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Governance of innovation: the case of advanced metering

Master Thesis

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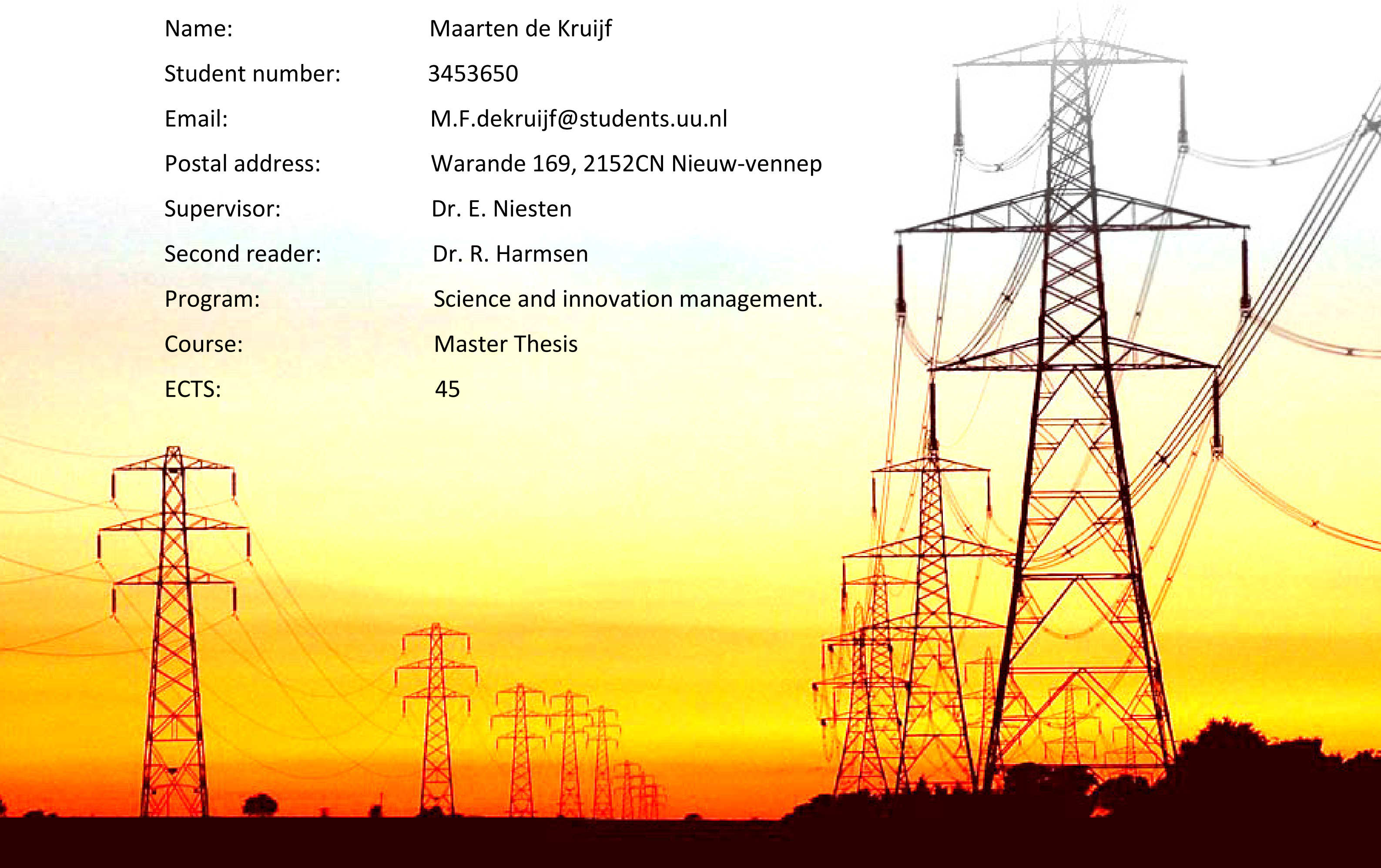

Abstract

Major innovations in the electricity system are necessary to prepare for the coming transition to new forms of mobility and electricity generation. One step in this direction is the implementation of advanced metering infrastructures (AMI). The organization of this process is in many cases, like the EU, influenced by the liberalization and subsequent unbundling of the electricity industry. This research sets out to uncover how the organization of an innovation like advanced metering infrastructures differs between an unbundled and vertically integrated industry. Transaction cost economics (TCE) argues that policy makers in competitive environments adopt organizational forms that align with the attributes of the transaction they support. It is argued that unbundling influences this process because it forces certain organizational forms on an industry. The standard transaction cost framework is extended in this study to take the innovative nature of this development into account. To this end the transaction attributes of product complexity, systemic nature and appropriability regime have been added to the TCE framework. A comparative case study between the Swiss vertically integrated and Dutch unbundled electricity industries was conducted and in each case, five smart metering projects were studied. The transactions, modes of governance and innovative performance were identified in each subcase. The difference between the two case studies showed that firms in unbundled industries found ways to avoid the limitations imposed by unbundling. In the unbundled sector it was found that applying a regulatory mode of governance or lowering asset specificity, are ways of circumventing the limitations posed by unbundling. The regulatory mode of governance was found to address the need for more coordination in the development process due to the systemic nature of the innovation and to lower the behavioral uncertainty of the transactions. However, the comparison has also shown that certain transactions are being avoided in the unbundled industry which limits innovative performance. The results of this research can be used to get a better insight into the role of innovation in transaction cost theory.

Keywords: Transaction cost economics (TCE), Smart metering, Unbundling, advanced metering infrastructures (AMI), systemic innovation.

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1 Introduction

Present day electricity grids have predominantly been developed before the 1970's and are faced with many challenges. Some challenges are caused by the aging of the infrastructure, but most are caused by changes in the environment (ETP, 2010). Changes in the environment entail global warming and the depletion of fossil fuels, which have stimulated the development of new distributed ways of electricity generation, such as solar and wind power. It has also spurred the development of new transport options such as electric vehicles or plug-in hybrid vehicles.

Facilitating these developments creates challenges for the electrical grid. Distributed generation requires new ways of managing and balancing the load on the electrical grid. A rising number of electric vehicles will cause peak demands for electricity that could overload the grid capacity and the aging of the infrastructure has made ensuring the reliability of the electricity system a pressing issue (IEA, 2011). The challenge is to facilitate these developments by creating smart solutions which will stimulate the efficient use of electricity and limit the necessity to expand network capacity.

An innovative solution that is currently being implemented to help overcome some of these challenges is advanced metering infrastructures (AMI). AMI comprehends the entire infrastructure to measure, collect and exchange information about electricity consumption and production digitally. AMI also enables two-way communication about electricity prices and the consumption of electricity, between the distributor/supplier and the consumer (Woo, 2008). The implementation of AMI consists of installing smart meters[1] in the homes of consumers, connecting the meters to a communication network and creating data management systems (IEA, 2011).

The main advantage of real time data regarding the electricity use of consumers is that it allows distribution system operators (DSOs) and electricity suppliers to steer consumer demand in real time. Variable electricity tariffs combined with real time information on electricity use will help limit peak demands and help to make better use of green energy of which the offer may fluctuate due to the weather conditions (Woo, 2008). For example, when demand is high the price of electricity may go up. This will stimulate consumers to postpone using their tumble dryer or charging their electric vehicle. All stakeholders directly involved, such as DSOs, energy suppliers, metering companies and consumers, can potentially benefit from the implementation of AMI. The benefits of AMI include lower meter reading cost, better theft detection, remote connection and disconnection, better energy diagnostics and less investments needed in grid capacity.

1.1 Research problem

The development of AMI requires a joint effort by the energy suppliers, equipment suppliers and distribution system operators (ETP, 2010). Investments in the electricity network and software need to be coordinated. For example, it must be possible for the information systems of DSOs and energy suppliers to exchange data and to communicate with the smart metering infrastructure. The coordination issue raises questions regarding *what the most efficient governance and regulatory structures are* to facilitate the development of this innovation (IEA, 2011). The major structural changes in governance structures, which have taken place in many electricity sectors in the past decade, complicate coordinating the development of advanced metering infrastructures. These structural changes have been driven by the rational to create a competitive energy sector. The electricity sector needed to be unbundled to become competitive, this process was initiated in Europe by the European Commission in the early 90's (Niesten, 2006). The formerly integrated

[1] The European Smart Meters Industry Group (ESMIG) defines four minimum functionalities of a smart meter: remote reading, two way communication, support for advanced tariff and payment systems, and remote disablement and enablement of supply.

electricity companies are now split up in competitive segments, such as the generation and supply of electricity and natural monopoly segments like transmission and distribution (Joskow, 1996).

A large body of research addressing the efficiency of governance structures is based on transaction cost economics (TCE). The term governance structure relates to the way transactions or activities are organized, which can be done through the market, the firm or hybrid modes such as alliances. Transaction cost theory analyses the efficiency of governance structures by focusing on the transactions and how they align with governance structures. The basic argument of TCE (Williamson 1996) can be summarized as follows; in competitive environments the market forces lead decision makers to adopt organizational forms that align with the attributes of transactions they support. This raises the interesting questions about what happens when a mode of governance is imposed upon an industry by regulators, as is the case with the electricity industry.

TCE based literature that investigated this issue like Joskow (1996), Crocker (1996) and Fetz & Filippini (2010) found that the specific efficiencies created by vertical integration are compromised by unbundling the electricity sector. Yvrande-Billon and Menard (2005) found in their study of the unbundled British railway sector, that firms tried to adjust the transaction attributes to fit the newly imposed modes of governances or tried to revise the mode of governance by trying to influence regulations. However, the effects of unbundling on innovation are not covered in these studies.

Williamson (1991) argues that the introduction of innovation complicates the transaction cost analysis and additional attributes of transactions need to be taken into consideration (Williamson, 1991). TCE research that addresses these kinds of transactions is limited. Pisano (1990), De Figueiredo & Teece (1996) and Sampson (2004) provide different insights about which attributes of innovation transactions influence the alignment with governance structures. Sampson (2004) also found empirical evidence for the fact that misalignment limits the innovative performance of firms.

The current insights on unbundling and innovation transactions are combined in this study to investigate how transactions, governance structures and innovative performance differ between vertically integrated and unbundled electricity sectors. A comparative case study approach will be taken to study the effects of unbundling on innovation. A comparison will be drawn between the Dutch unbundled electricity sector and the Swiss vertically integrated sector.

1.2 Research question

The electricity sector faces significant challenges which call for new innovative technologies and solutions such as AMI. Getting a better understanding of how innovation in the electricity grid is affected by unbundling could help make current and future innovations in the electricity sector more successful. This research is therefore concerned with the following research question:

"How do the transactions, governance structures and innovative performance of advanced metering infrastructures differ between the Dutch unbundled and the Swiss integrated electricity sector?"

The following sub questions are posited to provide an answer to the main research question:

1. What are the transactions and attributes in the development of an advanced metering infrastructure and how do they compare between the Dutch and Swiss electricity sector?
2. Which governance structures do the Dutch and Swiss energy firms apply to develop advanced metering structures and how do they compare?
3. How successful have firms in the Dutch and Swiss electricity sectors been in implementing advanced metering infrastructures?

Even though the results of this research will only directly apply to firms in the Swiss and Dutch electricity sector, it could also inform policy makers in other nations and other sectors, about the possible consequences of unbundling and its effects on innovation. This case study will also contribute to a better understanding of the concept of innovation within the theoretical framework of TCE.

1.3 Outline of the thesis

The next chapter will discuss the case backgrounds and explain why the cases of Switzerland and the Netherlands have been chosen. Chapter 3 will explain what advanced metering infrastructures are and what the possible benefits of such systems are. Chapter 4 explains what transaction cost theory entails and how it has been supplemented to incorporate innovation. The methodological approach has been explained in chapter 5. The Swiss results concerning the modes of governance and transaction attributes have been worked out in chapter 6. In chapter 7 this is repeated for the Dutch case. The innovative performance of the Swiss and Dutch cases is discussed in chapter 8 and a comparison between the two cases is drawn in chapter 9. The answer to the main research question is discussed in chapter 10 and the limitations of this research, and propositions for future research are discussed in chapter 11.

2 Case background

Electricity sectors around the world have very similar features and operate therefore in quite similar ways. The physical supply of electricity can be divided into three separated functions (Joskow, 1996).

1. *The generation of electricity*, through the means of water power, internal combustion engines, solar panels or windmills. And through the use of steam turbines powered by uranium, coal, natural gas and bio mass.
2. *The transmission of electricity* refers to the transportation of electricity through high voltage (110 kV and above) three-phase alternating current (AC). The transportation takes place between de generation sites and regional distribution centers and is operated by transmission system operators (TSO). Transmission lines also connect the national grid to grids of neighboring countries. An important function of the transmission grid is balancing out the differences between supply and demand
3. *The distribution of electricity* entails the transportation of electricity through medium and low voltage power lines to homes and businesses by distribution system operators (DSO).

Some electricity sectors have been unbundled to make competition possible between energy companies. Unbundling entails the separation of the above outlined functionalities of electricity supply. The natural monopoly segments, such as distribution and transmission, remain monopolies, however generation is liberalized and subject to competition. A separate function besides the physical supply of electricity is the retail of electricity. Some electricity retailers (Electricity suppliers from here on) are integrated into generation, but this is not necessarily always the case. It is also possible for retailers to buy electricity supply in the market.

In unbundled energy sectors there are additional parties active which are part of the energy market or facilitate competition. These parties are traders, brokers and balance responsible parties and new entrant such as independent energy producers. (Netbeheer Nederland, 2011). In unbundled electricity sectors, competition and sector specific authorities also play a large role, which is to ensure fair competition between the market parties. Besides parties that operate in the vertical electricity supply chain, there are peripheral parties which are not directly involved in the supply of electricity. These are companies such as consultancy firms, equipment manufacturers, ICT companies, maintenance and development contractors, investors and consumer associations. These actors all facilitate in the development of AMI by supplying knowledge, developing hardware and software or installing systems. A schematic oversight of the actors is presented in figure 1

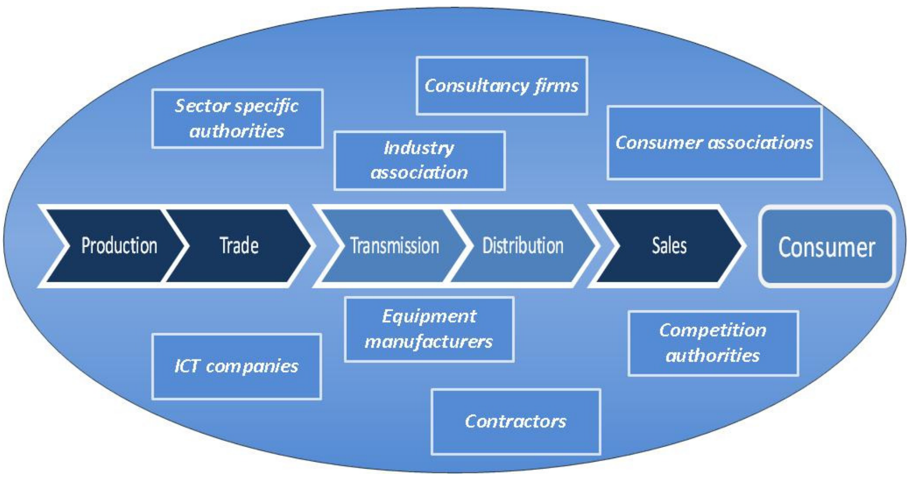


Figure 1. *Actors involved in the development of AMI surrounding the electricity value chain. The dark chevrons represent the liberalized parts of the electricity value chain. The Light colored chevrons represent the natural monopoly segments.*

2.1 The Dutch electricity sector

The Dutch electricity sector has been unbundled, which has led to the division of the Dutch energy firms into separate generation, transmission and distribution companies. The liberalization of the Dutch electricity sector is enshrined in the Electricity Act of 1998 (Netbeheer Nederland, 2011). This was in line with the first European electricity directive[2]. This act required energy firms to unbundle legally, which meant that the functions of network management and commercial activities needed to be placed in separated entities (Baarsma, 2007). Current Dutch legislation states that from 2011 on, all energy companies need to have implemented ownership unbundling. This is the most extensive form of unbundling, where the different company functions of distribution and supply are not only placed in a different legal entity, but also need to have different ownership and cannot be owned by electricity generating and supplying firms.

2.2 The Swiss electricity sector

The Swiss power market is characterized by vertical integration and has only been deregulated partially. Large consumers (Consumption of more than 100.000 kWh annually) have, since the implementation of the Electricity Supply Act (StromVG) in January 2008, the possibility to choose their own electricity suppliers[3]. For small consumers this should be possible five years after the enforcement of the StromVG. However, this decision is still subject to an optional referendum.

The largest electricity companies in Switzerland, which are municipal/canton owned, and are integrated into generation, transmission, distribution and supply. The four largest electricity companies control about 80% of the electricity production and are combined the owners of the transmission grid. One thing that will change in the coming years it that the new Electricity Supply Act states that a separate nationwide transmission system operator needs to be established. This new TSO entity is called Swissgrid and operates all transmission lines above 220 kV. In 2013, Swissgrid is to assume ownership of the 6,700 kilometer-long Swiss transmission system. The energy firms will therefore be able to *remain* integrated into distribution and were up until 2013 also integrated into transmission.

[2] First liberalization directives, EC, 1996

[3] www.strom.ch

3 Advanced metering infrastructures

Advanced metering infrastructures (AMI) comprehend the entire infrastructure to measure, collect and exchange information about electricity consumption and production. A major part of the implementation of AMI consists of the installation of smart meters. The meter aspect of the system stays the same, whether it's smart or not, the meter is used to measure the consumption of electricity and in some cases also gas and water. This research, however, focuses only on the metering of electricity, as this also could have larger applications and benefits in the light of smart grids.

