PV Prosumers in the Dutch electricity market

A transaction cost perspective to sketch a future market design

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EXECUTIVE SUMMARY

PV prosumers could have a significant contribution to the 20/20/20 goals, but the Dutch electricity system is not adequately equipped to facilitate the transactions resulting from the electricity production of those prosumers. The current net metering policy has an uncertain future and net metering takes away the time dependent component of the balance of demand and supply for prosumers, while this is crucial in the electricity system as a whole. The goal of this research is, first, to gain insight in the institutional configuration of the current electricity system concerning the feed in and settlement of privately produced PV electricity. Second, this research will devise a design of a future, transaction cost efficient configuration, tested against the values of all involved actors. The main research question and sub questions answered in this report to achieve these goals are:

How can the institutional configuration of the electricity market be adapted in order for PV prosumers to contribute optimally to a sustainable electricity system?

1	What can the application of Transaction Costs Theory tell us about the current configuration of the market?
2	What does the design space of the electricity market concerning PV prosumers looks like and what options can be formulated?
3	What option can be selected as a sketch of an adapted market constitution?

Transaction cost theory is thus used to structurally analyse the transaction attributes (uncertainty, asset specificity and frequency) and governance structure attributes (incentive intensity, administrative control and contract law regime), resulting in a clear picture of the problems in the sector. It is then explored if reversing the discriminating alignment hypothesis could be applied to this research: instead of matching governance structures to transactions attributes, turning this around and adapt, with technical and contractual means, transaction attributes to match with the existing governance structure of the market. The proposed means to adapt the attributes in the intended direction are combined into three market design options:

1. *It's all in the bundle*: Exclusive supplier – prosumer relation using bundles, real time pricing and in house storage;
2. *One for all, all for one*: Many to many trading platform with a technical layer and a competitive domain for trade between multiple actors, real time pricing, semi-automatic demand side management and storage on neighbourhood level;
3. *Today and beyond:* Current supplier – prosumer trading model with demand automatically controlled and in house storage.

These market design options are evaluated by means of their impact on the problems that resulted from the transaction cost analysis. The results of this evaluation are compared to the requirements following from actor interviews conducted in the field research. Market design option 1 ('It's all in the bundle') turned out to be the preferred market design option, because it has the biggest impact on the intended direction of change of the attributes and it corresponds to the requirements named by the actors.

Future research should, first, take the direction of fine tuning this market design, taking into account more system features (cooperatives, impact on the grid, the credibility of future policy, et cetera) and focusing on consumer acceptance and production costs as well. Second, it should also be explored if the reversed discriminating alignment hypothesis could also work for other areas of research and what consequences in terms of complexities resulting from the reversal need to be taken into account. Finally, the second market design option ('One for all, all for one' – the many to many market) could still be a promising market design if innovative structures to keep administrative control manageable could be designed. Therefore this market design option should also be explored in further research.

PREFACE

The start of this thesis was a glimpse of a world I did not foresee would be suited for my graduation project: a master class about two-sided markets at transaction consultant Innopay that I joined out of curiosity. Quite quickly a meeting point between my academic specialty and Innopay's expertise was found: the emerging two-sided market in the electricity sector. Prosumers are generating electricity from 'the other side of the market', contributing to a sustainable energy system, while at the same time still receiving electricity from the grid. A hot topic: only in the course of this research two 'general consultations' about decentralized energy took place in Dutch parliament, talking for a big part about the private, decentralized contribution to the 20/20/20 goals and the future of net metering policies (= salderen). Moreover there have been numerous newspaper articles, opinion pieces, congresses et cetera et cetera, dedicated to the subject of this research: the topic was very much alive and talked about. It has been extremely motivating to explore a system that is considered this vital to the Dutch economy and its sustainability goals.

ACKNOWLEDGEMENTS

One of the reasons that this topic is 'hot', is the amount of actors in the system, and their very different interests. For this research it was vital to talk to all of them, in order to have a complete picture of the system. The enthusiasm and openness of all actors surprised me in the positive sense. I want to thank all interviewees for their valuable time; it is very much appreciated and important for this research.

Instead of taking on a research project within the university, I choose to take on a graduation internship position at Innopay. I wanted to a look into the world of consultancy and gain some experience in working in a dynamic environment. And dynamic it was. Nick Smaling, being the company supervisor from Innopay, has helped out a lot in the beginning, defining the subject of the research and motivating me to act fast and set strict deadlines. After a few months Nick took up a job opportunity elsewhere, and Jip the Lange took over the role of company supervisor. Jip has been very critical (in the positive sense) on both the content and the way it is presented, really taking this research and report to a higher level. Thank you both very much for your time and feedback, it has been crucial to completing this research and delivering this report. Douwe Lycklama, thank you very much as well, first for giving me the opportunity to take up this graduation internship at Innopay and second for constantly showing interest, inspiring me and thinking along, despite your incredibly busy schedule. It meant a lot. Soon also iNRG (specialized in energy managements systems) became involved in the research and its director Pascal van den Bosch was able to share a lot of valuable contacts and his own time and he transferred some of his never-ending enthusiasm and drive to make the world a sustainable place on to me.

Within the graduation committee, I have been most in contact with Theo Fens and Aad Correlje. A very good but also very difficult combination, because of their very different perspectives on the research. Theo took on a very practical perspective and advised me on every chapter of this report, mostly on the practical feasibility of what I had come up with. Thank you very much for the hours and hours that we have talked about the research, and the hours before that, that you must have spent reading the report. It gave me valuable insights. Aad took on a more theoretical perspective, challenging me to apply and translate abstract theoretical terms to this research. It has taken Aad quite some time to explain and discuss this with me, thank you very much for taking this time. Next to Aad and Theo, the chair of the committee, Rolf Kunneke, and the second supervisor Laurens de Vries are also much appreciated because of their guiding comments during the kick-off, midterm and green light meeting. Those comments have contributed a lot to the structural approach of the research.

