified qualitative effects and new business models and to study whether the actors involved are more inclined to act on the outcome of the different stages of the value case on different ways.

In this study the current discussion on discount rates has already been mentioned. This discussion concerns the question what is a suitable interest rate for future effects. Currently a set rate is used for all effects, with disregard of the dimension of the effect. Some scholars such as Koopmans (2010) suggest differentiating between reversible and irreversible effects. The discount rate of future effects should be researched in the light of this current discussion on future people and planet effects. As Koopmans (2010) suggests, one could argue that effects from different dimensions should be handled differently based on the notion that profit effects are fully interchangeable while planet effects can have a lasting impact. For example cutting down a tree to build a house is permanent. Planting a new tree on a different location can compensate for some functions of the tree, but it will never fully replace the original tree, while one hundred euros can be completely compensated by another one hundred euros. Different discount rates and especially different discount rates between dimensions will change the outcome of the value case. A future study should focus on the current discussion on discount rates and whether differentiating these rates between dimensions will provide a more realistic or perhaps more honest view on the current and future impact of an intervention or innovation.

Finally, in order to be able to generalize the usability of the value case methodology, the methodology must be applied to other cases. For example other cases with alignment problems could be subject to value case methodology studies, as well as cases where the implementation of configurational technology innovations hampers should be considered.

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Appendix

Studies on smart meters

Table 10, Studies on smart meters.

Studies on Smart Grids	Studies on Smart Homes
Dollen, 2009	Chan et al., 2008a
Faruqui & Woods, 2008	Chan et al., 2008b
Faruqui et al., 2010a	Hargreaves et al., 2010
Faruqui et al., 2010b	Jonge, 2009
Gill, 2009	Kamarilis et al., 2010
Haney et al., 2009	Levin et al., 2010
Hoch et al., 2008	Maestre & Camacho, 2009
Honebein et al., 2009	Meyers et al., 2010
Jamasb & Pollit, 2008	Parra et al., 2009
KEMA, 2010	Perumal et al., 2008
Kemp et al., 2007	Perumal et al., 2010
Neenan & Hemphill, 2008	Raad & Yang, 2009
Newsham & Bowker, 2010	Renewable Energy Focus, 2009
Owen & Ward, 2006	Yamazaki, 2007
Owen & Ward, 2007	
Owen & Ward, 2008	
Vasconcellos, 2009	
Vasconcelos, 2008	

Overview of changed activities per actor

Table 11, Overview of changed activities per actor.

Actor	Activity
Activation group (Favela Fabric)	Arranging gifts/tokens for participants (pictures, information booklet etc.)
	Building network of contacts in the neighbourhood
	Community-building
	Create awareness on energy consumption among residents (short term)
	Provide means to save energy to residents (medium term)
City of Amsterdam	Enabling new energy services
	Smart grid implementation
DSO (Liander)	Balancing grid based on real time consumption
	Detecting energy fraud/steeling based on real time consumption
	Detecting network failures based on real time consumption and gateway data
	Enabling demand response

	Enabling new energy services
	Invest in smart grid
	Lending displays to residents
	Manage implementation
	Remote energy usage data gathering
	Smart grid implementation
	Energy data storage
Project management (part of DSO)	Being present at public meetings
	Community-building
	Recruiting participants with display
	Smart grid implementation
	Stakeholder management
Energy producer	Produce energy based on energy demand
Energy supplier	Consumer billing
	Enabling new energy services
	Sell energy
Housing corporation	Communication with residents
	Implement smart home functions
	Make houses available for the project
	Urban development/renovation in social housing areas
Others	Criminal activity with respect to smart meters and energy data
Residents	Using new energy services
	Living, using energy
	Participating in activation sessions
	Receiving feedback on energy consumption with displays
	Receiving information on how to reduce energy consumption
Society	Building network of contacts in the neighbourhood
	Community-building

Assumptions

Table 12, Assumptions underlying the calculations.