However what puts the *smart* in smart metering is *how* the data about consumption is measured stored and communicated and *what* is being done with it. Standard electricity meters are usually analog and use induction to measure the amount of kWh's that have been consumed. The analog meter is read at two points in time so the electricity company can calculate how much electricity has been consumed during that period. This is a manual process which requires someone to come round to visit the consumer and read the meter. A smart meter measures the electricity consumption and production digitally. This makes it possible to store the data and provide insights about the energy use at specific points in time. The data that is measured is collected in the head-end system of the meter. The head-end system is able to communicate with the advanced metering infrastructure so it is able to transfer the data to the party operating the system. It is also possible to connect the head-end system to an in-home display to visualize real time or interval based data about electricity consumption. Two-way communication is also possible depending on how advanced the system is set up. This provides new possibilities for energy and distribution companies, because it allows them to control the energy flow better, but also send tariff signals. Technically the smart meter provides the following new capabilities (Gerwen et al., 2006):

- Real time registration of electricity use and/or local generated electricity (e.g. Through photovoltaic's or wind);
- Remote meter reading (on demand);
- Remote limitation of throughput through the meter (e.g. cutting of electricity);
- Connection to local devices (e.g. energy display, smart appliances);
- Possibilities to connect other types of meters (e.g. gas or water);

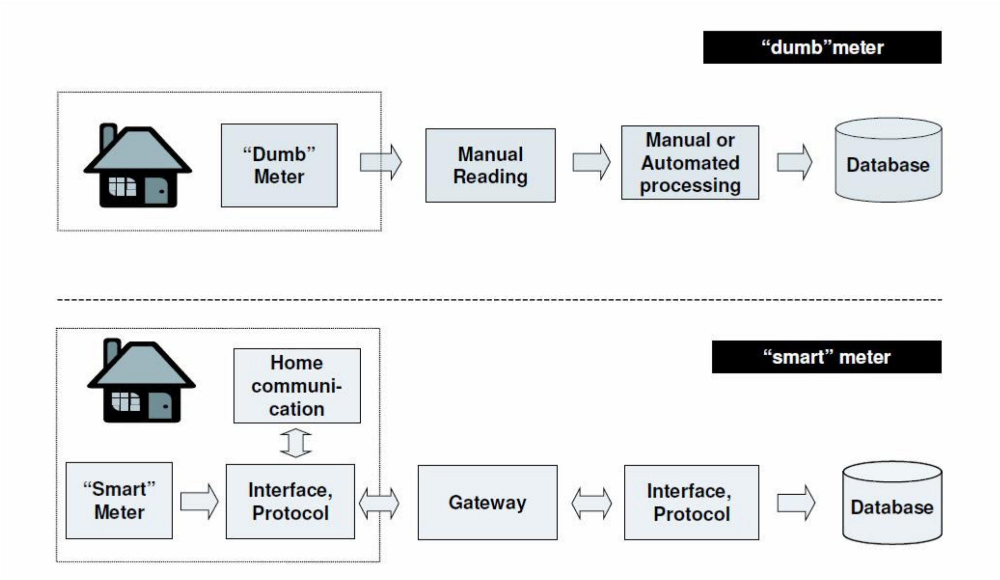


Figure 2. New and old metering process (Kema, 2006)

The new and old metering processes are displayed in figure 2. This image shows that the data will no longer only flow in one direction, but that the data will flow in two directions. Changes along the whole system are made, from the consumer side to the network side.

3.1 Consumer benefits

Installing a smart meter provides the consumers with some straight forward benefits. A smart meter can provide much more accurate information about energy consumption. This information can be provided through multiple mechanisms like in-house displays, online or mobile applications, or informative billing (Haney et al., 2009). In some cases it is even imaginable that consumers receive information about the energy use of similar consumers as to gage their electricity consumption. Studies have shown that consumers receiving direct feedback about their electricity use reduce their consumption by 5 to 15%, whereas indirect feedback generally is found to lead to a reduced consumption of 0 to 10% (Darby, 2006). Smart meters can also improve the service level, by providing the possibility of monthly and more accurate billing. The process of moving to a different house or switching between electricity suppliers could also be simplified by the introduction of AMI. These types of benefits can be classified as operational benefits.

The remaining benefits come from demand side participation also referred to as demand response, which focuses on limiting 'peak' demands. These 'peak' demands occur in the top 1% hours of the year. This requires installing peak generation capacity that is used less than a hundred hours a year, and additional grid capacity to cope with these peak demands. The prognosis is that these peak demands will only grow more out of proportion with the base load because of intermittent generation (PV and wind) and electric vehicles. Such a scenario is projected in figure 3. The most opportune way to try and reduce peak demands is to provide accurate price signals to customers that convey the true cost of power – that is, implement dynamic pricing. By giving consumers price signals they can decide whether to continue consuming power or wait till the prices drop. This will help shave off peak demands and can save consumers substantial amounts of money (Faruqui, 2010).

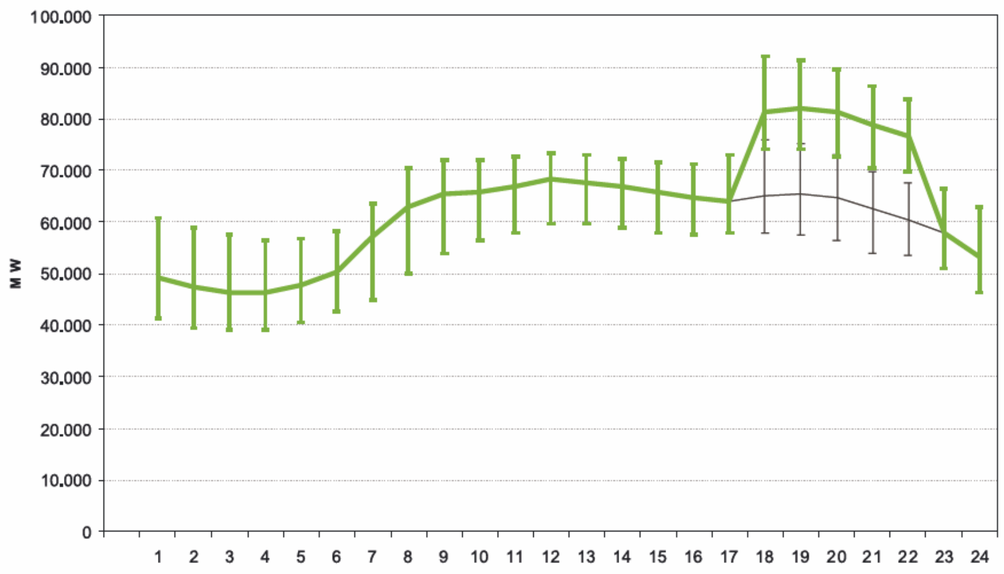


Figure 3: Average electricity demand on a Wednesday in Germany (black line) displayed against a scenario of 20 million electric vehicles (green line). (WWF, 2009).

3.2 Benefits for firms in the electricity value chain

The implementation of smart metering provides benefits to most parties in the electricity value chain. These benefits can be either of a cost saving or service enhancing nature. The first and most obvious source of cost reductions come from the possibility of reading the meters centrally, which improves the efficiency of the metering service. The party that benefits the most from this is the party who is responsible for reading the meter. Even though the avoided cost of meter reading is seen as the most substantial cost reduction, its relative advantage differs between firms and regions. Smart metering, for example, allows for better fraud detection, which was in Italy one of the main drivers of the business case (Rousseau, 2007). In other cases, such as in Basel, it proved a very efficient solution to cutting off power to clients who did not pay their bills (source; IWB).

Electricity providers are also able to provide more and better services because billing data is more accurate, which will lead to fewer complaints. It also opens up possibilities for electricity suppliers to apply new sales or business models. New energy data services could be provided and different ways of billing can more easily be applied, such as prepaid billing or the implementation of dynamic tariffs.

Dynamic tariffs are a major part of demand response programs, which, as explained above, are focused on lowering peak demands. Smart meters make dynamic tariffs possible because they can both record interval data about electricity consumption and receive signals about price changes and display these to the consumer. Lower peak demands mean that there is less need for the installation of peak generation capacity. Demand response programs could also provide an effective way to make more efficient use of renewable energy sources such as wind and solar power. The production of wind and solar power fluctuates a lot as weather circumstances change. Dynamic tariffs could shift demand to timeframes where supply of renewable energy is the highest. Demand response also reduces the need to expand network capacity. These are long run benefits but have been found difficult to quantify, because these are heavily dependent on system configuration which varies by region (Faruqui et al, 2010). The benefits of lower investment in capacity and generation both accrue to the transmission and distribution system operators.

4 Theoretical framework

A transaction cost theory framework has been applied to get a better understanding of how unbundling affects the development of advanced metering infrastructures. Transaction cost economics (TCE) distinguishes itself from neo-classical economics by describing firms in organizational terms (modes of governance) and not in neo-classical terms (as production functions). The basic insight of TCE is that transactions of every kind need to be governed and generate transaction cost. Depending on the type of transaction some modes of governance are more efficient than others (Williamson 1985). TCE provides a relevant perspective for studying the topic of unbundling, as unbundling affects firms in their ability to apply certain governance structures.

The basic tenets of the TCE perspective were introduced by Coase (1937). He combined insights from law, economics and organization into one perspective. He suggested that the question of organizing transactions internal to a firm (hierarchically) or between firms (in the market), should be regarded as a decision variable. This decision should depend on transaction cost. Underlying the notion of transaction cost are the behavioral assumptions of bounded rationality and opportunism. Herbert Simon's notion of bounded rationality assumes that humans are *intendedly* rational but only *limitedly* so (Simon, 1976). Williamson adds, that agents might show acts of opportunism, through which the agent is self-interest seeking and might act misleading or deceiving (Williamson, 1985). The consequence of bounded rationally and the threat of opportunism, is that contracts or agreements are inevitably and effectively incomplete. The incompleteness arises from the fact that humans are limited in their capability to plan for all possible future contingencies and for the contracting parties to successfully negotiate and communicate plans to deal with these contingencies in advance. The economic consequence of contractual incompleteness is that circumstances which are not accounted for in the contract, could lead to costly renegotiations and arguing about the contractual terms. Especially problematic are circumstances where one of the parties acts misleading and thereby placing the other party at a disadvantage. This leads to the insight that we need ex post governance structures, such as hybrids and hierarchies to supplement the incomplete contracts.

The predictive framework of transaction cost economics is largely based on the behavioral assumptions of bounded rationality and opportunism and applied in what Williamson (1985) calls the discriminating alignment hypothesis. This hypothesis states that transactions, which differ in their attributes, need to be aligned with governance structures, which differ in their cost and competence, to economize on transaction cost.

Governance structures are generally described in TCE literature as either vertically integrated hierarchies, hybrids or markets. Vertical integration also, referred to as hierarchy, is the governance of transactions through a formal organization. The polar extreme of this mode of governance are transactions which are governed through the market. Hybrid forms such as long term contracting, franchising, strategic alliances and joint ventures are in between these two modes of governance. Attributes of the modes of governance are described by Williamson (1991) as incentive intensity, administrative control and the contract law regime. Incentive intensity represents the stimulus for firms to work efficiently and to be competitive. The intensity is higher in the market because of the direct competition with other firms and the bureaucratic limitations of hierarchies. On the other hand, hierarchies have better administrative controls, which allow firms to monitor and coordinate more efficiently. The contract law regime refers to the way disputes are settled. In market transactions, disputes are usually settled through court ordering, whereas hierarchies will most likely solve disputes internally. The mode of conflict resolution applied in hybrid modes of governance is mixed, such as arbitrage by a third party. Table 1 provides an overview of how the aforementioned attributes match with the respective governance structures.

Attributes	**Governance structure**		
	Market	**Hybrid**	**Firm / Hierarchy**
Incentive intensity	High	Intermediate	Low
Administrative control	Low	Intermediate	High
Contract law	Court ordering	Mixed	Internal dispute resolution

Table 1. Dimensions of governance

The discriminating alignment hypothesis argues that transactions need to be matched in a discriminating way with governance structures to create the highest efficiency. The attributes of the transaction determine the mode of governance in this matching process. Asset specificity is considered the most important attribute of transactions in the TCE literature. Williamson describes asset specificity as follows: '*Asset specificity has reference to the degree to which an asset can be redeployed to alternative uses and by alternative users without sacrifice of productive value' (Williamson 1991. p.281*). Asset specificity creates contracting hazards because such investments are generally not re-deployable and have little value if one of the contracting parties backs out of the agreement or does not perform as expected. Firms will want to protect themselves against the hazards created by potential investment devaluation in asset specific transactions. This makes writing contracts, monitoring performance and settling disputes more elaborate and costly. Contracts provide limited safeguards and as the degree of specificity goes up, it becomes more efficient to organize transactions in hybrid governance modes or to integrate the transaction into the firm (Williamson, 1999). Hierarchies or hybrid modes of governance allow for better monitoring of the transactions and provide better safeguards against the possible loss of the investments made.

A second attribute of transactions, commonly considered in the alignment analysis, is behavioral uncertainty. Behavioral uncertainty is the uncertainty that is created when contracting parties may behave opportunistically. Behavioral uncertainty grows as the possibilities of opportunism grow more numerous or the consequences of such acts become more severe (Williamson, 1991). In transactions where assets are non-specific, this has little relevance because new deals can be made easily elsewhere in the market. This is no longer the case when asset specific investments are involved. In this case both contracting parties will benefit from continuity in the trading relationship and will attempt to work things out contractually (Williamson, 1985). This results in higher governance costs due to more complex contracting and monitoring.

Applying the TCE logic, results in the stylized alignments presented in table 2. What can be seen in table two is that the market mode of governance aligns with transactions that involve low degrees of asset specificity. Transactions which involve an intermediate or high degree of asset specificity and behavioral uncertainty respectively align with hybrid or hierarchical modes of governance. Hybrid or hierarchical modes of governance provide more efficient dispute settlement and coordination mechanisms, something that becomes more important as investments become more specific to the transaction.

Governance modes	**Attributes**	
	Asset specificity	Behavioral uncertainty
Market	Low	low-High
Hybrid	Intermediate	Intermediate
Hierarchy	High	High

Table 2. Alignment of transactions attributes with modes of governance.

The main field of study to which transaction cost theory has contributed, is the field of economics (Richman & Macher, 2008). The application of TCE in economics is concerned with when and whether particular governance modes provide efficiency benefits as outlined above. One of the first systematic efforts of researchers to investigate how asset specific investments related to modes of governance was a research by Monteverde and Teece (1982) on the automobile manufacturing industry. They coded qualitative data from surveys to measure asset specificity. This study together with the case studies of Masten (1984) and Anderson and Schmittlein (1984b), provided an important start for the empirical examination of the make-versus-buy decision through a TCE perspective. Since then, a large body of research has focused on explaining the phenomena of vertical integration (make or buy) and long term contracting in industries such as the electricity sector (Joskow, 1985; Crocker 1996), aerospace (Masten, 1989) and the aluminum industry (Stuckey, 1983). More recent papers examine the effects of various types of asset specificity on governance (Nickerson, 2003; Shelanski, 2004) and try to explain the efficiency of a variety of hybrid modes of governance (Elfenbein, 2003; Sampson, 2004). A subject which has been dealt with less in TCE literature is innovation. Williamson (1985, 1991) stated that innovation complicates the analysis of transactions and their alignment. The following section reviews the existing body of TCE literature that covers the subject of innovation.

4.1 Innovation transactions

Williamson (1985) discusses the role of innovation in the vertical integration decisions. Hierarchies have better capabilities concerning the coordination and cooperation between stages of production. However, hierarchies also limit the incentive to innovate compared to market forms of governance. The incentive to innovative is limited by hierarchies because, the benefits of the innovation are generally divided equally, but not according to the actual contribution. This is the case, because unequal division would create large disparities among the production stages. Secondly even if it were possible to correctly and fairly divide the benefits of the innovation, it is generally questionable whether this will be respected by the owners of the firm.

The tradeoff outlined above leads Williamson (1985) to suggest that assets should be categorized according to their innovative potential, which is the degree to which the good or service is susceptible to cost-saving improvements. For assets with low innovative potential, the earlier argument made about alignment remains intact (that of asset specificity and uncertainty), but for assets with innovative potential it is different. Assets with innovative potential can be divided into generic or proprietary cost savings. Market procurement is the most economic option when generic cost savings are involved. Market procurement is less suited for innovation transactions that involve proprietary cost savings, because these are generally associated with asset specific investments. However, as discussed earlier, hierarchies impair the incentives to innovate. Williamson (1985) suggests that this complex trade off calls for hybrid forms of governance. Additionally, hybrid modes of governance are generally faster in their response in regimes of rapid innovation than hierarchies. Nonetheless, the notion of proprietary cost saving remains quite vague and has not been fully operationalized by Williamson (1985). Williamson concludes by stating more study is needed regarding the relation between organization and innovation.

There are several other TCE based studies that investigate and acknowledge other attributes of innovative transactions that might affect alignment with governance structures or provide empirical evidence for this relation. Armour and Teece (1980) suggest that vertical integration supports innovation when important technological interdependencies are involved. They found that there is statistical evidence for the influence of vertical integration on R&D performance in the petroleum industry, but cannot definitively ascribe this to interdependencies in the value chain. Pisano (1991) investigated the influence of innovation on governance. He found that innovation that is characterized by uncertain property rights, transaction-specific assets and complex technology transfer, is mostly organized through vertical integration, where firms integrate into marketing and sales-channels or backwards into new R&D firms. Other governance solutions such as inter-firm collaboration or market contracting are found to be more dominant when these innovation characteristics are not present.

De Figueiredo and Teece (1996) acknowledge that the standard attributes of asset specificity and uncertainty are of importance for analyzing alignment in innovation transactions. De Figueiredo and Teece also suggest that other attributes of innovative transactions need to be taken into account. Product complexity is one of these attributes, which has also been suggested by Pisano (1991). As products become more complex it becomes more difficult to monitor and coordinate the performance of the transaction, thereby creating contractual hazards for the transacting parties. De Figueiredo and Teece (1996) also suggest that the systemic nature of the innovation is an important attribute in the alignment of innovation transactions. A distinction is made between innovations which are of an autonomous kind and of a systemic kind. Autonomous innovations can be implemented or developed independently from other innovations. Systemic innovations can only be realized in combination with the development of other complementary innovations. The consequence is that systemic innovations need more and better coordination concerning development and investments. Systemic innovations are therefore more efficiently organized in a hybrid or hierarchical mode of governance (Chesbrough & Teece, 1996). An example of a systemic innovation is the Polaroid camera which was not only an innovation of camera hardware, but also required new film technology.

De Figueiredo and Teece (1996) also suggest that the appropriability regime is an important attribute of innovative transactions. Innovation is generally accompanied with new knowledge which is susceptible to imitation by competitors. This creates a hazard of leakage by which De Figueiredo and Teece (1996) mean the following: *'when we use the term leakage, we do not mean to imply that intellectual property rights have necessarily been violated. We have in mind the quite legal imitation and emulation that takes place in the normal course of business'.* A hazard of leakage poses challenges to how successful firms can appropriate benefits from the innovation. The term appropriability regime was coined by Teece (1986) and determines how severe the hazard of leakage is. The first dimension of this regime is the nature of the technology. This entails whether or not the product can be protected through trade secrets (e.g. the formula of Coca Cola). The second dimension is the effectiveness of legal mechanisms to protect the innovation. A tight regime of appropriability would have a low hazard of leakage, because the innovation is properly protected by either trade secrets or iron clad patents or copyright. A weak regime would provide none of these securities (Teece, 1986). The costs of governing market transactions will go up as a result of the hazard of leakage. Better safeguards for protecting proprietary knowledge are provided in a hierarchy.