From time to time I realized that talking to myself about what choices to make caused delays and that those internal conversations did not contribute to significant decisions. I needed discussions with and feedback from others, to be able to have a clear view on what would be next steps to take. Sophie Kerckhoffs in the period before the kick-off meeting, Roy Heijnsdijk around the midterm and Eva Verwijs towards the green light meeting: thank you for reading through this enormous pile of paper and taking the time to give feedback on it! It contributed enormously to this report.

Many friends, classmates and colleagues have expressed their compassion about my home situation: my boyfriend Roy van den Heuvel and me graduating in the same period; that must be very ‘ongezellig’. But, as Roy would say, nothing was less true. Graduating at the same time has been very motivating. Both being focused on graduating resulted in the same schedules and a lot of mutual understanding. So, last but not least, thanks Roy! The last few months have been much less heavy and actually fun, because we were doing it together!

A full page of acknowledgements; that must be enough. But it remarkably illustrates how many people have been involved in this research.

I wish you a nice read,

Renée Bekker

November, 2014

LIST OF ABBREVIATIONS

20/20/20 goals	Climate goals set by the European Commission: ▪ 20% reduction in EU greenhouse gas emission from 1990 levels; ▪ Raising the share of EU energy consumption produced from renewable resources to 20%; ▪ 20% improvement in the EU's energy efficiency. (EC, 2009)
ACM	Autoriteit Consument & Markt
AMS	Automatic/Advanced Metering Systems (smart meters)
CBS	Centraal Bureau voor de Statistiek
CHP	Combined Heat Production (Warmtekrachtkoppeling)
DRES	Distributed Renewable Energy Sources
DSO	Distribution system operator (regionally dependent)
EC	European Commission
ECN	Energie Centrum Nederland
ESCO	Energy Service Company: specialists in providing a broad range of energy solutions
EV	Electric Vehicle
gWh	Gigawatt-hour – large measurement for electricity production and consumption
kWh	Kilowatt-hour – measurement for electricity production and consumption
MIN EZ	Ministry of Economic Affairs
PR	Program Responsibility
PRP	Program Responsible Party
PV generated electricity	Photovoltaic (source = solar) generated electricity
RES	Renewable Energy Sources
ROI	Return On Investment
TSO	Transmission system operator (Tennet in NL)
USEF	Universal Smart Energy Framework
VPP	Virtual Power Plant

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1. Introduction

This introduction will scope towards the subject of this report, describes the current situation and will introduce the problem and the related goal of the research. At the end the approach will be explained and the structure of the report visualized.

1.1 Renewables & decentralized generation

The Dutch electricity sector experienced big changes following the Electricity act of 1998. The sector was liberalized and privatized to introduce competition in the market which would lead to sharper tariffs and better service. In 2007 The Netherlands committed, together with all other EU members, to the 20/20/20 goals (enacted in the EU energy package in 2009) (EC, 2009). For the Netherlands this meant a 14% share of consumed energy of renewable energy sources by 2020. This number was increased by the Rutte II government to 16% by 2023 (ECN, 2012a). In 2013 only a share of 4.5% consumed energy from renewable sources was reached (CBS, 2014b), a strong incentive to make a transition towards renewable energy sources faster than we do now.

The production of renewable energy can be divided in two main groups: centralized and decentralized. Traditionally, renewable energy has for a big part been produced decentralized (Figure 1). ECN (2012b) recognizes this trend of decentralization (and diversification) of energy production as well and marks it as being small but fast growing and important to reach the 20/20/20 goals. Benefits of the decentralized initiatives include the power source being close to the point of use, thus avoiding transport losses, increased reliability and a better match of demand and supply (El-Khattam & Salama, 2004; Shandurkova et al., 2012). As a result of their small size, decentralized energy sources can also be used more flexibly (Bayod-Rújula, 2009).

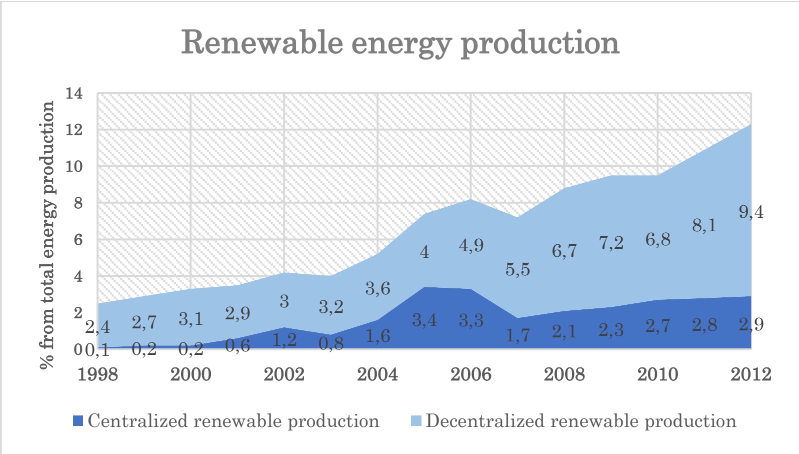


Figure 1: (De-)centralized Dutch renewable energy production (cbs.nl)

Next to decentralized commercial production activities, private initiatives are unfolding as well. Many of the private initiatives change the role of the consumer to that of (occasional) producer. The private consumers are now able to not only receive electricity from the grid, but also release the produced electricity from their solar panels, micro wind turbines, micro CHP et cetera that exceeds their own demands. The term used in this report for this type of consumers will be '*Prosumer*'.

[Prosumer] Economically motivated entity that (Shandurkova et al., 2012):
- Consumes, produces, and stores electricity and energy in general;
- Optimizes the economic and to some extent the technological, environmental decisions regarding its energy utilization;
- Becomes actively involved in the value creating effort of an electricity or energy service of some kind.

Prosumers experience a number of advantages when producing their own electricity: the electricity bill is lower, they can sell surplus electricity and provide their own back up and are therefore less dependent on suppliers (Shandurkova et al., 2012).