Assumptions			
Connections project	541	Connections	ASC (2011)
Displays project	60	Displays	ASC (2011)
Connections E 2010	2.900.000	Connections	Alliander (2010)
Connections G 2010	2.100.000	Connections	Alliander (2010)
Households in Amsterdam	422.073	Households	CBS (2011b)
Households in the Netherlands	7.104.520	Households	CBS (2011b)
Infrastructure + meter costs	1.300.000	€/project	Project finding
Cost per meter + installation	386	€/meter	Project finding
Cost per display + installation	50	€/display	Project finding

Cost per EMS + installation	300	€/EMS	Project finding
Total project cost (-infra, meter + display)	350000	€/project	Project finding
Grid losses in the Netherlands	4.450.000.000	kWh/year	CBS (2010b)
Grid loss savings	70	%	Faruqui et al (2010a)
Grid losses Alliander	103.000.000	€/year	Alliander (2010)
Electricity use reduction	3,9	%	Project finding
Gas use reduction	0	%	Project finding
Average electricity use households Netherlands	3.350	kWh/year	CBS (2009a)
Average gas use households Netherlands	1.700	m3/year	CBS (2009b)
Electricity prize	0,279	€/kWh	CBS (2010a)
Gas prize	0,764	€/m3	CBS (2010a)
CO2 emission regular electricity	0,4515	kg/kWh	Essent (2011)
CO2 emission natural gas	1,78	kg/m3	Volkskrant (2006)
CO2 emission rights	16,58	€/tCO2	Energeia (2011b)
Radioactive waste	0,000197	g/kWh	Essent (2011)
Energy fraud	175.000.000	€/year	Elsevier (2005) Energiened (2007)
Energy fraud detection	80	%	Faruqui et al (2010a)
Failure cost	3	€/household/year	Gaslicht (2011)
Failure cost reduction	80	%	Faruqui et al (2010a)
Energy use data gathering	39.000.000	€/year	Alliander (2010)
Energy use data gathering cost reduction	90	%	Faruqui et al (2010a)
Energy tax (residents)	0,1121	€/kWh	Rijksoverheid (2011)
Energy tax (residents)	0,1639	€/m3	Rijksoverheid (2011)
Linear implementation assumed over	8	Years	Assumption
Interest rate	5	%	Assumption
Electric vehicles per home in 2020	20	%	Assumption
Reduced grid investment per electric vehicle	10	€/vehicle/year	Hoorik and Westerga (2011)
Reduced energy cost from electric vehicle charging	18	€/household/year	Hoorik and Westerga (2011)
Production energy display/EMS	2,84	*10^3MJ	Socolof et al (2005)
Lifespan meter	40	Years	Assumption
Lifespan display/EMS	40	Years	Assumption

Smart meter enabled trials

Location	Year	Trial size	Trial length	Aim	Configuration	Outcome	Source
California	2005	52 control-71 treatment	5 months	Peak load savings	Unknown	12% peak savings*	Faruqui & Sergici (2010)
California	2004-2005	2004: 104 control-122 treatment; 2005: 101 control-98 treatment	2 years	Peak load savings	GoodWatts System (Smart meter, load control, thermostat, internet gateway)	27-51% peak savings	Faruqui & Sergici (2010)
California	2003-2004	2500 customers	18 months	Peak load savings	Smart Thermostat**	2,2-27% peak savings***	Faruqui & Sergici (2010)
Colorado	2006-2007	1350 control-2349 treatment	1 year	Peak load savings	Ac Cycling Switch and PCT**	2,51-54,22% peak savings***	Faruqui & Sergici (2010)
Florida	2000-2001	2300 customers	2 years	Peak load savings	Appliance control	22-41% peak savings	Faruqui & Sergici (2010)
France	1996-current	400,000 customers	15 years	Peak load savings	Cost announcements	-0,79 price elasticity****	Faruqui & Sergici (2010)
Idaho	2005-2006	TOD: 420 control-85 treatment; EW: 355 control-68 treatment	2 summers	Peak load savings	Cost announcements	0-1,26 kWh savings per peak hour	Faruqui & Sergici (2010)
Illinois	2003-2006	1500 customers	2 years	Peak load savings	AC Cycling Switch, Glass Orb***** and Cost announcements	3-4% energy savings during the summer	Faruqui & Sergici (2010)
Missouri	2004-2005	TOU: 89 control-88 treatment; TOU/CPP: 89 control-85 treatment; TOU/CPPw: 117 control-77 treatment	2 summers	Peak load savings	Cost announcements and smart thermostat*	0-35% energy savings *** (12-35% for the most advanced technology group)	Faruqui & Sergici (2010)