Sampson (2004) investigated how misalignment in the governance of alliances affected the R&D performance of firms. She investigated misalignment which caused excessive opportunism hazards and misalignment which caused excessive bureaucracy. Alliances on the market end of the vertical integration spectrum, such as pooling contracts for which the risk of opportunism is high, would more efficiently be organized in hierarchical modes of governance, such as joint equity ventures. This type of misalignment creates excessive opportunism hazards, because the risk of leakage and free riding are insufficiently controlled. This also deters firms from committing an optimal amount of resources to the alliance. Excessive bureaucracy is present in misaligned alliances where the risk of opportunism is low and a less hierarchical mode of governance would provide sufficient safeguards. The result of excessive bureaucracy is that bureaucratic costs are higher than necessary and that innovative activity is dampened by bureaucratic controls. Both forms of misalignment are found to limit innovative activity, but Sampson found that excessive bureaucracy seemed to generate higher cost than misalignment that allowed for excessive hazards. Sampson's study shows that the cost generated by misalignment, whether it is excessive bureaucracy or excessive opportunism hazards, can limit innovative performance.

4.2 Conceptual model

The transaction cost framework discussed in chapter 4.1 has shown empirically that in competitive environments decision makers in firms align their modes of governance with the transaction attributes they support. Unbundling influences this process because it forces certain modes of governance upon an industry which in some cases results in misalignment. Yvrande-Billon and Menard (2005) found that firms adjusted to this situation by adjusting transaction attributes or tried to find a way to adapt regulations or the mode of governance. This study attempts to uncover how unbundling has affected the modes of governance and transaction attributes in the case of developing smart metering infrastructures. Therefore the following propositions are tested;

(1) The transaction attributes will become the decision variable if firms are not able to adjust the mode of governance due to unbundling.

(2) Parties will try to find ways to alter the regulations or modes of governance if there are no possibilities to adjust the transaction attributes.

Subsequently the influence on innovative performance is studied. Sampson (2004) has shown that misalignment reduces the innovative performance of firms. This study therefore also looks at how unbundling affects the innovative performance of firms and tests the following proposition;

(3) Innovative performance will be negatively affected by unbundling if there are no possibilities for adjusting the transaction attributes or modes of governance.

The conceptual model in figure 4 incorporates both the standard transaction attributes and the attributes of innovation transactions, which are complexity, appropriability regime and systemic innovation. It also incorporates the modes of governance and innovative performance. An important assumption in the conceptual model is based on the earlier made argument, that in competitive environments decision makers try to adopt modes of governance to transaction attributes that support each other.

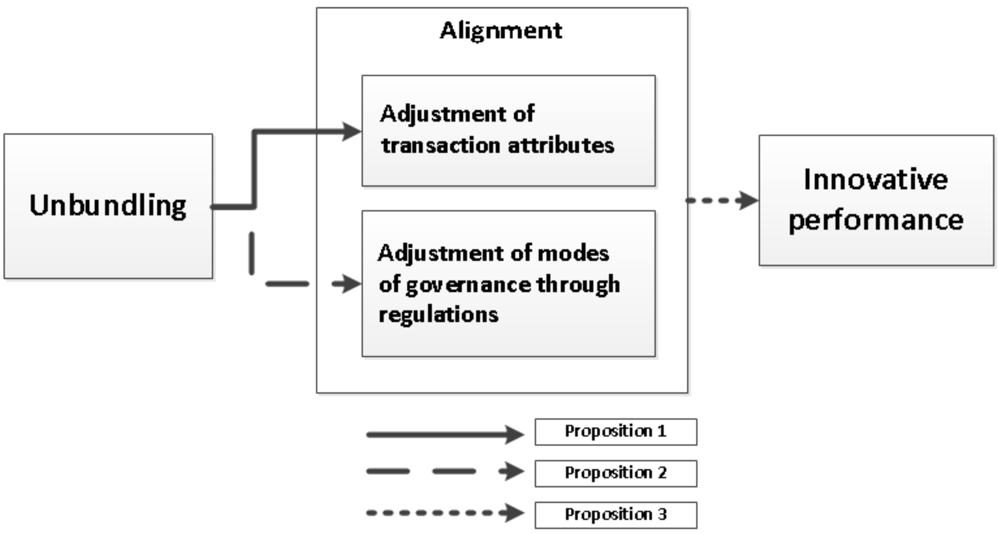


Figure 4. conceptual model.

5 Methodology

5.1 Research strategy

This research is aimed at explaining how unbundling affects transactions, governance and innovative performance. A comparative case study approach will be applied to investigate the effects of unbundling on the development of advanced metering infrastructures. The strength of the case study approach is identifying causal relationships of complex social phenomena in an analytic manner (Ragin, 1987). Case studies allow for in-depth interviews which make it possible to draw accurate inferences about causations. The use of in-depth interviews also increases the internal validity of the findings. Whether the case study approach is an appropriate research strategy can be determined by the three conditions suggested by Yin (2003). From these three conditions can be concluded that this research is suited for a case study approach. Namely, this research is concerned with a '*how*' question, does not require *control over events* and focuses on *contemporary events*.

This research will compare two contrasting cases, which are the unbundled electricity sector of the Netherlands and the vertically integrated electricity sector of Switzerland. Comparing these contrasting cases will provide more evidence on the effects of unbundling on innovative performance than, for example comparing two similar cases (Yin, 2003). The units of analysis, which are innovation transactions, are embedded within these two cases. Yin (2003) refers to this type of research as embedded case studies, because the units of analysis are embedded in larger cases.

5.2 Data acquisition

The main source of data comes from interviews. Within each sector, employees of firms have been interviewed that are responsible for the development or implementation of an advanced metering infrastructure. The interviewed employees mainly consist of project managers, executives or other employees who are directly involved with the development of the advanced metering infrastructure.

The interviews are semi-structured and consist of a series of open questions and a series of factors that needed to be scored by the interviewee. The use of semi-structured interviews is chosen over surveys, because the respondents might not have the same knowledge level as the interviewer and might misinterpret the questions when only a survey is presented (Patton, 2002). Furthermore, interviews make it possible to ask additional questions when the answer remains unclear or might reveal other important factors which were not yet identified in the theoretical literature.

A pilot interview was held with someone in the field of smart metering to see if the questions were relevant and matched the indicators outlined in the conceptual model. The interviews were adapted after the pilot interview with a development and strategy consultant at Landis and Gyr. Table 3 provides an overview of the firms that have been included in this research and the persons interviewed at these firms. The interviews lasted between 45 and 75 minutes. In most cases I visited the companies personally, but some interviews have been conducted by means of Skype and in one case a written answer the interview questions was provided. The interview formats can be found in appendix II and III.

The subcase selection has been based on the smart metering activities of the participating firms. Firms that qualified had developed advanced metering infrastructures and were the main project client. In the Swiss case it was additionally required that the firms were integrated into supply, distribution and generation. A selection of five subcases Switzerland and the Netherlands was made to provide a sufficient representation of the AMI developments in each country.

Country	Actor	Type of firm	Interviewee
CH (pilot)	Landis & Gyr	Manufactures of metering equipment	Development and strategy consultant
CH	Ewz	Integrated supplier of electricity	Project leader field study
CH	IWB	Integrated supplier of electricity	Manager metering services
CH	Ewb	Integrated supplier of electricity	Head of energy measurement
CH	BKW-FMB ag./inergy	Integrated supplier of electricity	Director inergy
CH	CWK	Integrated supplier of electricity	Head of energy Measurement
NL	Delta netwerkbedrijf	Distribution system operator	Project leader
NL	Enexis	Distribution system operator	Manager smart metering operations
NL	Liander	Distribution system operator	Manager rollout
NL	Westland infra	Distribution system operator	Manager marketing and communication
NL	Oxxio	Independent energy supplier	Senior strategic marketeer

Table 3. Oversight of conducted interviews

Interviews were not the only source of data. Other data sources have been used to triangulate the finding in the interviews (Yin, 2003). Sources like public statements, legislation, project documents, product descriptions of manufacturers and industry reports have been used to verify and supplement the interview data. Scientific articles have also been used as data source, like in the assessment of the appropriability regimes. The list of additional data sources has been provided in Appendix I. References to these data sources are made throughout the results section.

5.3 Method of analysis

5.3.1 Comparative analysis

The logic of Mill's method of difference will be applied to compare the results of the two cases. Applying Mill's methods makes it possible to make inferences about which variables are responsible for the observed differences or similarities between the two cases. Comparing *'well selected'* cases makes it possible to make conclusive statements even when the number of cases is as low as two or three (Hanké, 2009).

The method of difference states that when the outcome differs and only one of the possible causal circumstances differs, this is the causal factor that explains the difference between the two outcomes (Ragin, 1987). This method is superior to the method of similarity because it tests both the null hypothesis and the alternative hypothesis.

5.3.2 Data preparation and operationalization

Table 4 presents the operationalized variables which have been described in the conceptual model. Most indicators will be measured on the basis of interviews where after a judgment can be made about the presence or degree of the indicators, this is indicated in table 4 as qualitative measurement. Other indicators are to be scored by the interviewees themselves. A qualitative content analysis method (Flick, 2009) was applied to analyze the collected data. This type of data analysis makes use of categories which have been derived from theory. The interviews have been recorded and were transcribed to get a full oversight of the interview data. The second step was to categorize the data and to assign these categories to the indicators outlined in the conceptual framework. The third step was to interpret the data and reduce the material to useful quotes. The following section will explain how this has been done for each indicator.

Concept	Variable	indicators	Measurement
Governance	Governance structure	Dependent on the degree of vertical integration, hierarchy, hybrid or market.	Nominal
Attributes of innovation transactions	Asset specificity	Site specificity	Qualitative
		Physical asset specificity	Qualitative
		Human asset specificity	Qualitative
		Dedicated assets	Qualitative
	Behavioral uncertainty	Difficulty of measuring performance	Qualitative
	Complexity	Quantity of customized components	Scale
		Hierarchical position in technological system	Qualitative
		Degree of technological novelty	Scale
		Width and depth knowledge and skill input	Qualitative
	Systemic nature	Degree of interdependence	Qualitative
	Appropriability regime	Possibility of trade secrets	Qualitative
		Efficacy of the legal system	Qualitative
Innovative performance	Success of innovation	Remote meter reading	Qualitative
		Smart metering for billing purposes	Qualitative
		Reduction of metering costs	Qualitative
		Faster fraud detection	Qualitative
		Limiting energy throughput	Qualitative
		Monitoring energy demand /forecasts	Qualitative
		Peak shaving	Qualitative

Table 4. Operationalization

Modes of governance

The modes of governance described by transaction cost economics are the market, hybrid or hierarchy. To gain insight into which modes of governance had been applied in each transaction a set of questions was posed to the interviewee. First the participating firms were identified by asking which firms had been responsible for developing certain parts of the advanced metering system. Subsequently it was asked which parts of the system had been developed in-house. Finally the interviewee was asked how the transactions with these firms had been organized. A set of options such as, buying, standard contracts, long term contracts, collaboration, strategic alliance or joint equity ventures were proposed. Buying and standard contracts are considered to be market modes of governance whereas the remaining options are considered to be hybrid modes of governance.

Asset specificity

The degree of asset specificity can be measured through the presence of three types of asset specificity. These are physical and human asset specificity and third, dedicated asset investments (Williamson 1991).

1. Williamson defines *site specificity* as "*where successive stations are located in a cheek-by-jowl relation to each other so as to economize on inventory and transportation expenses*" (Williamson 1991 p.281).
2. *Human asset specificity* refers to investments in relationship specific human capital which mostly results from a process of learning by doing.
3. *Dedicated assets* are *"general investments by a supplier that would not otherwise be made but for the prospect of selling a significant amount of product to a particular customer*" (Joskow, 1988 p.18).

The asset specificity was measured qualitatively, based on the descriptions given by the project leaders. Asset specificity was categorized in low, moderate or high values. Asset specificity was rated *low* when the interviewees indicated to have bought 'off the shelf' or standard products which required no further investments by the supplier. Asset specificity was rated *moderate* when certain adaptions were needed for the client, but part of the product was re-deployable in other transactions. *High* asset specificity occurred in cases that required a fully build to order product that has little to no use outside the transaction and required the supplier to make considerable investments.

Behavioral uncertainty

The behavioral uncertainty was categorized in low, moderate and high values. A commonly applied indicator of behavioral uncertainty in TCE literature is performance ambiguity. Other indicators have also been suggested but have been applied to a lesser extent (Niesten & Jolink, 2012). Performance ambiguity refers to the difficulty for the buyer to assess *ex-post* the performance and adherence to the contractual agreements of a supplier. It is argued that the likelihood of opportunistic behavior goes up as it becomes more difficult to assess performance (Heide, 1990). The interviewees were asked how the performance of the supplying parties was measured and how well the outcomes were observable. Descriptions of the transacted assets have also been used to gain insight into how observable the outcomes of the transactions are. Behavioral uncertainty was ranked low if clear standards and specifications had been outlined by which the companies were able to measure the performance of the smart meter manufacturers. High, if the interviewees indicated that they had difficulty measuring the adherence to the contractual agreements by the suppliers or if performance standards were difficult to develop for that product.

Appropriability regime

The term appropriability regime as explained by Teece (1986) is determined by whether the nature of the technology allows for the application of intellectual property rights (IPR) and the efficacy of the legal system to protect those rights. The presence of patents, trade secrets and copyright is regarded to reinforce the appropriability regime. Scientific literature was consulted to gain insights into the efficacy of certain types of IPR to protect against knowledge leakage. The appropriability regime was rated based on this data, weak, moderate or tight. A tight appropriability regime means that IPR can be applied and can be protected through the law. A weak appropriability regime means that IPR is difficult to apply and can easily be worked around by competing firms. An example is web design, which is often protected through copyright, but this can easily be worked around and is difficult to enforce.

Complexity

The complexity of the advanced metering systems has been measured by the four indicators described by Hobday (1998). Two of those indicators have been scored on a Likert scale by the interviewee. A Likert scale was used because definitive numbers concerning the quantity were generally not readily available and the Likert scales helped provide an estimate. These indicators were the *quantity of customized components* and the *degree of technological novelty*. For the remaining indicators the interviewees were asked if the advanced metering solutions should be regarded as an integral part of the electricity network or should more be regarded towards a standalone solution. This was done to get an indication of how high the AMI systems had been integrated into the electricity network *hierarchy*. Second, the interviewees were asked which types of knowledge input were involved in the development of the advanced metering infrastructures. This was done to get can insight into *the depth and width of knowledge and skill inputs*.

The analysis of the complexity indicators was done by means of a small N analysis which is applied by Moors and Faber (2007) in their investigation of the adoption factors of orphan drugs in the Netherlands. According to Moors and Faber (2007) controlling for the majority counts and averages eliminates the effects of outliers in the datasets. Based on the data each indicator is assigned a value of low, moderate or high which translates into -1, 0 or 1. Adding up the four scores results into a score between -4 and 4. The values ranging from -4 to -2 are rated as not complex. Scores ranging from -1 to 1 are moderately complex and scores above that are rated highly complex

Systemic nature

No empirically tested Indicators of what constitutes a systemic innovation, as described by Chesbrough and Teece (1996), had been developed prior to this research. Advanced metering infrastructure as described in the literature seem to meet Chesbrough and Teece's description of systemic innovation because, multiple innovations and adaption's are necessary to support smart metering. However, additional input by the interviewees was used to verify this observation. Chesbrough and Teece (1996) explain that systemic innovations require considerable amounts of design coordination between different parties and that often certain parts need to be developed in parallel. The interviewees were therefore asked whether coordination had taken place between the transacting parties in the design phase of the system and whether or not certain parts had been developed in parallel.

Innovative performance

The operationalization of innovative performance is based on the realization of the innovative potential of the advanced metering infrastructures. Innovative potential refers the possible benefits and functions that could be developed as a result of advanced metering (Bradford & Florin, 2003). The benefits and functions of advanced metering infrastructures have been discussed in several scientific papers (e.g. Haney, Darbey, 2006; Haney, 2009 & Faruqui et al., 2010) and industry reports (Kema, 2006 & Sustainability First, 2006). This literature has been the basis for the indicators that measure innovative success. The interviewees have been asked about the realization of the following indicators;

- Remote meter reading
- Smart metering is used for billing purposes
- The reduction of metering costs
- Faster fraud detection
- The remote limiting of energy throughput
- Monitoring of energy demand / forecasts
- Peak shaving

The next chapter will discuss the Swiss subcases and the modes of governance that have been applied for organizing the development of the advanced metering structures. Subsequently the observed attributes of the transactions are discussed in detail. The following chapter repeats this process for the Dutch case.

6 Results: Switzerland

Within Switzerland five smart metering projects have been studied, each one serves as a sub-case in the case-study of Switzerland. The five projects have been led and executed by the following companies:

- Project 1: Elektrizitätswerk der Stadt Zürich (ewz)
- Project 2: Industrielle Werke Basel (IWB)
- Project 3: Energie Wasser Bern (ewb)
- Project 4: Bernische Kraftwerke - Forces Motrices Bernoises energie AG (BKW)
- Project 5: Centralschweizerische Kraftwerke AG (CKW AG.)

All projects have in common that they are advanced metering pilots, although the focus of the pilots sometimes differs. What the companies listed above have in common though is the fact that these companies are all integrated into electricity generation, distribution and supply (sales). These firms are in some cases also the suppliers of gas, heat and water. The companies are fully owned by governmental parties with the exception of CKW and BKW-FMB which are only partly owned by governmental parties, although for more than 50%. The first chapter will present the cases, transactions and respective modes of governance. The second chapter discusses the transactions and their attributes in more detail.

6.1 Swiss smart metering cases

6.1.1 Project 1: ewz

The smart metering activities of ewz started in 2008 with a field study which measured how people reacted to information about their energy use. The smart meters that were placed at the homes of the consumers were *not* connected to a data communication network, which meant that it can't be considered as a fully functioning advanced metering infrastructure, however part of the process of setting up a smart metering infrastructure has been worked out. The smart meters were installed at the consumer's house and connected to a separate device which shows the energy use of the consumer graphically (ewz, 2010). There were several reasons for the fact that ewz choose not to hook up the smart meters to their metering system:

"Only one group has smart meters but even those don't really qualify as smart meters, because we have limitations in hooking them up to our system. There are different reasons for that, first of all we don't have a system yet in which it can be implemented, second there are privacy issues that have not been solved yet and third for the study we have to randomize the households so we can't concentrate on one area which would require connecting every meter one by one, which is not feasible". [Project leader field study ewz]

The transactions in this project have been organized the following ways;

1. The development and production of the smart meters was governed by the *market,* as they were purchased from Landis+Gyr.
2. The development of the consumer interface used to display the energy consumption was governed by a *hybrid* mode of governance. Ewz collaborated with a small startup company on the integration and customization of the consumer interface.