1.2 Photovoltaic (PV) electricity

A recent study of ECN (2012b) points out that from the private decentralized energy production options, photovoltaic (PV) electricity is very attractive for small consumers, mostly because of the relatively small investment and easy installation. Of the small scale options it is also mostly used – but still small. Total electricity production in the Netherlands in 2013 equals 98.574 GWh. From this 12% is from renewable energy sources: The 665,5 MW of installed PV capacity in the Netherlands generates 584 GWh. This is **5% of renewable electricity production and 0,6% of total electricity production** (Van Sark, 2014) (CBS, 2014, 2014a). In Germany, electricity production from solar panels equals 5% of total electricity production (Koot, 2013). But in 2012 and 2013, installed PV capacity in the Netherlands was doubled (Figure 2).

[Photovoltaic generation] Solar cells (grouped together on a panel) convert sunlight into electricity. Amount of electricity produced depends on the amount of sunlight and geographical location (Shandurkova et al., 2012).

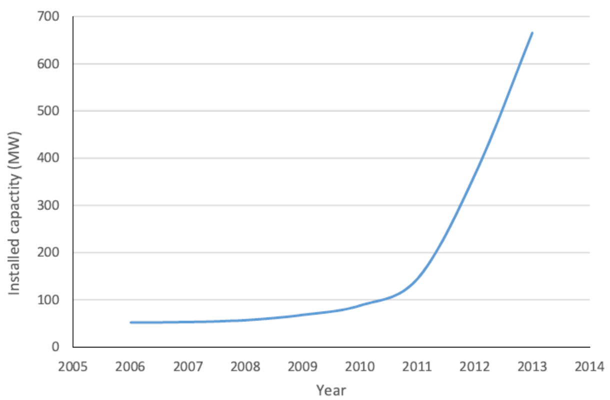


Figure 2: Installed PV capacity in the Netherlands (Van de Water, 2014)

The declining prices and collective buying of solar panels, high electricity prices for consumers and the temporary investment subsidies in 2012 and 2013 formed the basis for the growth of PV in the Netherlands the past few years. Together they resulted in, first, so called 'grid parity' (generation costs of one kWh PV electricity is equal to the price of one kWh from the grid, including purchase, installation, maintenance, financing costs et cetera (see Figure 3) and, second, low payback times (less than 10 years at current electricity prices). This makes it very attractive for consumers to engage in the PV electricity generation market.

From 2010 on, Dutch electricity production has decreased (CBS, 2013). If this trend continues, and combined with the persisting steep rise of electricity production from PV and renewables in general, the renewables and PV percentages will grow significantly, contributing greatly to the 20/20/20 sustainability goals. If the sector keeps growing with 40% per year (which is less than the current growth figures), 6% of Dutch electricity will be generated by solar panels in 2020 (Koot, 2013). It should be noted that the above figures are businesses, collectives and prosumers together, thus, not only prosumers, and that this research does focus solely on prosumers.

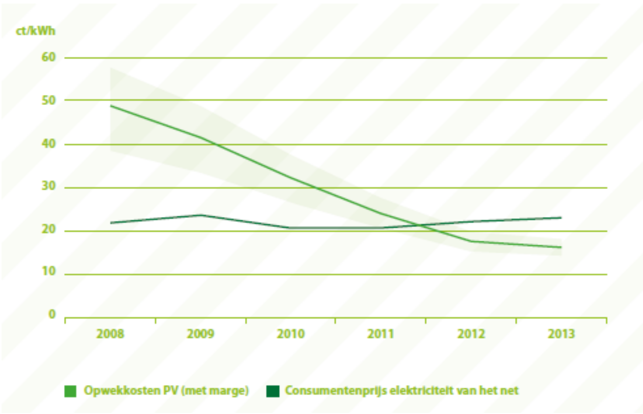


Figure 3: Grid parity: development of PV generation costs and consumer electricity price

Surprisingly, the doubled number of Dutch households operating solar panels on their roof in 2012 still only represents 1% of all Dutch households (ECN, 2012b). On the positive side, a collective of actors in the Dutch PV industry joined together in the Nationaal Actieplan Zonnestroom and estimates that by 2020 it may be possible to realize PV electricity generation of 3 to 6 % of the total Dutch electricity consumption (0,3% in 2013), making it a very important technology to realize the 20/20/20 goals and achieving a sustainable Dutch electricity market (ECN, 2013).

This research will focus on exploring the possibilities to enlarge and accelerate the private contribution to the 20/20/20 goals. Because PV electricity generation is the most attractive and mostly used form of private generation, the focus will be on this source primarily, but it is expected that results can easily be expanded to other technologies (small wind turbines, micro CHP) as well, because for these electricity generation technologies the mechanism of supplying 'back' to grid works the same. An overview of the scope we have arrived at is visualized below.