New Jersey	1997	Unknown	4 months	Peak load savings	Cost announcements	26% peak shifting and 4,9% energy savings	Faruqui & Sergici (2010)
New Jersey	2006-2007	450 control-836 treatment	2 summers	Peak load savings	Cost announcements and smart thermostat*	3-21% peak savings without PCT; 21-47% 0peak savings with PCT	Faruqui & Sergici (2010)
New South Wales	2006	TOU: 50000 customers; SPS: 1300 treatment	1 year	Peak load savings	Cost announcements	20-24% peak savings	Faruqui & Sergici (2010)
Ontario	2006-2007	125 control-373 treatment	8 months	Peak load savings	Cost announcements	2,4-11,9% peak shifting; 6,0% energy savings	Faruqui & Sergici (2010)
Washington	2001-2002	300,000 customers	2 years	Peak load savings	Pricing scheme	5% peak savings	Faruqui & Sergici (2010)
Washington and Oregon	2005	28 control-84 treatment	9 months	Peak load savings	High speed internet, electric HVAV system, electric water heater and electric dryer, two way communication system, price signals.	0-21% energy savings***	Faruqui & Sergici (2010)
The Netherlands	2009-2010	189 survey-54 detailed	15 months	Energy savings	Meter + display	7,8-1,9% energy savings (after 4-15 months)	Dam et al (2010)
Norway	1995-1997	2000 households	3 years	Energy savings	Increased billing frequency and accuracy	8-10% energy savings	Darby (2010)
Sweden	1995	600 households	unknown	Energy savings	Increased billing frequency and accuracy	0% energy savings	Darby (2010)
USA	Current	10,000,000 households	Unknown	Energy savings	Independently offered increased billing frequency and accuracy	1,5-3,5% energy savings	Darby (2010)
Ontario	2006	382 households	1 year	Energy savings	Power Cost Monitor	6,5% energy savings	Darby (2010)
Oregon	Uknown	365 households	unknown	Energy savings	Power Cost Monitor	0% energy savings	Darby (2010)

Newfoundland and Labrador	Uknown	Unknown (small sample)	unknown	Energy savings	Power Cost Monitor and electric water heater	22% energy savings	Darby (2010)
Ontario	2009	30,000 households	unknown	Energy savings	Power Cost Monitor	4,5-6,7% energy savings	Darby (2010)
Massachusetts	2009	3,500 households	unknown	Energy savings	Power Cost Monitor	1,9-2,9% energy savings	Darby (2010)
The Netherlands	2009	14 control-18 treatment	3 winter months	Energy savings	Power Cost Monitor	4% electricity and 13% gas savings	Darby (2010)
Denmark	Uknown	Unknown	unknown	Energy savings	Interactive website	17% energy savings	Darby (2010)
Groningen	2006	300 households	5 months	Energy savings	Interactive website	4,3% energy savings	Darby (2010)
Maine	2010	91 high-consumption households	1 year	Energy savings	Smart Meter + interactive website	9,3% energy savings	Darby (2010)
The Netherlands	2004	150 households	2 years	Energy savings	Energy community	17-20% gas and 5-8% electricity savings	Darby (2010)
United Kingdom	2009	Households in 8 streets	unknown	Energy savings	Energy community	25% energy savings	Darby (2010)
New South Wales	2009	144 students in 8 person cottages	26 weeks	Energy savings	Smart meter + ecometer	20% electricity and 19% gas savings	Darby (2010)

* Peak savings can be peak shifting to off peak hours or actual energy savings, not all programs define the difference.

** Only provided to some customers

*** Depending on the technology and program used

**** No savings data

***** Lamp with different colours depending on the current energy price

Detailed statistics

Electricity use

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Daily2011corrected	7,1630	29	3,75892	,69801
	Daily2010	6,8248	29	3,37467	,62666

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Daily2011corrected & Daily2010	29	,916	,000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Daily2011corrected – Daily2010	,33817	1,51199	,28077	-,23696	,91330	1,204	28	,239

Natural gas use

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Daily2011corrected	3,5696	28	1,52516	,28823
	Daily2010	3,4379	28	1,33463	,25222

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Daily2011corrected & Daily2010	28	,866	,000

Paired Samples Test

	Paired Differences	t	df	Sig. (2-tailed)

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Daily2011corrected – Daily2010	,13171	,76364	,14431	-,16440	,42782	,913	27	,369