6.1.2 Project 2: IWB

The utility company of the city Basel (IWB) started in 2008 with a pilot project where smart meters were installed in 2000 homes. This pilot project was mainly focused on testing available smart metering technologies (IWB, 2010). The second part of the project which is scheduled to start later, will also involve the marketing and sales department of the utility company. The focus there will be looking at possibilities for new pricing strategies. In the reviewed project four main transactions can be distinguished:

1. The development of the smart meter was governed by the *market*. IWB bought the smart meters from its *default meter supplier.*
2. The development of the communication module that is connected to the smart meter was governed by the *Market.* IWB bought the module.
3. The data transfer from the meters to IWB was partly *internalized* and partly organized through the *market*. IWB contracted the use of Swisscom's GPRS network but also connected some of their meters to its own fiber optics network.
4. The development of the advanced meter management software (AMM) was organized through the *market*. IWB bought the software suit from a software development company.

6.1.3 Project 3: ewb

The smart metering project for the city of Bern is a pilot, which involved the installation of 2000 smart meters in the city of Bern. The project was mainly focused on the technological feasibility as ewb's head energy measurement explains:

"It's currently just a test phase, we have installed 2000 smart meters. But we have a different way of looking at the smart meter system. We are not targeting energy reduction on the customer side, but the focus is based on learning which processes are necessary to integrate smart meters into the network. Especially with regards to the meter to cash process." [Ewb head of energy measurement]

The case study identified three main transactions that were organized the following ways;

1. The development of the smart meter was governed by the *market*. Ewb bought the smart meters from Echelon.
2. The data transfer from the meters to ewb was *internalized*. The communication to the meters was handled by means of PLC (power line communication), which meant that ewb used its own power lines for communication purposes.
3. The development of the advanced meter management software was organized through the *market*. Ewb also contracted Echelon for their advanced meter management software (AMM).

6.1.4 Project 4: BKW-FMB

The BKW smart metering project started in 2008. It was one of BKW's pilots that tested new energy related technologies. The smart metering project was named iSmart and focused on studying the power consumption of consumers when they receive feedback on their energy use. About 270 consumers in the city of Ittigen received a smart meter. The smart meters were connected through technologies like UMTS or GRPS. BKW created a public-private partnership called *inergy* to develop the advanced metering infrastructure.

"*We brought some industry partners together like IBM for processes and technologies. We brought Swisscom onboard for communications and customer experience ….. and last but not least we have the city of Ittigen which is where we do the Pilot.'' [Director inergy]*

The case study identified four main transactions in this project that were organized the following ways;

1. The development of the smart meter was governed by the *market*. BKW bought the smart meters from Landis and Gyr.

2. The data transfer from the meters to IWB was organized through the *strategic alliance of inergy*. IWB's alliance partner Swisscom provided access to its wireless data communication network.
3. IBM developed an algorithm for the *inergy* project that allowed household appliances like electric boilers to switch off and on, based on energy demand. IBM was part of the *inergy* strategic alliance which meant that a *hybrid* mode of governance was applied to this transaction.
4. The development of the consumer interface was a *market* transaction. BKW ordered the development of the interface from a small software company.

6.1.5 Project 5: CKW

The advanced metering pilot of the central electricity provider of Switzerland started in 2010. About a 1000 smart meters have been installed and 700 customers are involved. The main focus of the project was learning about consumer behavior regarding smart meters and their electricity use. Additionally, CKW was trying to determine if it's possible to make a business case for a large scale rollout of smart meters (CKW, 2011). The project tested two different price structures. The first group had prices changes four times a day although at fixed levels. In the second group the prices changed as well but were flexible and depended upon the daily electricity markets. The pilot also sets out to test multiple ways of communication with the smart meters. The technologies tested were power line communication (PLC), GPRS (Wireless communication), and DSL (Cable) (CKW, 2012). The electricity consumption is measured in intervals of 15 minutes and consumers are able to monitor their electricity use through an internet portal and a smartphone app. The case study identified four main transactions in this project that were organized the following ways;

1. The development of the smart meter was organized through the *market*. CKW bought the smart meters from Landis and Gyr.
2. The data transfer from the meters to CKW was partly *internalized* and partly organized through the *market*. CKW made use of its own power lines to enable communication; however communication through copper (DSL) or wireless (GPRS) has also been applied. For these last two modes of communication CKW has had to contract other firms.
3. The development and modification of the meter management software was organized through the *market*. CKW contracted the use of Robotron's data management and meter reading software.
4. The development of the consumer interface was organized *internally*. CKW developed the interface itself.

6.2 Transaction attributes

The attributes of the transactions identified in the case descriptions are discussed in detail this chapter. The transactions where overlap between the cases has been found and therefore occur most frequently are discussed in this chapter. The overlap allows for a comparison between the cases. The attributes of each type of transactions will be reviewed and valued according to the descriptions given in the interviews and additional literature. The following transactions will be reviewed;

1. Development of the smart meter
2. Data transfer from the smart meters to the distribution company
3. Development of the data management and meter reading software
4. Development of the customer interface

6.2.1 Development of the smart meter

Asset specificity

The smart meters transactions in all five cases were *low* in asset specificity. From the interviews with the project leaders could be deduced that no special demands or functions had been requested by the electricity companies;

"There we're no real modification concerning the software systems or the technology of the meters. It's just the way you order it." [Manager metering ewb]

"We used a standard smart meter from L&G and used the existing interfaces, e.g. CS connection. So there was no need to discuss any special demands" [director inergy]

The asset specificity in these transactions is rated *low* due to the fact that *no* dedicated investments have been made and there was *no* physical asset specificity involved in this transaction.

Behavioral uncertainty

The behavioral uncertainty in these transactions is rated *low.* The smart meters have clear specifications and there were no special requirements that needed to be fulfilled by the meter manufacturers. It was therefore possible for the utility companies to make a good ex post assessments of the adherence to the contractual agreements by the meter suppliers. Behavioral uncertainty gets lower as the performance of the supplying party is easier to observe.

"The definition of the criteria was more on the technical side. If these criteria were fulfilled, the satisfaction with the company was automatically higher" [Head of energy measurement CKW]

One exception to this observation was found in the case of ewb. Here the behavioral uncertainty was rated *moderate*. The metering manager of ewb explained that there was some difficulty in measuring the outcome of the transactions because they had little experience with such projects and little reference for comparison;

"Yes, it was a little bit difficult (to measure the outcome of the transaction)… First of all it was difficult because we had no experience in a fully integrated metering system like this. So what should we compare our project with? In addition it was difficult to separate the parts of the "meter producer" and "software developer", because the software company is as well the reseller of the meters here in Switzerland". [Manager metering ewb]

Appropriability regime

The technologies in the smart meters are of such a nature that patents are applicable to them. Incorporating IP in standards is also a possibility for appropriating the benefits of the innovation as a *development and strategy employee* at smart meter manufacturer Landis and Gyr explains;

"There are some patents for our smart meters. There is also a coalition that tries to set standards. So what companies try to do is build their IP in that standard and try to push that standard through. The art is more to know in which kind of communication technology to invest, because there are more kinds of technologies competing". [Employee development and strategy of Landis+Gyr]

The fact that smart meters contain patented technologies is also acknowledged in the interviews with the electricity companies;

"The AIM system provided by Landis & Gyr contains proprietary knowledge like the communication protocols, drivers, etc." [Head of energy measurement CKW]

And "We did develop some IP of our own but we didn't patent it. However the smart meter does have some patents on it (owned by the manufacturer)."[Manager metering services IWB]

The applicability of patents and other forms of IP make it that the regime of appropriability is rated *tight* for this transaction. A tight appropriability regime indicates that the technology is well protected from the hazard of leakage (Teece, 1986).

6.2.2 Data transfer from the smart meters to the distribution company

Asset specificity

Three out of the five cases used multiple ways of setting up the communications from the meter to their central databases. BKW, IWB and CKW used communication infrastructures such as GPRS, Power line communication (PLC) or fiber optics (CKW, 2012; IWB, 2010; BKW, 2011). Only ewb's rollout was dedicated to one technology (PLC), and ewz did not make use of any communication infrastructure up to this point. The communication networks used were already present (physically) before the rollout of smart meters and were therefore not developed specifically for these projects. This leads to the conclusion that there have been no dedicated developments or investments for the physical communication infrastructures. This is also supported by the interviews with the respective project leaders;

"..another company which is Swisscom, helped us to make a vpn (virtual private network) for the GPRS so we could communicate safely. …. This is a standard product." [Manager metering services IWB]

And: *"we used standard smart meters from L&G (Landis and Gyr) and used the existing interfaces, e.g. CS connection. So there was no need to discuss any special demands. The same was true for the communications infrastructure where we used standard telecom services like GSM, GPRS of UMTS." [Director inergy]*

Concluding; the communication transaction contained a *low* amount of asset specificity, because no forms of asset-specificity were present in the transaction.

Behavioral uncertainty

The behavioral uncertainty in these transactions has been rated *low*, due to the standard nature of the transaction and the good measurability of the outcome. In general the outcome of the transaction, which is "transferred data", can clearly be observed by the electricity companies and serves as an indicator to measure the adherence to the contractual agreements of the supplier (Anderson, 1985). This is supported by the observation that CKW actively tests this, because CKW is evaluating multiple modes of data transfer for its smart metering purposes (CKW, 2012). The results of these tests were not known while writing this report.

Appropriability regime

There has been no mentioning of any patents or trade secrets that were applied to protect proprietary knowledge for setting up the data communication infrastructures. However, leveraging profits from this innovation is in the case of data communication mainly determined by the ownership of the data infrastructure and GPRS/UMTS licenses. These licenses are held by four providers of mobile data services in Switzerland of which Swisscom is the largest (DETEC, 2005). This license model makes it easier for Swisscom to leverage its IP as there are only three other competitors. The nature of this technology restricts competition from entering the market because the investments are highly capital intensive (Harmantzis & Tanguturi, 2007). This leads to the conclusion that these transactions have a *tight* appropriability regime.

6.2.3 Development the data and meter management software

Asset specificity

The transaction of the data and meter management software was observed in the cases of ewb, CKW and IWB. The meter management and data software manages the smart meters and the data transferred from the meters. These systems can then be linked to other software applications such as consumer interfaces, analytical tools or enterprise resource systems. IWB and ewb indicated that they bought a standard system and that the contracted parties did not develop any specific features for them. Ewb worked with Echelon for the software that is used to read out the meters and collect the data. This software is called LonWorks and can according to the product description be applied in multiple situations from smart metering to smart buildings (Echelon, 2010). No dedicated investments have been made for this project by the software developers. This is also underwritten by the meter manager of ewb;

"I guess there were no really new developments for this project and our company also not really."
[ewb head of energy measurement]

The standard nature of the products purchased by IWB and ewb leads to the conclusion that these transactions contained a *low* amount of asset specificity. The case of CKW was slightly different, the data management system of CKW was provided by Robotron. The energy data management system is one of Robotron's standard products that handle data concerning the energy consumption of the utility's clients (Robotron, 2009). Some modifications needed to be made in order for it to be able to communicate with other systems in the advanced metering infrastructure of CKW.

"Some enhancements to the interface of the SAP system to the EDM (Energy data management) system had to be made" [Head of Energy Measurement CKW]

This indicates that physical asset specificity was present to some degree in this transaction, due to the fact that part of the investment in this software was dedicated to this transaction. The asset specificity in this transaction is rated *moderate* because most features in this product can also be deployed in other situations.

Behavioral uncertainty

The behavioral uncertainty was rated *low* in the cases of CKW and IWB. The specifications and capabilities of the product were known and could be applied as indicators for the ex post assessment of the supplying parties;

"The definitions of the criteria were more on the technical side. If these criteria are fulfilled, then satisfaction about the supplying company is automatically higher." [Head of Energy Measurement CKW]

The demands are of a technical character, the project team was therefore able to observe whether or not they were fulfilled. The behavioral uncertainty is therefore rated *low* in this transaction. This was different in the case of ewb. A *moderate* amount of behavioral uncertainty is present in this transaction. The project leader explained that their lack of experience with such projects made it difficult to assess the outcome afterwards. What made it more difficult was the fact that one supplier supplied both the smart meters as well as the software system as an integrated system, making it difficult to review the outcome of the two transactions separately.

Appropriability regime

The appropriability regime in all three cases was rated *moderate.* In all three cases there was some form of intellectual property rights (IPR) present. The LonWorks software supplied by Echelon to ewb is protected through patents (Echelon, 2010), just as in the case of the software system used by IWB. Research did not show that any specific patents were granted to the Robotron energy data management system used by CKW (Robotron, 2009; EPO). However the head of CKW's energy measurement did indicate that trade secrets were a form of IPR applied in this AMI system.

Undermining the regime of appropriability is the fact that the efficacy of patents, copyright and trade secrets to protect technology in software like this is limited (Menell, 1994). One of the main reasons for this is the difficulty of enforcing property rights in software and the relative low costs of designing around some of these protective measures (Davis, 2001). These two observations lead to the conclusion that a *moderate* appropriability regime is in place;

6.2.4 Development of the customer interface

Asset specificity

CKW and BKW both created a web based consumer interface that allows customers to monitor their electricity consumption. CKW developed the web-portal completely in-house and BKW outsourced the development. The web-portals are both specifically made for these projects, and completely new developments, the asset specificity in these transactions is therefore rated *high.*

"The software for the smart meter and gateways is standard as are the database software. But the customer interface is made especially for this project." "We have recently gotten a request from, I think IWB, that they wanted to use our customer interface. But we don't know how we will do that." [Director inergy]

CKW developed the portal in-house, although it did invest in additional human resources by hiring people from CBS an interim organization for IT specialists.

"*The web portal was a completely new development" [head of energy measurement CKW]*

Additional to the *physical* asset specificity that is present in these transactions, CKW invested in *human* assets specifically for this transaction. Ewz had a different approach to the consumer interface. A tablet computer was connected wirelessly through a *Devolo* device to the smart meter. On this tablet ran the interface, showing data regarding the consumer's energy use (ewz leaflet, 2010). This solution was provided by a start-up company and they worked together to customize the solution of the pilot study;

"The devices are paired (with the smart meter) and they work with an ordinary android based interface. For the interface we worked with a start-up company. They had a solution and we (ewz and start-up company) customized it. They had a solution and we could tell what we wanted, so a display, the recording functions etc. So it was a custom solution only for the study. So we won't roll this system out." [Project leader field study ewz]

This leads to the conclusion that some of the functionalities were already present in the interface, but some features had been developed specifically for this project. The modifications that were needed indicate that *physical* asset specificity was present in this transaction although at a *moderate* value.

Behavioral uncertainty

The behavioral uncertainty in the consumer interface transactions of CKW, BKW and ewz has been rated as *low.* The main reason for this is the fact that the performance of the suppliers could be assessed *ex-post* according to the outlined requirements. The project leaders of ewz and BKW explain how they monitored the transactions:

"We worked very closely with our provider of the home display system (consumer interface). We developed the interface together by using the scrum method. The integration of all the parts (meter with communication module, PLC-system, Android tablets) was done by them. They met almost all of our demands." [Project leader field study ewz]

And "For the database connection and the feedback portal we worked with a small software company. Based on a project contract with detailed specifications we had regular project meetings and adapted demands as needed. It was an interactive process." [Director inergy]

Appropriability regime

In the case of ewz and BKW no visible patents or other forms of intellectual property had been applied to the consumer interface. Ewz prefers to work with as little IP as possible, the manager of the smart meter study explains:

"We want to use as little proprietary information in our system as possible because we want to have the possibility to change suppliers, so we can avoid being locked in. I think it's a big danger that if you go with one supplier and they change something it forces us to also change something, so it means that you're really dependent." [Project leader field study ewz]

This makes the appropriability regime for the interfaces *weak* as open standards and no copyright protection open up possibilities for other companies to provide a similar product, which makes it more difficult to capture the profits of the innovation for the supplying company. Copyright protection was applied to protect the proprietary knowledge of the CKW web-portal (CWK web-portal). However as discussed in previous cases, the efficacy of IP like copyrights is limited when it comes to protecting software against the leakage of knowledge. The appropriability regime is therefore rated *moderate.*

6.2.5 Complexity

The complexity of the advanced metering projects has been measured by means of four indicators. The resulting overall scores resulted in three of the five projects being scored *moderately* complex and two scored *highly* complex as can been seen in table 5. The first indicator looked at how high the system had been integrated into the overall electricity system hierarchy. Innovations high in the design hierarchy require a lot of changes to surrounding adaptions and features. Innovations lower in the design hierarchy can be implemented without much alterations to existing processes (Hobday, 1998). This was the situation in the cases of ewz, ewb and CKW:

"At the moment it's just an extension, but probably in the future it can be more involved in the network than it is at the moment" [Head of energy measurement ewb]

And

"*The advanced metering infrastructure can be considered as more of an extension because no integral solution has been carried out in the project". [Head of energy measurement CKW]*

The AMI systems of BKW and IWB were rated *high* in the design hierarchy due to fact that they had taken a more integrative approach:

"We use our electricity network to communicate, which is through PLC (power line communication), and I see that the metering itself belongs a bit to the network. So IWB's network side would not function properly the way it does if we would separate the network and energy supply. So I would consider it an integral part of the network." [Manager metering services IWB]

The second indicator 'the width of the knowledge input' for the development of smart meter system is rated high in all cases. The main knowledge inputs mentioned by the project leaders were; communication technology, IT, metering technology, project management, electrical engineering, knowledge about the relationships in the energy market and integrative thinking. Whereas simple technologies require 1 or 2 knowledge background, highly complex products need a wide variety of 5 or more knowledge backgrounds (Hobday 1998). This is also the case for this development as the project leaders explain;

"We didn't have innovation projects yet, they are completely new. So you have to build up a lot of knowledge, e.g. project management, innovation processes and basic skills, especially IT." [Project leader field study ewz]

"ICT is a really big part of this project. Communication technology was also very important ….. And I think everything that has to do technically with the meter. So you have to have some electricity and physics background, but where we had to learn the most was communication" [Manager metering services IWB]

The remaining two factors, the degree of technological novelty and quantity of customized components have been scored by the project leaders. The processing of the data to get an overall score has been discussed in the methodological chapter.