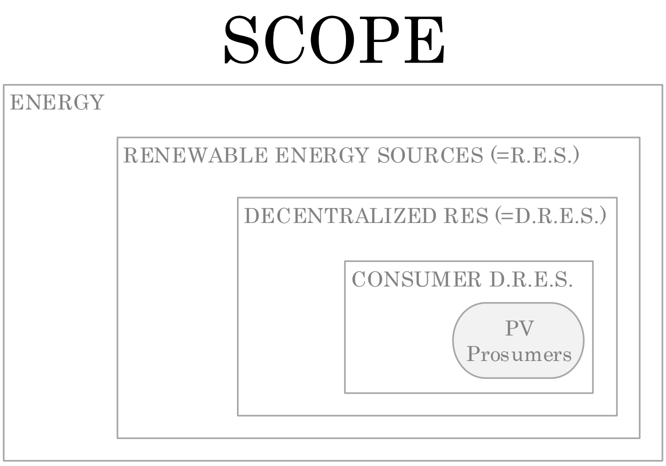


Figure 4: Scope of this research

1.3 Net metering

The current Dutch mechanism to compensate small prosumers (with a connection of less than 3x80A) for their generated electricity is called net metering (in Dutch: 'salderen'). It is a tax exemption for privately generated electricity, independent from the time of consumption (prosumers do not need to take the balance of supply and demand at each point in time into account, while this is very important for the system as a whole). Whenever households produce more electricity than they use themselves, it can be fed to the grid and drawn back at a later point in time, with no extra costs. In the figure below a graphical representation explains this mechanism. The grey and dark green part represent electricity consumed by the household. At times of no electricity production but in house consumption, electricity has to be drawn from the grid (grey). But during daytime when electricity is produced (yellow and dark green), the electricity need can be provided by the own generation system (dark green). On top of that, there is excess produced electricity (yellow) that is fed back into the grid. On the bill at the end of the year, this (yellow) is netted with electricity that was drawn from the grid (grey). Thus, the electricity peaks in consumption that lie outside of the times of production (dark grey peaks) do not ask for a change of consumption behaviour; this electricity can be drawn from the grid and is netted with the surplus electricity that was fed to the grid at times when there was a lot of production but no need for electricity (yellow). If there was overall more consumption than production, the prosumer has to pay for it and only over this part the prosumer pays energy taxes. If there is net production, the prosumer receives a fixed tariff per kWh from their provider (Energiegids.nl, 2014).

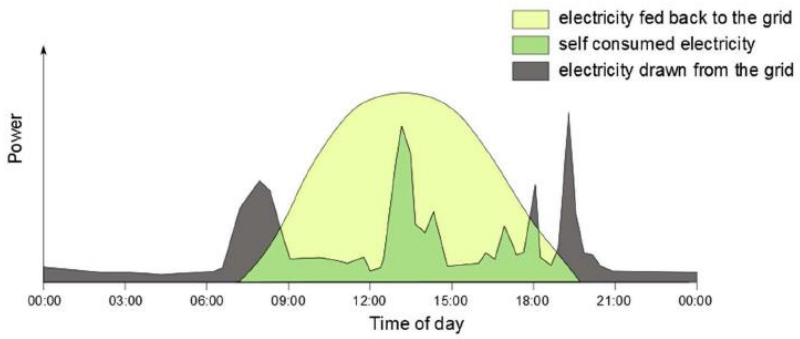


Figure 5: Graphical representation of net metering (Van de Water, 2014)

The business case for PV prosumers is mostly based on this net metering mechanism with the tax exemption 'behind the meter' and the net metering of production and consumption at different points in time (Simmons, 2013). An example to illustrate this: when a prosumer would draw 1000 kWh from the grid to load his electric vehicle (EV), this would cost him approximately 250€ (±0,25€/kWh = kWh price with taxes and transport costs). When the prosumer has solar panels producing the 1000kWh, or the panels have produced the 1000 kWh at another point in time and the prosumer can draw it from the grid for 'free' using the net metering mechanism, this costs the prosumer nothing (except investment in solar panels). However, when the prosumer would feed this 1000kWh to the grid and does not consume it later, the prosumer would be paid 60€ (±0,06€/kWh = part of kWh price without taxes and transport costs). Thus, by making use of the net metering policy he gains 190€ per 1000kWh. The difference is this big because the total kWh price is for a large part (±0,19€ of the 0,25€/kwh) made up of taxes and transport costs.

Net metering was officially enacted in article 31c that was added to the electricity act of 1998 on July 14th 2004 (before that it was already unofficially applied by prosumers via bidirectional meters) and it obliged network operators and energy suppliers to apply net metering. The regulation was only applicable to small generators (<3000kWh/year fed back into the grid). In 2011 the limit was increased to 5000kWh/year and from that time on there were also energy suppliers that allowed unlimited net metering (without being obliged to do so by law). From the 1st of July 2014 unlimited net metering was also enacted by law.

The aim of the net metering tax exemption (Initiated by Samson in 2004) was to provide prosumers with a reasonable compensation and therewith stimulate consumers to produce electricity from renewable sources. The simple solution of net metering did just that: the already installed bidirectional meter accounted for little administrative effort: it runs 'forward' when electricity is drawn from the grid, and backwards when it is fed into the grid (given that there is no reverse lock) and resulted in a reasonable compensation, because the amount electricity that was fed to the grid could be drawn from the grid for free at another point in time.

Without a bidirectional meter, the process of calculating the net amount of electricity from the grid is a more complex administrative process. This is the case when a digital or smart meter is installed, which is more and more the case in recent years. Following the positive results of the tests where 600.000 meters were replaced by smart meters, all Dutch households should have a smart meter by the end of 2020 (Kamp, 2014). The reasons stated for this large scale deployment are energy savings, efficient grid management, the introduction of smart grids and less administrative processes – but for the net metering mechanism, more administration is needed.

1.4 Problem description

Two primary reasons exist for the execution of this research:

1. The future of the Net metering mechanism is uncertain. Minister Kamp (Economic affairs) announced that from 2017 it will be assessed whether the current policy has to be adapted in 2020 (with a promised transition period of two years), and that the chance that it will be adapted is significant. The reason for this is the loss of income for the government following the net metering mechanism. This loss of income is expected to grow significantly the coming years (Simmons, 2013). This uncertain future of net metering leads to uncertainty in the sector. Prosumers cannot be sure of their return on investment, because it is unknown what policy or mechanism will replace net metering after 2020. But this uncertainty is also an opportunity to review the current system and propose future market design options in the course of this research.
2. Prosumers get paid a fixed tariff for the net excess of electricity they provide to the grid, regardless of the point in time. This does not reflect the value of electricity at that point in time; it is not subject to market forces of supply and demand and it does not contribute to the system balance of supply and demand.

In response to these reasons, preliminary interviews have been held and various forms of literature have been studied (newspapers, blogs, scientific journals, et cetera) to get a clear view of the different actors in the system and their concerns about the electricity system and PV prosumers. The focus was on the four most important actors: consumers, distribution system operators (DSO's), suppliers and governmental bodies. Their goals and problems are outlined in the table on the next page.