Project/complexity indicator	hierarchy	width and depth of knowledge	quantity of customized components	Degree of technological novelty	Combined overall score
Ewz	*Low*	*High*	*Low*	*High*	***Moderate***
IWB	*High*	*High*	*Low*	*High*	***High***
Ewb	*Low*	*High*	*Moderate*	*Moderate*	***Moderate***
BKW	*High*	*High*	*Moderate*	*High*	***High***
CKW	*Low*	*high*	*Low*	*Moderate*	***Moderate***

Table 5. Complexity of Swiss AMI projects.

6.2.6 Systemic nature

De Figueiredo and Teece (1996) draw a dichotomy between innovations of a systemic nature and autonomous nature. Autonomous innovations can be implemented or developed independently from other innovations. Systemic innovations can only be realized in combination with the development of other complementary innovations. More coordination in the design phase is therefore necessary. Systemic innovations always need alternations to the surrounding infrastructure as opposed to the project that scored high on the *hierarchy* indicator for the complexity attribute.

Only the AMI system of ewz was rated autonomous due to the fact that the system was currently not connected to the grid and systems within ewz. The other project leaders explained that a great deal of coordination in the design phase was necessary for the development of their systems.

"Yes we needed a lot of coordination. If we had some problem with the software or a program that didn't work we assembled everyone at one table, including our own ICT department and solved the problem"… "I could imagine that this project would have been a lot harder if this company was split up. Because now we could do all these things very informally, we all know each other and less negotiation is needed" [Manager metering services IWB]

And: *"We have a project organization, so we have a project leader and all the contributors (cooperating companies) are organized in this project organization regardless of their organization." [Director inergy]*

A complete oversight of all transactions and their transaction attributes can be found in appendix IV.

7 Results: the Netherlands

Five advanced metering projects have been studied for the case study of the Netherlands. Four smart metering projects have been carried out by public distribution entities (DSO) and one by a private energy supplier. As of January 2012 a mandatory rollout of smart meters by the DSOs has been ordered by the Dutch government (EL&I, 2011a). The first phase of the rollout involves placing smart meters at newly constructed homes, renovations or in the case of meter renewals. A large scale rollout is planned in 2014 whereby all traditional electricity meters will systematically be replaced by smart meters (EL&I, 2011b). The legislature also prescribes that the DSO entities will be responsible for the rollout and describes which functionalities should be supported by the smart metering infrastructure. The five subcases that will be discussed are;

1. Project 1. Delta netwerkbedrijf
2. Project 2. Enexis
3. Project 3. Liander
4. Project 4. Westland Infra
5. Project 5. Oxxio

The first chapter will present the cases and transactions with the respective modes of governance. The second chapter will discuss the transactions and their attributes in more detail.

7.1 Dutch smart metering cases

7.1.1 Project 1: Delta netwerkbedrijf

Delta netwerkbedrijf is a distribution system operator in the south west of the Netherlands with about 200.000 clients, which are connected to the gas and electricity network. The first smart metering activities of Delta started in 2007 before the company was split off from its commercial supply and generation branch. During the pilot phase Delta tested multiple technologies and decided on using GPRS as communication technology for the small-scale rollout. However, for the small-scale rollout Delta decided to work together with Liander for the data communication and advanced meter management software. The transaction of the smart meter was organized in a strategic alliance with all other distribution system operators (DSOs) of the Netherlands in the association for Dutch DSOs called Netbeheer Nederland (TNO, 2011). The purpose of this collaboration was to specify collective requirements for smart meters, test the smart meters and create a public offering.

The transactions in this project have been organized the following ways;

1. The development and production of the smart meters has been outsourced and was organized through a joint tender with all other Dutch DSOs. Three producers of electricity meters have been contracted to supply the smart meters making this a *market* governed transaction.
2. Provision of the data communication and data management software has been organized through cooperation with *Liander* making this a *hybrid* governed transaction.

7.1.2 Project 2: Enexis

Enexis is a Dutch DSO, which manages about 2.6 million household connections to the electricity grid making it the second largest DSO of the Netherlands. Enexis began their smart metering activities in 2007, which were at that point mainly driven by the political pressure to start rolling out smart meters (Source: interview). Enexis saw prior to the political pressure no incentives to invest in smart metering mainly due to the lack of a business case (Source: interview). Enexis started in 2011 with the small-scale rollout. The smart meters were purchased through the same process as explained in the Delta case. Enexis joined an alliance with all other Dutch DSOs in the Netbeheer Nederland association to define the smart meter requirements and formulate a joint tender (TNO, 2011). The data communication takes place by means of GPRS and is provided by Vodafone through their m2m platform. The advanced meter management platform has been developed by Energy ICT. The transactions in this project have been organized in the following ways;

1. The development and production of the smart meters has been outsourced and was organized through a joint tender with all other Dutch DSOs. Three producers of electricity meters have been contracted to supply the smart meters making this a *market* governed transaction.
2. The GPRS data communication was organized by means of a *market* transaction. Enexis contracted Vodafone to provide them with GPRS services
3. The development of the software package for managing the smart meters and meter data was ordered from *Energy ICT.* The mode of governance for this transaction was the *market.*
4. The transfer of metering data to independent energy suppliers and third parties was governed through the *market*. The DSO makes the data available, but the energy suppliers are themselves responsible for picking up the data and processing this.

7.1.3 Project 3: Liander

Liander, part of Alliander, is a Dutch DSO which manages 2.9 million household connections to the electricity grid making it one of the largest DSOs in the Netherlands. Liander started its first smart metering pilots as early as 2001. This was before the unbundling and Liander was still an integrated part of NUON. In 2005 a larger scale rollout was started and multiple technologies were tested like PLC and GPRS. The conclusion of the pilot was that PLC was not ready for a large scale rollout due to its unreliability (ISPLC, 2010; Interview manager Liander). Plans for large scale rollouts have been postponed multiple times due to privacy and security concerns of the government. The uncertainty about governmental regulations that this created led Liander to postpone a large scale rollout in anticipation of new regulations. Liander started in January 2012 with the small scale rollout. Liander joined an alliance with all other Dutch DSOs for the standardization and procurement of smart meters. The data communication was handled by means of GPRS, a service that was provided by KPN. The advanced meter management software was purchased from Netinium. The transactions in this project have been organized the following ways;

1. The development and production of the smart meters has been outsourced and was organized through a joint tender with all other Dutch DSOs. Three producers of electricity meters have been contracted to supply the smart meters making this a *market* governed transaction.
2. The GPRS data communication was organized by means of a *market* transaction. Liander contracted KPN to provide them with GPRS services
3. The development of the software package for managing the smart meters and meter data was ordered from *Netinium.* The mode of governance for this transaction was the *market.*
4. The transfer of metering data to independent energy suppliers and third parties was governed through the *market*. The DSO makes the data available, but the energy suppliers are themselves responsible for picking up the data and processing this.

7.1.4 Project 4: Westland infra

Westland infra is a DSO situated in the west of the Netherlands with about 50.000 households connected to the electricity and gas network. The smart metering activities of Westland infra for its private customers started in January 2012 with the small scale rollout. About ten percent of the household had been equipped with smart meters around August 2012 (Source: interview). Westland infra joined an alliance with all other Dutch DSOs in the Netbeheer Nederland association to define the smart meter requirements and formulate a joint tender. The communication is handled by means of GPRS and the software suit has been bought by Westland from a software company but was modified to Westland's specification internally. The following transactions have been observed;

1. The development and production of the smart meters has been outsourced and was organized through a joint tender with all other Dutch DSOs. Three producers of electricity meters have been contracted to supply the smart meters making this a *market* governed transaction.
2. The GPRS data communication was organized by means of a *market* transaction.
3. The development of the software package for managing the smart meters and meter data was bought in the market. The mode of governance for this transaction was the *market.*
4. The customization of the software package for managing the smart meters and meter data was organized *internally* by Westland infra.
5. The transfer of metering data to independent energy suppliers and third parties was governed through the *market*. The DSO makes the data available, but the energy suppliers are themselves responsible for picking up the data and processing this

7.1.5 Project 5: Oxxio

Oxxio is an energy supplier in the Netherlands and a subsidiary of Eneco as of 2011. Oxxio was founded in 2005 from the merger with two other energy supplying companies (Source: Oxxio website). 2005 was also the year that Oxxio started its smart metering activities. The main incentive to rollout smart meters was the wish to be independent from the traditional energy suppliers for meter readings of their own clients (Source: interview strategic manager). The Dutch energy market had been liberalized since 2001, but ownership unbundling was not implemented till 2011. This resulted in the situation where the meter readings of Oxxio clients were being carried out by one of the incumbent integrated electricity suppliers. This caused confusion among the Oxxio clients according to a strategic marketeer at Oxxio. The smart meters and AMM system were bought from IBM and the GPRS communication was provided by KPN (IBM, 2006). The data handling software and interface was specifically designed for Oxxio and produced by their default software supplier. Four main transactions and their governance modes have been observed in this case.

1. The development and production of the smart meters has been outsourced to IBM. Making this transaction a *market* governed transaction.
2. The GPRS data communication was organized by means of a *market* transaction. Oxxio contracted the services of KPN.
3. The development of the software package for managing the smart meters and meter data was bought from IBM as well. The mode of governance for this transaction was the *market.*
4. The design and development of the consumer interface was outsourced to Oxxio's web developer. Normal contracts were applied to govern this transaction making it a *market* transaction.

7.2 Transaction attributes

The attributes of the transactions identified in the case descriptions are discussed in detail this chapter. The transactions where overlap between the cases has been found and therefore occur most frequently are discussed in this chapter. The overlap allows for a comparison between the cases. The attributes of each type of transactions will be reviewed and valued according to the descriptions given in the interviews and additional literature. The following transactions will be reviewed;

1. Development of the smart meter
2. Provision of the communication infrastructure
3. Development of the data management and meter reading software
4. Transferring metering data to independent energy suppliers and third parties.
5. Development of the customer interface

7.2.1 Development of the smart meter

Asset specificity

The Dutch DSOs collaborated on drawing up specific requirements for the smart meters. The main goal of the alliance was to enforce standards upon the smart meter manufacturers in order to avoid dependence on one smart meter supplier. The second goal was to gain a better negotiation position and lower the prices of the meters by buying in larger numbers (TNO, 2011a). The document that outlines the requirements for the smart meters is called the Dutch Smart Meter Requirement (DSMR) document. It is based on an earlier standard formulated in 2007 called the NTA8130 (Stratix, 2006) and Dutch legislation that outlines the minimum functionalities of the smart meters and related infrastructure (TNO, 2011b). These requirements result in the fact that the meter had to be developed specifically for the Dutch market as the project leader of Delta explains;

"The meter producers have had to invest because they had to adapt their meters to our market. The meters that will be sold here won't be sold anywhere else in Europe. Our demands are much stricter so the meters are very different" [Project leader Delta]

"We specified the requirements in collaboration with all other Dutch DSOs. The development of the meter has of course been done by the suppliers themselves" [Manager smart metering operations Enexis]

"The communication protocol outlined in the DSMR is not suited for other projects" [Manager marketing and communication Westland]

The tender that has been created by the DSO alliance requires that a minimum of three smart meter manufacturers would develop smart meters for the Dutch market. This was done to ensure that there the DSO won't be dependent on one meter supplier (TNO, 2011a). This last factor is to avoid being taken hostage by the manufacturer. A manufacturer lock in would give the manufacturer strong bargaining powers which opens up the door to opportunism (Williamson 1985). The DSOs avoid this hazard by contracting multiple suppliers.

The main factors responsible for the fact that the Dutch requirements are so strict are the extensive demands concerning privacy and security outlined by the government. The DSMR is mainly based on these regulations but it also incorporates certain technical details which have been outlined by the DSOs. From the statements above it's possible to conclude that this transaction contains a *high* level of physical asset specificity.

The smart meters ordered by Oxxio have been developed through a different process. Oxxio contracted IBM to implement and develop their smart metering system (IBM, 2006). A strategic marketeer explained that no special requirements other than the basic functionalities were requested by Oxxio;

"In principle it was an off the shelf product, we did not start with a white sheet of paper and started drawing up specifications."[Senior strategic marketeer Oxxio]

The main reason why Oxxio could use a stock product was that in 2005 no standards or regulations regarding the smart meters had been established in the Netherlands. However some adaptions needed to be made by IBM for Oxxio's smart metering infrastructure. The meter that was used had been developed for the Enel smart metering project in Italy, however those meters made use of PLC to facilitate communication. Oxxio did not own the electricity infrastructure so PLC was not an option. IBM therefore had to specifically develop a wireless communication module for the smart meter to make Oxxio's project work;

"Working with the Enel engineers who helped design the core solution, the IBM team led an innovative redesign of the communications infrastructure. In the place of the grid, IBM designed a wireless data communication module that gathers data from the meter and sends it directly to Oxxio's central control facility, effectively leapfrogging an entire communications layer" (IBM, 2006 p. 3)

This dedicated investment by IBM results in a *moderate* level of physical asset specificity. Most features and technologies of IBM smart metering technology are also used in other projects, but the wireless communication feature was at that point specifically developed for Oxxio's AMI system.

Behavioral uncertainty

The behavioral uncertainty is rated *low* in these transactions. Two observations indicate that it's possible for the DSO association to assess the outcome of the transaction ex-post. The DSO association has planned a test phase for assessing the smart meters. This phase was necessary because there were no smart meters market yet, that met the requirements of the DSRM 4.0 (Netbeheer Nederland, 2011). The DSRM provides a clear framework for assessing whether the contractual agreements have been met by the manufacturers or not.

Second, the technological nature of the product allows for a good measurement of the result. The product functions can clearly be measured and clear rules about the timely handover of the meters have been worked out.

"The requested volume will be divided among the equipment suppliers based upon business criteria to avoid one sided dependence on one supplier. If a manufacturer needs more time and delivers the meters later than agreed upon, it will result in a loss of market share." (TNO, 2011a p. 8)

Appropriability regime

The appropriability regime of the smart meters of the DSO organizations is rated *moderate,* due to the fact that there are factors undermining the appropriability regime, as well as reinforcing it. Reinforcing the appropriability regime is the fact that innovative knowledge used to develop the smart meters can be protected by intellectual property rights such as patents;

"The smart meter contains IP of course and it is owned by the manufacturer" [Project leader Delta]

"The smart meter also contains IP of course, but those are incorporated in the use of the meter" [Manager smart metering operations Enexis]

However the smart meters supplied in the Netherlands have to conform to the DSMR which is an open standard (TNO, 2011a). The open standard limits the appropriability of smart meter manufacturer by enabling suppliers to compete with each other on the same standard. This notion is also underwritten by Simcoe (2006) who argues that open standards make it harder for firms to apply certain appropriability mechanisms and enable more competition. This last factor does not apply to the smart meters bought by Oxxio. These were purchased before the first standards had been published and do therefore not conform to an open standard. The regime of appropriability is rated *tight* in the case of Oxxio.

7.2.2 Provision of the communication infrastructure

Asset specificity

The data communication from the smart meters to the central systems of Enexis, Liander, Oxxio and Westland mainly takes place by means of GPRS. The GPRS services used by Enexis are provided by Vodafone and are according to Enexis's Manager Smart Metering Operations, a standard product based on Vodafone's machine to machine platform (Vodafone website).

"Vodafone has the m2m platform which enables machines to communicate with each other. Most parts of that is standard; no personnel had to be specifically trained for us"

Enexis and Oxxio make use of KPN's data communication services which are also standard telecom products. No dedicated investments have been made by any of the telecom providers for these transactions, the asset specificity it therefore rated *low.*

Behavioral uncertainty

The behavioral uncertainty is rated *low* in these transactions due to the fact that clear performance indicators exist for measuring the performance of the contracted party (Anderson, 1984a). In the case of data communication the main indicator for measuring the adherence to the contractual agreements is the transfer of data. This can be monitored by the DSOs through their advanced meter management platform.

Appropriability regime

The appropriability regime for the data communication is rated *tight*. The main factor limiting the hazard of leakage and competition from imitating the product provided by Vodafone and KPN is the nature of the technology. Setting up a GPRS network is highly capital intensive (Harmantzis & Tanguturi, 2007). The competition is furthermore limited by the fact that only five licenses for the operation of a mobile communications network have been auctioned and only four are left today (Agentschap telecom).

7.2.3 Development of the data management and meter reading software

Asset specificity

The transactions for the software systems used to manage the smart meters were in the cases of Enexis and Liander found to be *moderately* asset specific and in the cases of Westland and Oxxio to have a *low* amount of asset specificity.

Enexis worked with *Energy ICT* a software provider for the development of their AMM. Enexis bought licenses for the use of their system and contracted *Energy ICT* to implement and adjust the system where needed. Some changes were needed due to the fact that the software had only been used for meter readings of commercial clients, which meant it was designed for lower numbers;

"The application to read out the meter is a software program that we bought. Part of the functionalities was standard in this software program and part of it was customized and specifically developed for us by Energy ICT. So the software is specifically how we want it to be, so we did not develop it ourselves but did say specifically how we wanted it to be." [Manager smart metering operations Enexis].

Liander contracted the software developer *Netinium* for the advanced meter management software. The project leader explained that the software system is not a standard product, but has been ordered to the specifications of Liander:

"We let other firms produce those systems, but according to the specifications of Liander, the smart meter itself as well as the data management (AMM) behind it. We define the requirements and make

a public offering so that meter producers and IT companies can make the product according to our specifications." [Manager rollout Liander]

These statements lead to the conclusion that physical asset specificity was present to a *moderate* extent in these transactions. Core functionalities of these systems can also be sold by the software providers to other utilities, but the customized parts of the system are dedicated to Enexis and Liander (Netinium, 2010; EnergyICT website).

The asset specificity in the software transactions of Oxxio and Westland are rated *low*. Westland bought a standard software system from a software developing company. Changes to the software system were made to the software but that was done internally according the Westland's marketing and communication manager:

"At the moment we're still using some of their services while we're building our own platform for the large scale rollout. So we basically acquired their system and made adjustments to it ourselves so that is meets our requirements"

This means that only the standard software program was part of this transaction. The customized part has been internalized and should be regarded as a separate transaction. The AMM software was also outsourced by Oxxio. IBM provided the solution which has been developed in cooperation with ENEL and had already been used for a large scale the rollout in Italy (IBM, 2006). The software system was not specifically designed for Oxxio, so none of the parties involved made dedicated investments. This leads to the conclusion that this transaction contains little asset specificity.