This initial, exploratory research has shown a situation where actors have both overlapping and conflicting wishes and concerns about the current and future institutional configuration of the Dutch electricity system concerning PV prosumers. This complex situation will be further analysed in chapter 4 using Transaction cost theory. This theory will be used because it provides the tools to analyse the complex transactions in the electricity industry and specifically PV prosumers, as well as the market structures that govern the transactions.

Table 1: Goals and drawbacks of four most important actors in the system

	Wants to…	However…
Consumer	- Contribute to **sustainability** - Be in **control** of electricity supply - Economize (ECN, 2013)	- Uncertainty of future policies makes ROI difficult to estimate (Simmons, 2013; Watson et al., 2008) - Fixed tariffs give few incentives to react to market dynamics - No reward for 'being green', other can 'free ride' on their sustainable efforts (Payne et al., 2001)
DSO	- Facilitate a cost efficient sustainable electricity system - Prevent cascading upwards where TSO/Tennet is concerned with the high voltage grid	- Electricity generation from the 'other side of the market' has a significant impact on the grid and is less predictable. (Passey et al., 2011) - Necessity to work with prosumer/consumer that has few knowledge of the system characteristics
Supplier	- Continue to be **profitable** in a transitioning market with volatile electricity supply - Are necessary to supply **back up capacity** when there is no supply from wind and sun	- The uncertainty of policy and development of the market makes investment decisions difficult - Impossible to incentivize customers to react on dynamic market prices when producing and consuming - They face large depreciations on large generators because these are occasionally used, when there is not enough supply from renewable resources.
Government (in various forms – regulator, policy maker legislator, tax office)	- Achieve **sustainability goals** (Watson et al., 2008) - Safeguard **security of supply** (Passey et al., 2011) - Establish a **level playing field** in liberalized electricity market	- Significant tax losses due to the growth of PV (Simmons, 2013) - With the bidirectional meter net metering was a simple solution for a rare phenomenon. Nowadays (with digital and smart meters) the mechanism is not simple anymore.

1.5 Goal

The problem description in the previous paragraph shows an uncertain future and a restricted electricity market for suppliers concerning PV prosumers. The opposing interests and concerns of the actors show that the electricity system is institutionally not equipped to incorporate prosumers in the long term. This can be seen as an opportunity to change the market design in order to remove the barriers towards a contribution of PV prosumers to a decentralized sustainable energy system. Therefore, the objective of this research is twofold:

1. Gain insight in the institutional configuration of the current electricity system concerning the feed in and settlement of privately produced PV electricity, from a transaction cost perspective.
2. To devise a design of a future, transaction cost efficient configuration, tested against the values of involved actors.

The results can be used to set-up an innovative market model to handle market transactions associated with the settlement of electricity in two directions: from and to the distribution network. Actors in the electricity market (policy makers and regulators, suppliers, producers, TSO, DSO's, 3th parties, et cetera) may use the results to critically review the current system and consider an adaptation of the market design towards a new configuration.

1.6 Research boundaries

For this research the report of the Planbureau voor de Leefomgeving (PBL) is taken as a starting point. It states – in their August 2014 report on the potential of solar energy in the built environment – that the current distribution grids can handle 16 GW of solar power, while at this point 0,7 GW is operated in the Netherlands. For 2020 it is expected to raise to 4 GW, largely within the distribution grid constraint (PBL, 2014). It should however be noted that this concerns the general processing capacity of the Dutch distribution grid and does not apply to each and every area or situation, such as single extensions of the grid with big suppliers at the end and neighbourhoods with above average installed PV capacity that supply all at the same time; when the sun shines (simultaneity factor is 1). Nevertheless, we will not take the technical processing capacity of the distribution grids as a constraint in this research.

It is also assumed that any technology following from the smart grid transition that would be needed to facilitate a solution is technologically achievable and ready to use.

Lastly, the current policy for cooperatives to apply net metering on their PV initiatives is the 'postcoderoosregeling'. This provides the opportunity to (partly, no full tax exemption) apply the net metering mechanism to solar panels at 'another roof', which is attractive for cooperatives and/or households without a private roof. This research will only focus on prosumers operating from their own home and not via cooperatives and the 'postcoderoosregeling'.

1.7 Research question

Following the problem statement and research objective in the previous paragraph, the research question and its sub questions (answering them will answer the main question) can be found in Table 2. They will be used to conduct this research in a structural manner.

Table 2: Research questions and sub questions

How can the institutional configuration of the electricity market be adapted in order for PV prosumers to contribute optimally to a sustainable electricity system?		
1	What can the application of Transaction Costs Theory tell us about the current configuration of the market?	Chapter 3&4
2	What does the design space of the electricity market concerning PV prosumers look like and what options can be formulated?	Chapter 5&6
3	What option can be selected as a sketch of an adapted market constitution?	Chapter 7&8

1.8 Approach

The current market configuration concerning PV prosumers will be analysed using the theoretical framework of Transaction costs theory. This theory describes how governance structures can be efficiently aligned with the attributes of transactions to guide those transactions. It can also be used to analyse existing situations; are governance structures and transactions aligned efficiently? If not, what are the properties that can be changed?

The analysis of the situation concerning PV prosumers with Transaction cost theory and the operationalization of the theory (using knowledge from desk and field research) will result in a design space, consisting of variables within the electricity system that can be changed to reach 'efficient alignment'. Multiple options will be composed from the design space and they will be judged on their impact on the problems resulting from the transaction cost theory analysis and using the field research. The data collection for the field research will be done via interviews that will be conducted with the various actors, resulting in a clear picture of the values, constraints and possibilities of the actors. A design option will be selected with consideration of opportunities, trade-offs and concerns.

The approach of this research is visualized in the figure below. It will serve as a guideline for the research and in it will be further explained in the next chapter. The approach is loosely based on the methods used by Herder and Stikkelman (2004). This framework will be further explained in the next chapter as well.