Behavioral uncertainty

The behavioral uncertainty was rated *low* in all software transactions. There are two indications for this, first there are good indicators for measuring the performance of the software suppliers and second the performances of the software manufacturers are structurally reviewed. The project leaders explain;

"We come together a few times a year to assess the performance of our collaboration…what we frequently do is evaluate the decisions we have taken." "Another example is when we have to pay for the work that they've done. Then we take a sharp look at their performance, did they for instance deliver it to us with a lot of bugs or not?" [Manager smart metering operations Enexis]

"If you create a tender you clearly state which requirements you want the system to meet and determine the timeframe in which the product needs to be delivered. On the basis of this and price you decide who to contract." [Manager rollout]

"Yes it is possible to measure outcome, because we know what the requirements of the smart meters and the systems behind that are. If you comply with those, then were done!" [Manager marketing and communication Westland]

Appropriability regime

The appropriability regime is rated *moderate* in this transaction. The software used by all parties is protected by at least one form of intellectual property rights (IPR). The software used by Liander and Delta is protected by licenses and trademarks (Netinium, 2010). Delta's project leader acknowledges this;

"The AMM contains intellectual property but this is licensed to Liander" [Project leader Delta]

The software system use by Enexis is also protected by means of legal documents; Enexis pays a license per smart meter connected to the system (EnergyICT website). The customized parts are only paid for once and remain the property of Enexis. The project manager of Enexis explains;

"The IT system is owned by Energy ICT en we play license fee's per meter. The licenses allow us to use to the system and all the developments on the core which they continuously update."..."The customized parts are paid directly by us. It is a single payment and is owned by us. They can't sell it to anyone else because it's customized. And if they would want to sell it, they would have to ask us."

ENEL has patented the AMM system that was used in the case of Oxxio. This AMM system is partly based on IBM technologies. Trademarks have also been applied to protect the brands that are associated with the AMM system of ENEL and IBM (IBM, 2006).

Although patents and other forms of intellectual property rights are applicable to these types of software it is generally regarded to provide only limited protection against the leakage of knowledge in these types of products (Menell, 1994; Davis, 2001). This is mainly due to the fact that software is difficult to patent and that these patents are difficult to enforce. Copyright is also problematic because small alterations to the product allow for companies to issue for a new copyright declaration.

7.2.4 Metering data transactions

Asset specificity

The metering data collected by the DSOs needs to be transferred to the independent energy suppliers for billing and commercial purposes. Additionally it must be possible for third parties also known as independent service suppliers to provide optional services for the consumers and to make use of the metering data if requested and authorized by the consumer. The asset specificity in this transaction is *low* due to the fact that the interface for collecting the data has been standardized by the DSOs (Stratix, 2006). This interface called the P4 port is the access point for energy suppliers to collect data when authorized to do so. This interface can therefore be applied to transact the data to any energy supplier in the Dutch market. It is the same the other way around any Dutch energy supplier can collect meter reading for any DSO using the same communication protocols. The NTA 8130 standard outlines the protocols and formats necessary to exchange the data. It also allows two-way communication, whereby energy suppliers are able to send messages to the smart meters (NEC, 2007).

Behavioral uncertainty

The behavioral uncertainty in this transaction is rated low. The outcome of the transaction is well assessable for the receiving parties (Stratix, 2006). An indicator for measuring the performance of this transaction is whether or not data from the consumer is received. The NTA 8130 can additionally be used to determine whether the data is being transferred in the agreed upon format.

Appropriability regime

The appropriability regime in this transaction is rated *weak*. The communication protocol is part of the NTA 8130 standard which is an open standard (TNO, 2011a). This means that any party can make use of this information to develop a similar type of portal. Not secrecy agreement or any other type of IP has been issued for this development.

7.2.5 Development of the customer interface

Asset specificity

Oxxio uses the smart metering data to provide its customers with an oversight of their energy use. Clients can visit the "myOxxio" web-portal to see their actual energy use (Source: Oxxio website). The development of this portal has been outsourced by Oxxio to their default web-developer and was a custom made development for Oxxio;

"The software to use the data for the "myOxxio" platform was developed specifically for us. We own this development. It works on the basis of the meter readings that come from the smart meters. It would be possible to buy it of the shelf, but we think that everything that has to do with client interaction should be owned and handled by us." [Senior strategic marketeer Oxxio]

This leads to the conclusion that the asset specificity is *high* in this transaction due to dedicated investment in human asset specificity made by the web-developer.

Behavioral uncertainty

The behavioral uncertainty in this transaction is rated *low*. The performance of the consumer interface developer can and is structurally assessed ex post, as the Oxxio's senior strategic marketeer explains:

"Our web-builder does more than developing the myOxxio platform, this company also builds our website. We officially evaluate their performance twice a year. For example on the basis of cost, quality and whether things got delivered on time. We also expect a kind of innovativeness from them"

Appropriability regime

The consumer interface is owned by Oxxio and an agreement has been made with the developer of the platform that no other energy firms can be served by them. Oxxio's senior strategic marketeer explains that there are some difficulties protecting IP like this;

"..part of the things they do for us are their core competences so it's really hard to prohibit them from making similar things for other companies, otherwise they can only make websites for us. We have the agreement that our web developer does not work for other energy suppliers."

This statement supplements the existing literature that intellectual property rights provide little protection against the leakage of knowledge due to the fact that it's difficult to enforce IPR in digital information and IT (Menell, 1994; Davis, 2001). The appropriability regime is therefore considered *weak*.

7.2.6 Complexity

The complexity of the smart metering infrastructures has been rated *high* in three of the five cases. The other two cases are rated *moderate*. The moderate rating of Delta's AMI system was due to the fact that a large part of the system has been outsourced to Liander which means that little components have been customized for their needs.

Westland indicated to be working with technologies like this for over 15 years. The commercial clients (the greenhouses in the Westland's) are part of a smart grid which adjusts supply to demand. Their energy use is measured in almost real time intervals instead of 15 minutes intervals which is the case for their private clients.

The advanced metering system is overall considered to be an integral part of the electricity and is therefore rated *high* in the design hierarchy. However there is a discussion about whether it is a crucial part of smart grids or not. However all project leaders agree that the installation of smart meters will stimulate the development of a smart grid;

"Basically we just install a different meter, so no new provisions need to be made. But it is an integral part of the network because you connect the smart meter to it."[Project leader Delta]

"*The smart meter system is in fact the handover point to the client and to collect the meter readings. However it will also be part of a smart grid in the future. Especially in the case of electric vehicles which have a big impact on the electricity network. But the gas and electricity network is not altered at the moment. But it will change if you need to scale up in order to accommodate due to EV's and* *distributed generation, you'll need more intelligence to balance these factors out." [Manager rollout Liander]*

"Maybe now it's seen as an extension, but I see it as an integral part and a necessary part, because you now have much more possibilities regarding your electricity network and what you can do with energy." [Senior strategic marketeer Oxxio]

The second indicator 'the width of the knowledge input' for the development of smart meter system is rated high in all cases. Communication, IT and knowledge about metering are the most prominently mentioned knowledge fields involved. However knowledge concerning privacy, secrecy, work preparation, stock management, liability and management have also been mentioned. This leads to the conclusion that the variety of distinct knowledge and skill bases was *high.*

The remaining two factors, the degree of technological novelty and quantity of customized components have been scored by the project leaders. The processing of the data to get an overall score has been discussed in the methodological chapter.

Project/complexity indicator	hierarchy	width and depth of knowledge	quantity of customized components	Degree of technological novelty	Combined Overall score
Delta netwerkbedrijf	*High*	*High*	*Low*	*Moderate*	***Moderate***
Enexis	*High*	*High*	*Low*	*High*	***High***
Liander	*High*	*High*	*Moderate*	*High*	***High***
Westland infra	*High*	*High*	*Moderate*	*Low*	***Moderate***
Oxxio	*High*	*High*	*Low*	*High*	***High***

Table 6. Complexity of Dutch AMI projects

7.2.7 Systemic nature

A systemic innovation is characterized by the need for large amounts of design coordination between the successive or complementary parts of the innovation (Chesbrough and Teece, 1996). The statements from the interviews lead to the conclusion that this was also the case in the development of this smart metering infrastructure. The project leaders explain;

"We had a year to set up the project for the small scale rollout for which we decided to work together with Liander. This was very short day. It meant meeting centrally somewhere every two weeks. This was a very close cooperation." [Project leader Delta]

"Yes, a lot of coordination was needed because, everything was completely new. This means that you don't exactly know what you need. It also means that this is very new to the ICT developer, so you need a very close collaboration in order to understand each other. And there is the risk that things might take longer and become more expensive" [Manager Smart meter operations Enexis]

"Yes, there is constant coordination and we have frequent meetings with the other parties" [Manager marketing and communication Westland]

A complete oversight of all transactions and their transaction attributes can be found in appendix V. The next chapter will discuss the innovative performance of the advanced metering projects and focusses on the differences between the Dutch and Swiss case.

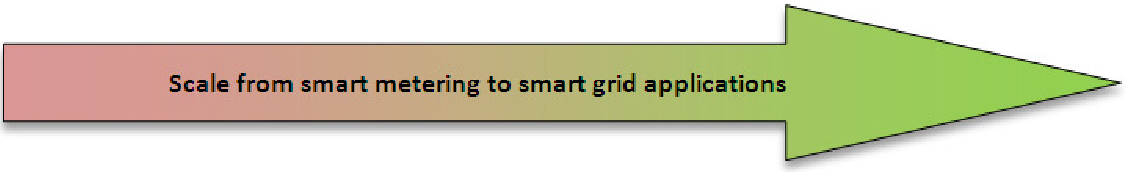
8 Results: Innovative performance

The thesis that unbundling leads firms to organize the transaction of their advanced metering projects differently in comparison with bundled industries leads to the subsequent suggestion that unbundling might also affect innovative performance.

The indicators of innovative performance of the advanced metering projects have been based on the envisioned potential benefits of smart metering and its possible applications. The functions range from more simple applications, like remote meter reading to more advanced smart grid applications, like peak shaving.

Table 7 indicates which projects have realized which smart metering functionalities. As can be seen in the case of Switzerland these are rather diverse, with a split between the companies who focused on remote metering and billing (IWB, EWB) and the companies who implemented dynamic tariff structures, possibilities for peak shaving and provided consumers with insight into their energy consumption (IWB,EWZ,BKW).

	Remote meter reading	Using data for billing purposes	metering costs reduction	Fraud detection	Limiting energy throughput	Monitoring energy demand /forecasts	Peak shaving
Switzerland							
EWZ	Not achieved	Not achieved	Not achieved	Not achieved	Not achieved	Achieved	Not achieved
IWB	Achieved	Achieved	Not achieved	Not achieved	Achieved	Not achieved	Not achieved
BKW	Achieved	Not achieved	Not achieved	Not achieved	Not achieved	Achieved	Achieved
EWB	Achieved	Achieved	Not achieved	Achieved	Not achieved	Not achieved	Not achieved
CKW	Achieved	Not achieved	Not achieved	Achieved	Not achieved	Achieved	Achieved
The Netherlands							
Delta	Achieved	Achieved	Not achieved	Achieved	Technically possible but regulated	Technically possible but regulated	Not achieved
Enexis	Achieved	Achieved	Not achieved	Achieved	Technically possible but regulated	Technically possible but regulated	Not achieved
Liander	Achieved	Achieved	Not achieved	Achieved	Technically possible but regulated	Technically possible but regulated	Not achieved
Westland	Achieved	Achieved	Not achieved	Achieved	Technically possible but regulated	Technically possible but regulated	Not achieved
Oxxio	Achieved	Achieved	Not achieved	Not achieved	Not achieved	Achieved	Not achieved



Achieved
Not achieved
Technically possible but regulated

Table 7. Performance indicators of smart metering projects.

The Dutch projects, on the other hand provide a very homogenous picture, where all firms target remote meter reading and possibilities for monitoring energy consumption have been developed. That last functionality is enabled by the smart meter legislation and the resulting DSMR. All DSOs have to provide energy suppliers with access to metering data of their clients. This access is provided through the so called 'P4' port which has been standardized so any energy supplier can (if granted) gain access to this data. Independent service providers are also allowed access to this data, if authorized by the consumer, which allows those providers to developed services for the consumer such as graphical projections of the consumer’s energy consumption/production.

The function that allows the DSOs to remotely cut off houses from power (Limiting energy throughput), in the cases of abandoned housing or overdue payments, is still heavily debated in the Netherlands. The DSMR outlines that the smart meters are technically capable of doing this, but the usage of this function is subject to strict regulations and the DSOs still consider this to be very risky as Delta´s project leader explains:

“There is a national discussion going on whether or not the remote switch should remain part of the meter or not. Cutting of power is now subject of strict rules and can only be done with the authorization of the client”

The innovative performance of the smart metering infrastructures does not differ significantly between the Dutch and Swiss cases. Most projects with the exception of ewz have realized 3 to 4 smart metering functionalities. However where the Dutch and Swiss cases deviate is on the overall scale.

The Dutch smart metering infrastructures are only geared towards remote meter reading and providing consumers with more insight into their energy use. In the Swiss case we can also observe that demand side participation has been actively implemented with smart solutions such as automated home appliances which enabled peak shaving. This leads to the conclusion that more innovative potential has been realized in the Swiss case.

9 Comparison

The following chapter will discuss the differences in modes of governance, transaction attributes and difference in innovative performance between the Dutch and Swiss cases. Differences that occur exclusively between the two cases are discussed, because these can possibly be attributed to unbundling.

Development of the smart meter

The way the transactions of the development and production of the smart meters have been organized shows a significant difference between the Dutch and Swiss utilities. The Swiss utility companies used standard smart meters for their pilots. Acquiring the meters in the market was therefore the most efficient way of governing these transactions; this was also observed in practice.

The smart meter transactions in the cases of the Dutch DSOs were *highly* asset specific, which was mainly due to security and privacy legislation, but also because of functional and interoperability requirements. This last requirement is a direct result of unbundling. The unbundling of the Dutch electricity companies came with the requirement that DSOs provide their services of meter readings without any bias to all energy suppliers in the Netherlands. All energy suppliers would therefore have to be granted access to the smart metering data. The resulting situation is that a lot of coordination between the DSOs and energy suppliers would be necessary to make the systems of all energy suppliers integrate into the systems of the DSOs.

The traditional setup of the transaction cost framework would classify the Dutch transactions as governed by the *market*. However, the high asset specificity in the transactions would require the DSOs to internalize the transactions to account for the risk of opportunism by the smart meter manufacturers. In practice we see that regulations in the form of legislation and standards have been put in place to govern this transaction. This mode of governance is described by Williamson (Williamson, 1999) as *regulation*. So what we see in the Dutch case is a combination between a *regulatory* mode of governance and the *market*. Williamson (1999) has expanded the standard contracting scheme to include a *regulatory* mode of governance, which can be applied to transactions with very high asset specificity. He describes the regulatory mode of governance as something that *"could be thought of as a very long-term contract of a cost-plus reimbursement kind in which the interests of the government are protected by embedding the agency in a complex regulatory apparatus, whence extensive rules, regulations and procedures will appear and provision will be made for periodic auditing." (Williamson, 1999; p.334)*

I also observed that the regulatory mode of governance was very effective in addressing the need for more coordination caused by the systemic nature of the advanced metering systems. The regulations and standards outlined in the DSMR and Dutch legislation provide a clear framework to which the involved parties need to adhere.

Provision of data communication

The Dutch DSOs have outsourced the data communication to telecom providers. In the Dutch case, this solution has been applied exclusively, because mobile services like GPRS and UMTS are regarded as the most reliable solutions. Companies like IWB, EWB and CKW in Switzerland have internalized this transaction by applying power line communication (PLC) or fiber optics. Outsourcing is in the case of PLC, which uses power lines to establish communication, unnecessary because the Swiss electricity companies already own and operate the power lines. The choice for PLC is justified from production cost considerations. Mobile data communication as arranged in the Netherlands is expensive and makes up, according to Enexis' manager smart meter operations, about a quarter of the total costs of the smart metering project. GPRS based smart meters are incidentally also more expensive than PLC smart meters. The low production cost make up for the higher cost that are made by integrating this step. A footnote to this is that PLC technology has technical limitations, but expectations are that within a limited time span the technology will be ready to facilitate a large scale rollout (Presentation Lonneke Driesen, 10-2012).

The discrepancy between the modes of governance applied in the Dutch cases and Swiss cases was therefore *not* caused by unbundling but rather because of technological properties and the difference in the rollout phase between the two countries. The Swiss companies can still experiment with new technologies, because they are still in the pilot phase. The Dutch companies use a more conservative approach due to the scale of the current rollout. Generally it is believed that PLC is a much cheaper technology and DSOs like Enexis are actively following the developments around new PLC technologies (Presentation Lonneke Driesen, 10-2012).

9.1 Differing transaction attributes

Asset specificity

Unbundling was not only found to have an impact on the modes of governance, but also on transaction attributes. In the case of the Netherlands this was observed in the transaction of the digital meter readings from the DSOs to the energy suppliers or third parties who use that data for billing and additional services.

The data transfer from the DSOs to the energy suppliers now happens through the P4 port which has been standardized in the NTA 8130 documentation. This means that every energy supplier can approach any DSO using the same communication and data protocols. The same counts for the DSOs, which now have to develop only one port for all energy suppliers and independent service providers. The result is a low level of asset specificity in the transaction of the metering data (Stratix, 2006). It can therefore be observed that asset specificity has been lowered in the Dutch case by the application of standards to create alignment between the unbundled DSOs and energy suppliers. This is a result of the fact that no modes of governance other than the *market* could be applied. The market does not facilitate the coordination needed to developing dedicated links and protocols to every energy supplier. This finding is also supported by a study of the British unbundled train industry by Yvrande-Billon and Menard (2005). They found that in reaction to the unbundling of the train industry parties started to adapt their transactions because they were unable to adapt their modes of governance. This led to more standardized material that could more easily be sold to other parties as to avoid dependence between the two transaction parties.

Behavioral uncertainty

The transactions in the case of the Dutch smart metering industries have all been rated to have low behavioral uncertainty. Some Swiss firms, however, indicated that they had more difficulty assessing the outcome of some of the transactions which led to a *moderate* level of behavioral uncertainty. The reason for why the behavioral uncertainty was rated low all of the Dutch cases, was because the DSMR could be used as an indicator for performance.

"Yes, we can measure the performance pretty accurately, because we know what the demands for smart meters and the related systems are. If the supplying parties comply with those standards then we're satisfied." [Manager marketing communication Westland]

This difference in behavioral uncertainty was not directly caused by the unbundling of the energy companies. However the unbundling of the energy companies did require the development of new legislation and standards concerning smart metering. These regulations helped lower behavioral uncertainty because they provide a reference point for suppliers and buyers about the final outcome of the development process. Therefore indirectly, more measures were taken in the case of the Netherlands to lower behavioral uncertainty.