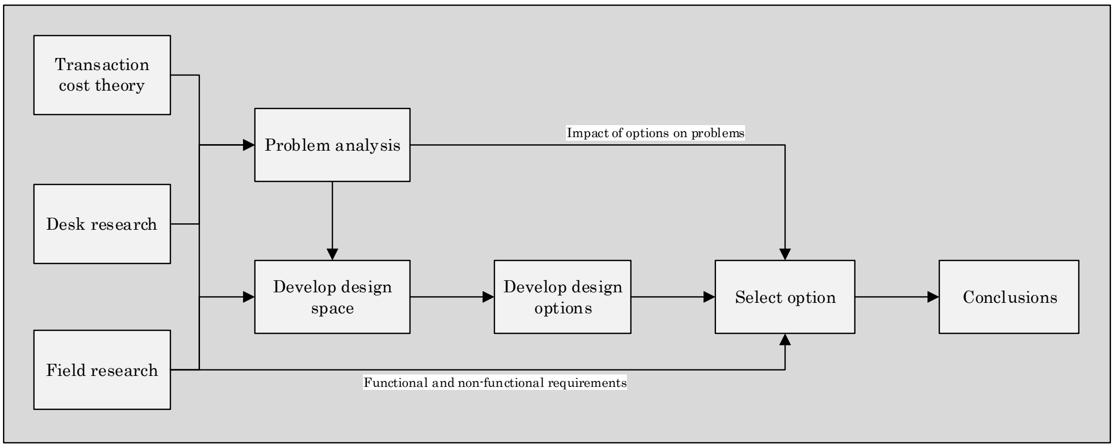


Figure 6: Approach

1.9 Structure

This report will be structured as follows (depicted in the scheme below): in the next chapter the methods of this research will be explained. Chapter 3 will provide the theoretical framework (Transaction cost theory) and chapter 4 will apply this theoretical framework to the problem under consideration. In chapter 5 this will result in a design space from which multiple design options will be composed in chapter 6. In chapter 7 the field research performed for this research is described. It will be used to reflect on the acceptability of the designs and the possible solutions and trade-offs (chapter 8). Chapter 9 will provide conclusions. Chapter 10 and 11 take a hindsight perspective: chapter 10 discusses the results and lastly chapter 11 gives a reflection on the process of researching and writing this thesis.

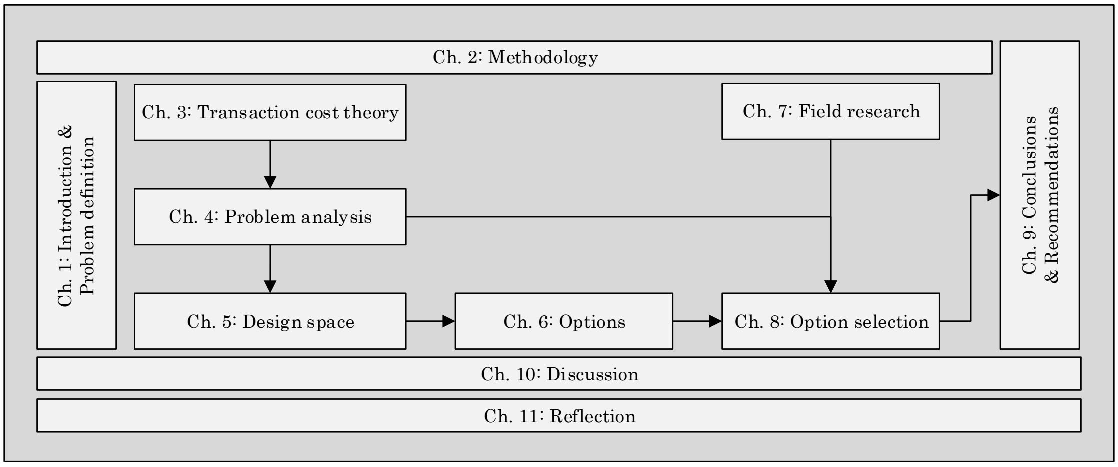


Figure 7: Structure of this report

2. METHODS

The previous chapter described the area and goal of the research and introduced the approach. This chapter will elaborate on the approach by explaining the methods used to tackle the problem. First the research framework will be explained, followed by the motivation for, and explanation of the use of Transaction cost theory and the field research.

2.1 Case study approach

The situation introduced in the previous chapters will be considered an explorative case study. The case study is a suitable approach because Transaction cost theory can be applied to the current configuration of the electricity market and PV prosumers (real-life context).

> **[Case study definition]** "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2003)

2.2 Introduction research framework

To give this research structure, a suitable research design is needed. This research will take Transaction cost theory to analyse the current electricity market concerning prosumers and to propose adapted designs. In this complex system, the concerned actors and their values and possibilities are highly important as well. However, transaction cost theory focusses on transactions, and does not take actor preferences into account. To make a combination of those two perspectives, a research design loosely based on the methods described by Herder and Stikkelman (2004) is used (Figure 8). This method has proven its value in the design of methanol clusters with a complex actor field in the Rotterdam Harbour area and collaborative MSc. courses between Carnegie Mellon University and Delft University of Technology. In the next paragraphs the research framework will be applied to the subject and all relevant terms, such as 'design space', will be explained.