9.2 Difference in Innovative performance

The former chapter concluded that in the Swiss case more innovative potential had been realized than in the Dutch case. This was mainly attributable to the development of peak shaving applications through the use of dynamic energy tariffs. This leads to the observation that some functionalities and transactions are being avoided in the Dutch case, whereas the Swiss actively engage in a larger diversity of smart metering functionalities. An example of this is the algorithm developed by the alliance of IBM and BKW. This algorithm allows smart appliances to adjust automatically to changing electricity prices by switching on and off automatically. Why was such a function of dynamic pricing to create peak shaving effects not applied in the Netherlands?

The Swiss vertically integrated electricity companies developed those systems with consumer demand in mind. The system not only allows for peak shaving, but also for consumers to save on their energy bill. The advantages of this technology go to the consumer and/or to the DSO. In the case of the Swiss energy companies this results in a win-win situation. The advantages of the peak shaving stay within the company and consumer satisfaction would goes up. In the Netherlands it gets more complicated, the cost of developing and implementing such a system would mostly accrue to the energy suppliers because they have the responsibility of pricing the energy and billing the consumer. The advantages however would accrue to the DSOs, because peak shaving would lower the distribution system operating costs (Pruissen, 2011). This advantage would not necessarily go along with lower costs for the energy supplier. The DSO would want to base the flexible tariffs on congestion in the grid, whereas the energy suppliers would want to base the tariffs on fluctuating electricity prices. This issue was also observed in the interview with Oxxio;

“We would only cooperate (with the DSOs) if they would compensate us. So we would not provide such services, only in the case where we can create an advantage for our clients.” [Senior strategic marketeer]

The result is that a lot of coordination is needed between the energy suppliers and DSOs to create such functionality and conflicts could arise about who should pay for it. In Switzerland these problems are avoided because the efficiency gains are appropriated within one company. The result of these coordination and alignment problems is that the incentive to innovate is impaired. An important aspect is the systemic nature of the technology. Such innovations require investments into resources by multiple parties in the value chain as is the case for peak shaving.

Other cases, where the unbundling has only taken place at an administrative level (the utility is still largely integrated), show that more incentives to develop systemic innovations are present. An example was provided by Enexis’s manager smart meter operations about the relationship between energy supplier EDF in France and ERDF, EDF’s subsidiary distribution organization;

“For example EDF wants to expand beyond the country borders and asks its DSO for new developments to help EDF grow as a company. Enexis would never get such questions, so it’s not something we would have to worry about.”

An example of this innovative push is the development of a new PLC technology. ERDF has started an alliance to promote its G3-PLC standard[4]. The alliance incorporates the EDF R&D department, but also industry equipment manufactures and semiconductor suppliers.

[4] Alliance information at; http://www.g3-plc.com/content/press-releases

10 Conclusion

This research started out with the observation that major innovations in the electricity system are necessary to prepare for the coming transition to new forms of mobility and electricity generation. The implementation of smart metering is considered to be an important step in that direction. The organization of this process is in many cases, like in the EU, influenced by the unbundling of the electricity sector. This study, therefore, sought to answer the following research question;

"How do the transactions, governance structures and innovative performance of advanced metering infrastructures differ between the Dutch unbundled and the Swiss integrated electricity sector?"

To research the effects of unbundling a transaction cost perspective was applied. The application of transaction cost theory on innovation transactions was found to be limited. This study is therefore aimed at contributing to the existing literature on unbundling and innovation transactions.

A comparative case study was carried out to investigate the differences between an unbundled and integrated industry. For that reason the development of smart metering, a new development in the electricity industry, was studied in both the unbundled industry of the Netherlands and the vertically integrated industry of Switzerland. The hypothesis that unbundling leads firms to adjust their modes of governance or transaction attributes has been confirmed. Additionally evidence was found for the fact that when those options are not available, firms restrain from committing resources to systemic innovations.

Different mode of governance

A large discrepancy between the Dutch and Swiss transactions was found in the development and procurement of the smart meters. Whereas the Swiss energy companies ordered stock equipment, the Dutch DSOs had to order smart meters specially designed for the Dutch market. The high asset specificity in the Dutch case was addressed by applying a combination of a *regulatory* mode of governance and the *market.* I would like to argue that the regulatory mode of governance not only controls the hazards created by high asset specificity, but also addresses the need for more coordination in the case of systemic innovations.

Transaction attributes

The Dutch DSOs were found to lower the asset specificity in the transfer of the meter reading data to the energy companies. The Dutch DSOs standardized the data transfer port, which enables energy suppliers to gain access to meter readings from their clients. This transaction had to be governed by the market due to unbundling and specific solutions for each energy supplier would have been very costly.

Behavioral uncertainty was found to be lower in the Dutch cases than in the Swiss cases. This was caused by regulations that had been put in place to govern the development of the smart meters. This is therefore indirectly attributable to unbundling, because unbundling created the need to more regulations.

The comparison between the Dutch and Swiss cases did not show significant differences concerning the transaction attributes of appropriability regime, system nature and complexity. But there are indications that the systemic nature of the smart metering infrastructures did have an impact on the chosen modes of governance and innovative performance. The systemic nature of the advanced metering infrastructures created the need for more coordination, between the energy suppliers, DSOs and manufacturers in the development process of the smart meters. In the Swiss case this additional need for coordination was resolved by vertical integration and ordering standard equipment. In the Dutch case this was addressed by additional regulations which explicitly outlined what the roles are for each party in the development of the smart metering infrastructure.

The influence of the complexity and appropriability regimes was less observable. The complexity and appropriability regimes of the advanced metering infrastructures did not differ significantly between the Dutch and Swiss cases. The advanced metering infrastructures were rated to be moderately to highly complex developments and the appropriability regimes also showed little differences. What can be concluded is that asset specificity played the largest role in the organization of the AMI developments. However, behavioral uncertainty and the systemic nature of AMI were also found to have contributed to the differences in the Swiss and Dutch cases.

Avoided transactions

The points made above lead to the conclusion that firms in unbundled industries have certain options to deal with the limitations imposed by unbundling. Other than affecting modes of governance and transaction attributes, unbundling led in the Dutch case also to lower innovative performance. The difference in the type of transactions and innovative performance between the Dutch and Swiss cases showed that the development of the peak shaving functionality had been avoided, a function which some Swiss energy companies have already developed and none of the Dutch parties. This could mainly be attributed to an incentive alignment problem, which originated from the fact that both the energy supplier and DSO have to invest, but only one party receives the benefits. Systemic innovations like this are best governed through hybrid or hierarchical modes of governance, because the benefits and costs of the innovation can then be appropriated within one organization. This research therefore confirms the hypothesis outlined by Chesbrough and Teece (1996); that the coordinated efforts required by systemic innovations, create a push towards to vertical integration.

Final thoughts

Before Dutch legislation required DSOs to rollout smart metering there were only a hand full of parties in the Dutch market that experimented with smart metering. Some of the Dutch interviewees explained that before the smart metering legislation existed there were no incentives to develop a smart metering infrastructure. So it’s still largely the question whether the rollout of smart metering in the Netherlands would be where it’s currently at without the current regulatory framework.

11 Discussion

The aim of this research was to identify how the developments of advanced metering infrastructures were organized in integrated and unbundled industries. Interesting insights and conclusions have been drawn. But there are limitations to the findings. The theoretical framework, method and data are therefore critically reviewed.

The findings have shown that unbundling the electricity sector does not have to lead to more misalignment when developing an advanced metering infrastructure. There are ways such as, applying a regulatory mode of governance or lowering asset specificity, to circumvent the limitations posed by unbundling in aligning transactions. However, it has also shown that certain transactions are being avoided which hampers innovation.

Theoretical framework

The theoretical framework used for this research is based on transaction cost theory which to large extent been has been outlined by Williamson (1985, 1991) and operationalized by TCE scholars (Klein and Shelanski, 1995). The application of transaction cost economics to study the issue of unbundling and innovation has provided interesting insights. The application of TCE on the topic of unbundling led to the expectation that unbundling has an effect on how innovations like advanced metering are organized.

Transaction cost theory has only to a limited extent been applied to transactions that deal with innovation. This study adds to the transaction cost literature additional attributes for determining alignment in the case of innovative transactions. The influence of *complexity* was difficult to observe, mainly due to the fact that the complexity of the AMI systems usually varied between moderate and highly complex and there was little difference between the Dutch and Swiss case. The appropriability regime attribute seemed to have a low impact on the alignment decision. This can possibly be ascribed to the fact that in 9 out of 10 cases one of the transacting parties was a publicly owned entity. The concern that the buying party would appropriate the benefits of the innovation was therefore limited. For example the possibility that a DSO would go into the software development business seems highly unlikely, because it would not be part of their mission statement.

The final indicator was that of systemic innovation. The advanced metering systems were rated as systemic innovations in 9 out of 10 cases. How big the impact was of systemic innovation on the organization of the transaction is difficult to tell due to the fact that there was little difference between the cases. But what was observed was the need for additional coordination between the parties in the electricity value chain and equipment suppliers in designing and implementing the system. Further testing of these transaction attributes is necessary to establish how significant their impact really is on the efficiency of the alignment outcome. What makes this research relevant in the light of existing literature on transaction cost economics is that it provides indications that the systemic nature of an innovation influences the way with which firms align their transactions with modes of governance.

The rational for unbundling the electricity industry has always been that the efficiency brought on by the competition among firms would outweigh the efficiencies that were created by internalizing electricity generation, distribution and supply. Joskow (1998) emphasized that efficiencies of central economic dispatch, network operations and investment complementarities are lost by unbundling the energy market. This research adds to this perspective that there is evidence that unbundling also reduces the incentive for developing systemic innovations in the electricity system.

Operationalization

The indicators used to operationalize the transaction cost framework have been based on several studies by scholars in the field of TCE (Williamson, 1985; Joskow, 1985; Anderson, 1985; Stump and

Heide, 1996), and innovation literature (Chesbrough and Teece, 1996; De Figueiredo and Teece, 1996; Hobday, 1998). The empirical testing of these indicators is in most cases limited with the exception of asset specificity, but the indicators have proven to be useful. Operationalizing the indicators for innovative performance proved to be more difficult. Financial or quantitative indicators do not capture all possible merits and outcomes of the innovation process. Additionally, there are a lot of external factors that influence the financial outcomes of an innovation from company to company. Finally an approach was chosen that measured to what degree the potential benefits of the innovation have been achieved (Bradford & Florin, 2003). This approach proved to be very instrumental in identifying the difference between the Dutch and Swiss cases.

Methodological approach

The overall methodological choice provided limitations as well as interesting insights. The choice for using a comparative case study approach made it possible to draw conclusions about the influence of unbundling. This approach was based on the application of Mill's method of difference. The sample of sub-cases selected in each country seemed to be appropriate and sufficient as it provided a good representation of the companies operating in both countries. In-depth interviews were held with the managers responsible for the development of the advanced metering infrastructures. The interviews helped give good insights into the development process and motivations behind certain choices. However it also created the potential problem that the interviewees did not answer the questions sincerely, but gave socially desired answers instead. The questions were therefore posed as neutrally as possible and additional resources such as, project websites, documentation and industry reports were used to validate and triangulate the answers given by the interviewees. Interviews with other project stakeholders, such as system suppliers, could have provided a more detailed depiction of the situation and would have created a higher internal validity, but the current setup satisfied the needs of this research. To make the findings more transferable I attempted to provide a *thick description* (Bryman, 2008) of the cases by including statements of the interviewed subjects in the analysis. Although this does not fully replace the criterion of external validity it does make it possible to use these findings in other research.

Limitations and practical implications

Care must be taken when generalizing these results. Firms might choose modes of governance based on a multitude of reasons which might not always have to be based on transaction costs arguments. Similarly these results might not translate to other types of transactions or innovations. However, the case of the electricity industry resembles to some degree other industries such as the railway and telecommunications industry where large interdependencies and vertical integration throughout the value chain are present. The findings in this research can therefore possibly be taken into consideration when reforming electricity sectors, sectors alike and in the development of smart grids.

Future research

Unbundling remains an interesting topic as not all effects of it have been uncovered. This research has revealed some new insights, but more research is necessary to establish what this means for the overall efficiency with which the electricity is organized. On the theoretical side more research should be done towards the application of TCE on innovation. The traditional elements making up the transaction cost framework like asset specificity and behavioral uncertainty have proven to be relevant, however the added innovation attributed less so. Additional research, therefore, needs to establish the true value of the innovation transaction attributes of *appropriability regime*, *complexity* and *systemic innovation*. There was not enough variation between the two cases to determine the impact of these indicators in the case of smart metering. However other cases, with more variation between the innovations, could prove to be more instrumental in providing insights into these matters.

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13 References

Anderson, E. (1984a), Integration of the sales force: an empirical examination. The Rand journal of economics, pp.385.

Armour, H.O. (1980), Vertical integration and technological innovation. The review of economics and statistics 62(3), pp.470.

Baarsma, B. (2007), Divide and rule. The economic and legal implications of the proposed ownership unbundling of distribution and supply companies in the Dutch electricity sector. Energy Policy 35(3), pp.1785.

Boekema J. (2011). Beoordeling uitvoeringsregelingen Slimme Meter No. TNO-RPT-DTS-2011-00463). Delft: TNO.

Boekema J. & J. Sluiman. (2011). Onderzoek overgangsbepalingen; Ontwerpbesluit Slimme Meter No. TNO-RPT-DTS-2011-01025). Groningen: TNO.

Bradford, M. & J. Florin. (2003), Examining the role of innovation diffusion factors on the implementation success of enterprise resource planning systems. International Journal of Accounting Information Systems 4(3), pp.205-225.

Bryman, A., ed. (2008), Social reserach methods (3rd ed. ed.). Oxford: Oxford U.P.

Chesbrough, H. & D. Teece. (1996), When is virtual virtuous? Organizing for innovation. Harvard business review 74(1), pp.65-&.

Coase, R.H. (1937), The nature of the firm. Economica 4(16), pp.386.

Crocker, K. (1996). In Groenewegen J. (Ed.), Regulatory issues with vertically disintegrated public utilities: A transaction cost analysis. NORWELL; 101 PHILIP DRIVE, ASSINIPPI PARK, NORWELL, MA 02061 USA: KLUWER ACADEMIC PUBLISHERS.

Darby S. (2006).
The Effectiveness of Feedback on Energy Consumption. A review for DEFRA of the Literature on Metering, Billing and Direct DisplaysEnvironmental Change Institute University of Oxford.

Davis, L. (2001). Profiting from innovations in digital information goods: The role of intellectual property rights. Paper presented at the Management of Engineering and Technology, 2001. PICMET '01. Portland International Conference on, , Supplement pp.471-480 vol.2.

De Figueiredo, J.M. & D.J. Teece. (1996), Mitigating procurement hazards in the context of innovation. Industrial and corporate change 5(2), pp.537.

Elfenbein, D.W. (2003), Ownership and control rights in Internet portal alliances, 1995-1999. The Rand journal of economics, pp.356.

ETP. (2010). Strategic Deployment Document for Europe's electricity networks of the future. http://www.smartgrids.eu: European Technology Platform.

Faruqui, A. (2010), Household response to dynamic pricing of electricity: a survey of 15 experiments. Journal of Regulatory Economics 38(2), pp.193.

Fetz, A. & M. Filippini. (2010), Economies of vertical integration in the Swiss electricity sector. Energy Economics 32(6), pp.1325-1330.

Flick, U. (2009). An introduction to qualitative research

Gerwen R., S. Jaarsma & R. Wilhite. (2006). Smart Metering KEMA.

Haney, A., Jamasb, T. & Pollitt, M. G. (2009), Smart Metering and Electricity Demand: Technology, Economics and International ExperienceFaculty of Economics, University of Cambridge.

Hanké, B. (2009). Intelligent Research Design (First ed.). New York: Oxford university press.

Harmantzis, F.C. & V.P. Tanguturi. (2007), Investment decisions in the wireless industry applying real options. Telecommunications Policy 31(2), pp.107-123.

Heide, J.B. (1990), Alliances in industrial purchasing: the determinants of joint action in buyer-supplier relationships. Journal of Marketing Research, pp.24.

Hobday, M. (1998), Product complexity, innovation and industrial organisation. Research Policy 26(6), pp.689-710.

IEA. (2011). Technology Roadmap: Smart Grids (RoadmapInternational energy agency. <www.iea.org>

Joskow, P.L. (1985), Vertical Integration and Long-term Contracts: The Case of Coal-burning Electric Generating Plants. Journal of law, economics, organization 1(1), pp.33.

Joskow, P.L. (1996), Introducing competition into regulated network industries: From hierarchies to markets in electricity. Industrial and Corporate Change 5(2), pp.341-382.

Joskow, P.L. (1998), Electricity sectors in transition. Energy Journal 19(2), pp.25.

Joskow, P.L. (1988), Asset Specificity and the Structure of Vertical Relationships: Empirical Evidence. Journal of law, economics, organization 4(1), pp.95.

Masten, S.E. (1989), Vertical integration in the US auto industry* 1:: A note on the influence of transaction specific assets. Journal of economic behavior organization 12(2), pp.265.

Menell, P.S. (1994), The Challenges of Reforming Intellectual Property Protection for Computer Software. Columbia law review 94(8), pp.2644.

Monteverde, K. & D.J. Teece. (1982), Supplier Switching Costs and Vertical Integration in the Automobile Industry. The Bell Journal of Economics 13(1), pp.pp. 206-213.

Moors, E.H.M. & J. Faber. (2007), Orphan drugs: Unmet societal need for non-profitable privately supplied new products. Research Policy 36(3), pp.336-354.

Netbeheer Nederland. (2011). Energy in the Netherlands 2011

Nickerson, J.A. (2003), Why aren't all Truck Drivers Owner-Operators? Asset Ownership and the Employment Relation in Interstate for-hire Trucking. Journal of economics management strategy 12(1), pp.91.

Niesten, E. (2006), Regulatory Institutions And Governance Transformations In Liberalising Electricity Industries. Annals of Public and Cooperative Economics 77(3), pp.291-307.

Niesten, E. & A. Jolink. (2011), Incentives, opportunism and behavioral uncertainty in electricity industries. Journal of Business Research

Patton, M.Q., ed. (2002), Qualitative research and evaluation methods (3rd ed. ed.). London: London : SAGE.

Pisano, G.P. (1991), The governance of innovation: vertical integration and collaborative arrangements in the biotechnology industry. Research policy 20(3), pp.237.

Pisano, G.P. (1990), The R&D Boundaries of the Firm: An Empirical Analysis. Administrative Science Quarterly 35(1, Special Issue: Technology, Organizations, and Innovation), pp.pp. 153-176.

Pruissen, O. (2011). Suppressing Peak Load at simultaneous demand of electric heating in residential areas

Ragin, C. C. (1987). The Comparative Method: Moving beyond qualitative and quantitative strategies. London, England: University of California Press, Ltd.