> **[Research design definition]** "blueprint of research, dealing with at least four problems: what questions to study, what data are relevant, what data to collect, and how to analyze the results" (Philliber et al., 1980)

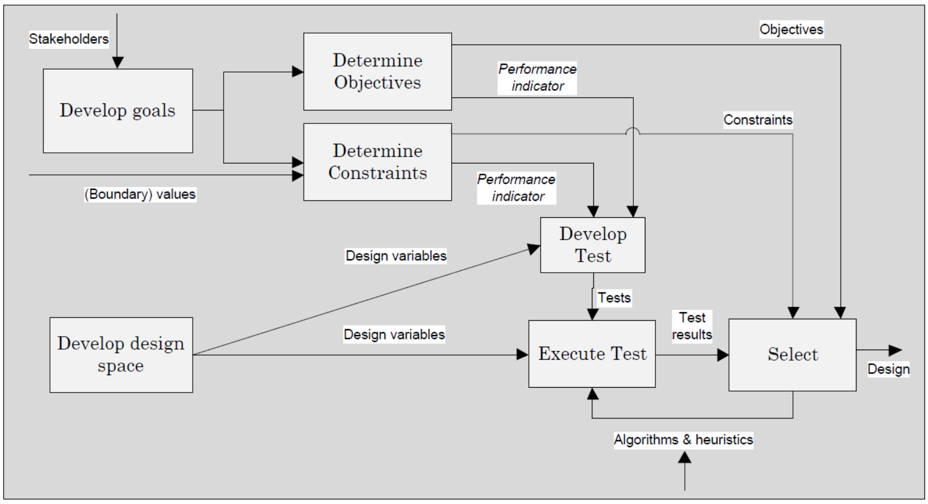


Figure 8: Generic conceptual design framework of Herder & Stikkelman (2004)

2.3 Application research framework

The approach of Herder and Stikkelman (2004) is adapted to this research; the approach created to serve as a research design is depicted below. The research questions that need to be answered using this approach can be found in chapter 1.

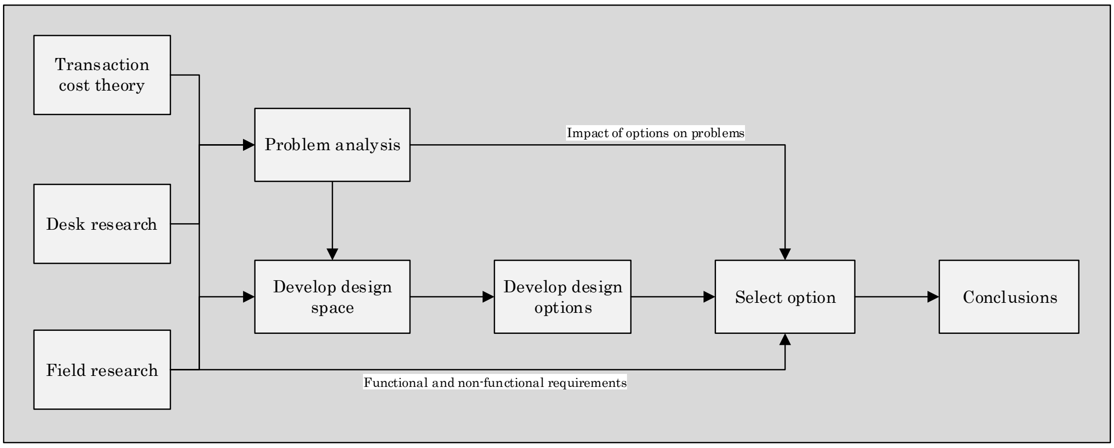


Figure 9: Approach

Transaction cost theory is used to analyse the current configuration of the electricity market, and – together with ideas derived from field and desk research – this analysis will be used to develop a design space. The design space will contain means, which, when they are used in various combinations, will result in different market design options. The different market design options are evaluated by the impact on the problems stated in the problem analysis and validated with the interviews performed in the field research. The conclusions will state the final market design options, together with the institutional changes required for the implementation of the final design option. The terms in the figure are further explained in the next paragraphs and Figure 9 will be used as a navigation tool throughout the report.

2.4 Use of theory & problem analysis

"Theory development prior to the collection of any case study data is an essential step in doing case studies" says Yin (2003). Theory development gives strong guidance to the research design in what data to collect and strategies to analyse it. The theory that will be used in this research is that of Transaction Costs.

Transaction cost theory is valuable to this research because it attempts to match governance structures and transactions (called discriminating alignment) in order to minimize transaction costs. Those costs are caused by inefficiencies in the way a transaction takes place and incomplete information and bounded rationality on the side of the actors that participate in the transaction.

The principle of matching governance structures with transactions to economize on transaction costs shows overlap with the subject of this research: the fairly new transactions that prosumers and suppliers are making concerning self-generated electricity and the contractual and technical structures designed to make this happen are possibly not aligned in the most transaction-cost-efficient way. Transaction cost theory will therefore be used to analyse the current situation and judge in what areas it is and is not configured in a transaction-cost-efficient way. Chapter 3 will elaborate on the theory.

2.5 Other economic theories

This research focusses, as explained, on the efficient functioning of a techno-economic system (Dutch electricity market concerning prosumers). The efficient functioning is said to be achieved when transaction costs are reduced by efficiently matching transaction attributes and governance structures (discriminating alignment). However, this theory is not the only economic theory that aims to achieve an efficiently functioning techno-economic system. This paragraph introduces other relevant economic theories and reasons why they have not been pursued in this research. The discussion (chapter 10) will in hindsight discuss the course this research could have taken when these other theories had been used.

2.5.1 Williamson's Cognitive map of contract

Within the same branch of institutional economics, Williamson introduces the 'cognitive map of contract', entailing multiple theories that analyse the efficiency of market structures (figure below). From this figure it follows that Property Rights theory and Agency theory might entail relevant concepts to apply to the subject of this research as well, since 'setting the incentives right' is the key question in the restructuring of the Dutch electricity market concerning prosumers: how to design the market in such a way that incentives lead to an optimal outcome in the transactions that a PV electricity prosumer brings about?