Richman B. D. & J.T. Macher. (2008). Transaction Cost Economics: An Assessment of Empirical Research in the Social Sciences No. 1581)

Rousseau Y. (2007). Assessment for the launch of a smart metering project: Illustration with the French business caseCapgemini.

Sampson, R.C. (2004), The cost of misaligned governance in R&D alliances. Journal of Law, Economics, and Organization 20(2), pp.484-526.

Shelanski, H.A. (2004), Transaction-level determinants of transfer-pricing policy: evidence from the high-technology sector. Industrial and corporate change 13(6), pp.953.

Simcoe, T. (2006), Open standards and intellectual property rights. H.Chesbrough, W.Vanhaverbeke und J.West (Hrsg.),‘Open Innovation: Researching a New Paradigm, pp.161-183.

Simon, H. A. (1976). Administrative behavior

Stuckey, J. A. (1983). Vertical integration and joint ventures in the aluminum industry

Stump, R.L. & J.B. Heide. (1996), Controlling supplier opportunism in industrial relationships. Journal of Marketing Research, pp.431-441.

Sustainability First. (2006). Smart Meters: Commercial, Policy and Regulatory Drivers

Teece, D.J. (1986), Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Research Policy 15(6), pp.285-305.

Teece, D.J. (1996), Firm organization, industrial structure, and technological innovation. Journal of Economic Behavior & Organization 31(2), pp.193-224.

Williamson, O.E. (1991), Comparative Economic-Organization - the Analysis of Discrete Structural Alternatives. Administrative Science Quarterly 36(2), pp.269-296.

Williamson, O.E. (1999), Public and private bureaucracies: a transaction cost economics perspectives. Journal of Law, Economics, and Organization 15(1), pp.306-342.

Williamson, O. E. (1985). The economic institutions of capitalism

Williamson, O.E. (1999), Strategy research: Governance and competence perspectives. Strategic Management Journal 20(12), pp.1087-1108.

Woo, C.K. (2008), Now that California has AMI, what can the state do with it? Energy Policy 36(4), pp.1366.

WWF. (2009). Auswirkungen von Elektroautos auf den Kraftwerkspark und die CO2-Emissionen in Deutschland. Frankfurt am Main: WWF Deutschland, Frankfurt am Main.

Yin, R.K., ed. (2003), Case study research: design and methods (3th ed. ed.). Los Angeles: Sage.

Yvrande-Billon, A. & C. Ménard. (2005), Institutional constraints and organizational changes: the case of the British rail reform. Journal of Economic Behavior & Organization 56(4), pp.675-699.

Appendix I: Data sources

Scientific literature

Davis, L. (2001). Profiting from innovations in digital information goods: The role of intellectual property rights. Paper presented at the Management of Engineering and Technology, 2001. PICMET '01. Portland International Conference on, , Supplement pp.471-480 vol.2.

Filipinni et. al., Deregulation of the Swiss Electricity Industry: Implication for the Hydropower Sector, CEPE Working Paper Nr. 13, (2002)

Harmantzis, F.C. & V.P. Tanguturi. (2007), Investment decisions in the wireless industry applying real options. Telecommunications Policy 31(2), pp.107-123.

Menell, P.S. (1994), The Challenges of Reforming Intellectual Property Protection for Computer Software. Columbia law review 94(8), pp.2644.

Simcoe, T. (2006), Open standards and intellectual property rights. H.Chesbrough, W.Vanhaverbeke und J.West (Hrsg.),'Open Innovation: Researching a New Paradigm, pp.161-183.

Project descriptions

BKW, Smart Metering presentation, Adrian Peter, (2011)

CKW, Newsletter; Experiences form the CKW pilot project, (2011)

CKW, Newsletter; CKW Prolongs its smart metering pilot, (2012), http://www.ckw.ch/internet/ckw/de/medien/news/archiv/2012/verlaengerung_smartmetering.-CKWSlot1-0006-File.File.FileRef.pdf/2012-04-27_Smart_Metering_Projektverl%C3%A4ngerung.pdf

CKW, Consumer web portal; https://www.ckwdirekt.ch/ivy/pro/CBSSP/CBSSPKS/index_frame.htm

EWZ, smart metering brochure for study participants, (2010)

IBM (Oxxio project), Newletter; Oxxio uses smart utility metering technology to give more control–and options–to customers, (2006)

Inergy (BKW), project website, http://inergie.ch/uber-uns/

IWB, Fact sheet smart metering, (2010); http://ebookbrowse.com/iwb-factsheet-smart-metering-0210-def-pdf-d90481894

Liander, Presentatie; Hoe slim is slim genoeg? (2009)

Lonneke Driessen, Presentation by Manager Smart Meter operation Enexis, 10-10-2012 Smart metering Billing/CRM Europe conference. (2012)

Oxxio website; http://www.oxxiopers.nl/achtergrond/geschiedenis-oxxio

Product descriptions manufacturers

Echelon, Bringing AMR and AMI Systems into a Smarter Grid, (2010)

EnergyICT, Website -Product description, http://www.energyict.com

Netinium, Product description, Unified management and control for multi-vendor, multi-utility smart metering and smart grids (2010), http://en.netinium.com/upload/PDF-s/netinium-product-data-sheet-amm-_lowres.pdf

Robotron, Self-contained and integrated solution and product portfolio for trade and sales, (2009) http://www.robotron-ecg.de/engl/res_download_engl.html

Vodafone; M2M platform, http://m2m.vodafone.com/discover_m2m/essentials/our_solution/

Industry rapports / Legislation

Agentschap Telecom, GPRS/UMTS licenties; http://www.agentschaptelecom.nl/onderwerpen/mobiele-communicatie

Austrian Federal Ministry for Transport (BMvit), Innovation and Technology; Smart Grids Initiatives in Europe (2010)

Bundesamt für Energie (BFE), Impact assessment smart metering Switzerland, (2012)

Capgemini, Assessment for the launch of a smart metering project: Illustration with the French business case, (2007)

Capgemini , From Policy to Implementation: The Status of Europe's Smart Metering Market, (2009)

DETEC (Department of the Environment, Transport, Energy and Communications Switzerland),(2005)

http://www.uvek.admin.ch/dokumentation/00474/00492/index.html?lang=de&msg-id=766

Netbeheer Nederland, DSMR Release Notes DSMR V4.0 Dutch smart metering requirements. (2011)

NEC (Nederlands Elektrotechnisch Comité). NTA 8130. Delft : Nederlands Normalisatie-instituut, ICS 17.120.10.(2007)

EL&I (Economische Zaken, Landbouw en Innovatie), Besluit op afstand uitleesbare meetinrichtingen, (2011a)

EL&I (Economische Zaken, Landbouw en Innovatie), Kamerbrief; Ontwerpbesluit houdende regels over op afstand uitleesbare meetinrichtingen (2011b)

EPO (European patent office); http://www.epo.org/searching/free/espacenet.html

ISPLC, Findings Linder PLC pilot, (2010); http://www.isplc.org/docsearch/Proceedings/2010/pdf/WPLC2010_05.pdf,

KEMA, Smart meters in The Netherlands; Revised financial analysis and policy advice, 2010

Stratix, Second Opinion Slimme Meter Communicatie, (2006);

TNO, Onderzoek overgangsbepalingen Ontwerpbesluit Slimme Meter (2011a)

TNO, Beoordeling uitvoeringsregelingen slimme Meter, (2011b)

Appendix II: Dutch Interview format

Introductie:

1. Wat is uw functie binnen ….. netwerkbedrijf?
2. Hoe bent u betrokken bij de implementatie van de slimme meters?

Organisatie

1. Wanneer is ….. gestart met de uitrol van slimme meters?
2. Wat is de huidige status van het slimme meter project?
3. Wat zijn dit bedrijf's doelstelling voor dit project?
4. Welke onderdelen van het slimme meter systeem zijn door (dit bedrijf) zelf ontwikkeld? (bijv. software, communicatie, interface etc..)
5. Welke andere bedrijven zijn bij de uitrol betrokken en op welke manier?
6. Zijn bij dit project ook eletriciteits- transmissie, generatie of verkoop bedrijven betrokken? (bijv. energie bedrijf of Tennet?)
7. Hoe is de samenwerking met de in vraag 4 en 5 genoemde bedrijven georganiseerd? Bijv: contracten, joint venture of strategische samenwerkingsverbanden?
   7.1. Zijn sommige van deze samenwerkingsverbanden veranderd gedurende het project?
   7.2. Blijven deze samenwerkingsverbanden bestaan na voltooiing van de implementatie?
   7.3. Hoe wordt de samenwerking gecoördineerd?
8. Hebben de samenwerkende bedrijven veel moeten investeren om aan jullie eisen te voldoen?
9. Hebben een van deze bedrijven onderdelen specifiek voor jullie ontworpen?
10. Hebben jullie geprobeerd om het succes van de samenwerking te meten?
    10.1. Zo ja, hoe?

Eigenschappen

1. Kan het slimme meter system worden gezien als een integraal onderdeel van het electriciteitsnetwerk of meer als een toevoeging?
   1.1. Waarom?
2. Welke kennis achtergronden zijn er betrokken bij dit project?
   2.1. Waarin heeft dit bedrijf moeten investeren?
3. Heeft de ontwikkeling en integratie van het slimme meter system, met o.a. de meters, software en communicatie technologie veel coördinatie en nauwe samenwerking geëist tussen de samenwerkende partijen? Of is het meer een sequentieel proces waarin elke partij na elke fase het van elkaar over neemt?
   3.1. Zijn bepaalde onderdelen parallel aan het elkaar ontworpen?
4. Welke onderdelen van het slimme meter system bevatten intellectueel eigendom (IP)?
   4.1. Hoe wordt deze kennis of technologie beschermd?
   4.2. Zijn deze technologieën gepatenteerd?
   4.3. Worden ze beschermd d.m.v. geheimhouding?
5. Is een of meer van de samenwerkende partijen van locatie gewijzigd (in de buurt van dit bedrijf) voor dit project?

Resultaten

1. Denkt u dat investeringen in netwerkcapaciteit op lange termijn kunnen worden beperkt door de invoering van slimme meters?
   1.1. Hebben jullie geprobeerd peak shaving in te voeren?
2. Wordt de data van de slimme meters op dit moment op andere manieren gebruikt dan voor afrekening/betalings-doeleinden?
   2.1. Hebben slimme meters een beter inzicht in het verbruikt van consumenten verschaft
   2.2. Waar kan de data van de slimme meters potentieel nog meer voor dienen (Ook zonder wettelijke beperkingen)
3. Kunnen de slimme meters ook worden gebruikt voor het ontdekken van fraude?
   3.1. Gebeurt dit sneller dan voorheen?
4. Zijn de kosten voor de meter lezen omlaag gegaan als een resultaat van de invoering van de slimme meters?

   4.1. Hoeveel sneller?
5. Zijn er nog andere voordelen van slimme meters die niet benoemd zijn?

Score vragen:

Hoe toepasselijk zijn de volgende statements?

Vraag	Score **1-7** is **Laag naar Hoog**
Personeel van andere bedrijven is speciaal getraind om het slimme meter system van dit bedrijf te kunnen ontwikkelen/implementeren. - Zo ja welke onderdelen?	
Het aandeel van hardware en software dat specifiek voor dit slimme meter systeem is ontwikkeld is:	
De technologische vernieuwendheid van deze technologie binnen onze organisatie is:	
Over het geheel genomen is het succes van de ontwikkeling en implementatie van de slimme meter:	

Appendix III: Swiss Interview format

Introduction:

1. What is your function within this company?
2. How are you involved in the development of an advanced metering infrastructure (AMI)?

Governance

3. When has *this company* started to develop an advanced metering infrastructure?
4. What is the current status of the advanced metering project?
5. Which parts of the advance metering infrastructure have been developed by *this company?*
6. Are other firms involved in the project, how are they involved?
7. Are all parts of the organisation involved in this project? E.g. transmission, distribution, generation and sales?
8. How has the cooperation with other firms been organised?

   e.g. mostly **internal development**, **cooperation**, through **contracting, joint ventures** etc.

   8.1. Have some of these collaborations changed during the development process?
   8.2. Are some of these collaborations persisting after the implementation of AMI?
   8.3. How is the development of AMI coordinated?
9. Did the cooperating firms need to invest in a lot of new resource to comply to your demands?
10. We certain developments made specifically for this project?
    10.1. Which one and how specific where they?
11. Is it possible to measure the performance of the cooperation?
    11.1. How is this measured?
    11.2. How is the quality of the transactions ensured?

Attributes

12. Can the advanced metering infrastructure be considered as an **integral part of the electricity network** or solely as an **extension**?
    12.1. Why?
13. What types of **knowledge backgrounds** are involved in the development of AMI?

    13.1. Which are the most crucial ones?

14. Does the **integration of smart metering into the network**, e.g. the smart meters, the data software and the communication network, require much **coordination and close collaboration between the cooperating parties or are the part sequentially handed over**?
    14.1. Have some of these systems been designed parallel to the AMI system?
15. Which parts of the AMI system contain considerable amounts of **proprietary information**?
    15.1. How are these technologies protected?
    15.2. Have these technologies been patented?
    15.3. Are these technologies protected through trade secrets?
16. Does the implementation of smart meters require contracting parties to relocate close to EWZ?

Success

17. Do you think AMI **will help limit investments in grid capacity**?
    17.1. Have some of these cost savings already achieved? (e.g. peak shaving)
18. Is the data on electricity use used in other ways than for billing?
    18.1. Has AMI provided **better insights into the energy use of consumers**?
    18.2. Has AMI led to more efficient procurement and selling of electricity?
    18.3. Have consumer changed their consumption patterns?
19. Has fraud been detected faster since the introduction of AMI?
    19.1. How much faster?
20. Have the cost of metering and billing been reduced?
    20.1. Is it possible to estimate a percentage?
21. What would you consider to be additional benefit of smart metering?

Scoring questions:

How appropriate are the following statements?

Question	Score **1-7** is **Low to High**
Personnel from other firms have specifically been trained to be able to develop and implement the IWB smart metering infrastructure.	
The percentage of hardware and software that has been specifically developed for the sole purpose of this smart metering infrastructure is:	
The degree of technological novelty in the advanced metering infrastructure is:	
The overall successfulness of the development and implementation of the advanced metering infrastructure is:	

Appendix IV: Results transactions Switzerland

EWZ

Transaction	Governance mode	Asset specificity	Behavioral uncertainty	Appropriability regime	Complexity	Systemic nature
Smart meter	*Market*	*Low*	*Low*	*Strong*	*Moderate*	*Autonomous*
Interface	*Hybrid*	*moderate*	*Low*	*Weak*		

IWB

Transaction	Governance mode	Asset specificity	Behavioral uncertainty	Appropriability regime	Complexity	Systemic nature
Smart meter	*Market*	*Low*	*Low*	*Strong*	*High*	*Systemic*
Communication device	*Market*	*Moderate*	*Moderate*	*Weak*		
Data communication	*Hierarchy /market*	*Low*	*Low*	*Strong*		
Software	*Market*	*Low*	*Low*	*Moderate*		

EWB

Transaction	Governance mode	Asset specificity	Behavioral uncertainty	Appropriability regime	Complexity	Systemic nature
Smart meter	*Market*	*Low*	*Moderate*	*Strong*	*Moderate*	*Systemic*
Data communication	*Hierarchy*	*Low*	*Low*	*Strong*		
Software	*Market*	*Low*	*Moderate*	*Moderate*		

BKW

Transaction	Governance mode	Asset specificity	Behavioral uncertainty	Appropriability regime	Complexity	Systemic nature
Smart meter	*Market*	*Low*	*Low*	*Tight*	*High*	*Systemic*
Data communication	*Hybrid (strategic alliance)*	*Low*	*Low*	*Tight*		
Control algorithm	*Hybrid (strategic alliance)*	Moderate	*Moderate*	*Moderate*		
Customer interface	*Market*	*High*	*low*	*Weak*		

CKW

Transaction	Governance mode	Asset specificity	Behavioral uncertainty	Appropriability regime	Complexity	Systemic nature
Smart meter	*Market*	*Low*	*Low*	*Tight*	*Moderate*	*Systemic*
Data communication	*Market*	*Low*	*Low*	*Tight*		
Energy data management	*Market*	Moderate	*Low*	*Moderate*		
Customer interface	*Hierarchy*	*High*	*Low*	*moderate*		

Appendix V: Results transactions The Netherlands

Westland netwerkbedrijf

Transaction	Governance mode	Asset specificity	Behavioral uncertainty	Appropriability regime	Complexity	Systemic nature
Smart meter	*Regulation*	*High*	*Low*	*Moderate*	*Moderate*	*Systemic*

Data communication and software	*Hybrid*	*Moderate*	*Low*	*Moderate*		
Installation	*Market*	*Moderate*	*Low*	*Weak*		

Enexis

Transaction	Governance mode	Asset specificity	Behavioral uncertainty	Appropriability regime	Complexity	Systemic nature
Smart meter	*Regulation*	*High*	*Low*	*Moderate*	*High*	*Systemic*
Data communication	*Market*	*Low*	*Low*	*Strong*		
Software	*Market*	*Moderate*	*Low*	*Moderate*		
Transfer metering data	*Market*	*low*	*low*	*weak*		

Liander

Transaction	Governance mode	Asset specificity	Behavioral uncertainty	Appropriability regime	Complexity	Systemic nature
Smart meter	*Regulation*	*High*	*Low*	*Moderate*	*High*	*Systemic*
Data communication	*Market*	*Low*	*Low*	*Strong*		
Software	*Market*	*Moderate*	*Low*	*Moderate*		
Transfer metering data	*Market*	*low*	*low*	*weak*		

Westland infra

Transaction	Governance mode	Asset specificity	Behavioral uncertainty	Appropriability regime	Complexity	Systemic nature
Smart meter	*Regulation*	*High*	*Low*	*Moderate*	*Moderate*	*Systemic*
Data communication	*Market*	*Low*	*Low*	*Strong*		
Software	*Market*	*Low*	*Low*	*Moderate*		
Software Customization	*Internal*	*High*	*Low*	*Weak*		
Transfer metering data	*Market*	*low*	*low*	*weak*		

Oxxio

Transaction	Governance mode	Asset specificity	Behavioral uncertainty	Appropriability regime	Complexity	Systemic nature
Smart meter	*Market*	*Moderate*	*Low*	*Strong*	*High*	*Systemic*
Data communication	*Market*	*Low*	*Low*	*Strong*		
Software	*Market*	*Low*	*Low*	*Moderate*		
Consumer interface	*Market*	*High*	*Low*	*Weak*		