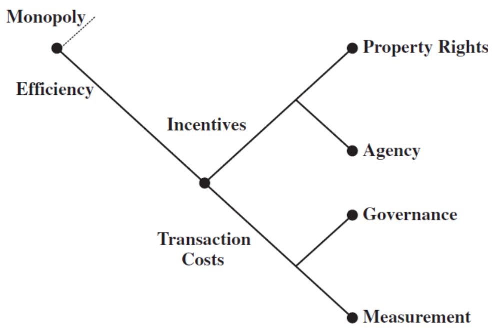


Figure 10: 'Cognitive map of contract' (O.E. Williamson, 1985)

2.5.2 Agency theory

Agency theory takes the principal-agent relationship and the incentives within the contract of this relationship as a point of focus and does not so much take on a system perspective. It optimizes (with constraints) the incentive alignment and thereby attempts to reduce monitoring and bonding costs between the principal and the agent, all *ex ante* – before the transactions take place. Thus when, according to the theory, the contract is set right, *ex post* features – that might arise due to contractual imperfections – are ignored and supressed (Kim & Mahoney, 2005). When taking into account Williamson's four layer model (explained in the next chapter), agency theory concerns the lowest level of analysis; the behaviour of the economic actors.

In the course of this research this would mean that (for example) the contractual relationship of supplier and prosumer is taken as the unit of analysis, assuming that this will be the prevailing relationship, in which the contractual arrangements can be optimized in order to align incentives of the two actors in terms of balancing supply and demand. Stretching the theory, the principal could also be 'the system', and the agent is the prosumer that is generating electricity, but (due to misaligned incentives) not in a way that benefits the system. The 'contractual relationship between prosumer and system' could therefore be optimized (Kim & Mahoney, 2005).

Transaction cost theory is chosen over this theory because it is able to take on a system perspective, where the attributes and relations within the whole market are taken into account (in order to reduce transaction cost both *ex ante* as *ex post*) because the existing organization form might result in inefficient economic outcomes. For this research it is undesired to take the existing relation of two actors as a focus point, instead of questioning this relationship. Also questioning the exact incentives within the contract between the economic actors would be undesired, because it concerns a too low level of analysis. First it needs to be determined which actors are in a contractual relationship and what incentives need to be in place in general.

2.5.3 Property rights

Property rights theory attempts to improve social welfare and minimize contractual problems by assigning property rights correctly, *ex ante* – thus efficiently set before the transactions take place. Who does, owns and controls what in order to achieve overall (social) welfare. An existing institution is evaluated in if it is doing 'its job' and leads to social welfare, what economic impact it has and how it affects public policy and the legal framework. If property rights are unsure and/or inefficiently assigned, this leads to unwanted/negative externalities (for example actors following their individual and differing incentives); the arrangement of property rights is therefore compared to possible other forms (Kim & Mahoney, 2005). When taking into account Williamson's four layer model (explained in the next chapter), property rights theory concerns the second level of analysis, determining the institutional relations between the actors.

Applied to the subject of this research, property rights theory could analyse the current laws concerning the unbundled electricity sector (who can own and control which part of the electricity sector) and for example net metering policy and/or compare it to a proposed future policy (Kim & Mahoney, 2005).

This theory is not chosen as a the central theory of analysis, because it focusses on solely on the *ex-ante* optimization of the contract to avoid externalities, where in this system it is likely that the complex relationships of actors and the complex functioning of the system will result in inefficiencies, even though the property rights are theoretically assigned right in the 'perfect institution'.

Transaction cost theory takes the important insights from both agency theory (on the lower level) and property rights theory (on the higher level) as building blocks and specifies them further on the level of governance structures and transactions. They are thus to a certain extend incorporate in Transaction cost theory.

2.6 Design space & Options

On the basis of the analysis of the electricity system with transaction cost theory, a design space is developed. This is done by means of theoretically improving governance structures and/or transactions and translating this 'transaction cost language' into technical and contractual terms of the electricity system. The problem analysis itself, desk research and field research are used to develop the design space.

[Design space] Consists of a number of 'degrees of freedom': the parameters of the system that may vary independently. Such as the amount of control over the prosumers' system that lies with the prosumer himself or is in the hands of the supplier or the DSO.

A simple example: if, from transaction cost theory analysis of the system, it follows that the practical translation of theoretical terms are the following parameters in the system: (1) the amount of control that lies with the prosumer, (2) to what extent the prosumer has a choice whether or not to pay to make use of back up capacity and (3) how storage in the system is arranged. Then an option could be to have a system with (1) absolutely no control for the prosumer (the supplier controlling the solar panels and a part of the in house energy consumption), (2) a low degree of self-determination of back up capacity for the prosumer (every Dutch household should pay a certain amount of money to have security of supply at all times) and (3) suppliers offering storage as a paid service (instead of installing small storage systems in every household).

2.7 Field research

The design options (containing different variations of the variables from the design space) will first be evaluated on their impact on the problems found in the problem analysis. Consequently, the result of this evaluation will be compared with the findings from field research. For this data will be collected via interviews that will be held with concerned actors and experts. An overview of the interviews can be found in attachment A, as well as how they are referred to in the rest of this report. These particular actors were selected because they correspond to the actors concerned with PV prosumers or because they have a lot of knowledge and/or interest in the subject, such as consultants, collectives or activists. For some sectors interviews have been conducted with more than one actor (DSO's, suppliers, consultants). The point of view of these actors could vary in such a wide range that a single interview with only one actor for the whole sector would not have given representative results. The spokesperson of the particular actor has been matched by the actors themselves (according to the research questions), or was referred to in earlier interviews.

The interviews are about what positive and negative sides the actors experience in the current market configuration concerning prosumers, what they expect from a future market configuration and what they do not wish to see in a future configuration. Also the way the actors deal with PV prosumers and the transitioning market as whole will be a subject of conversation, with special attention to innovative and new regulatory or physical test trajectories and solutions executed by the actors.

The interviews will be conducted via a prepared list of questions (attachment A), which will preferably be answered during an open conversation, instead of a one-by-one question posing. Remaining non answered questions will then be posed in the last phase of the interview. This is in line with the description that Rubin and Rubin (1995) give about interviews: "Interviews will appear to be guided conversations rather than structured queries. In other words, although you will be pursuing a consistent line of inquiry, your actual stream of questions in a case study interview is likely to be fluid rather than rigid." (Rubin & Rubin, 1995).

The interviews are not recorded. This choice is made to motivate the interviewees to speak as freely as possible and because it is the preference of the interviewer. At the start of the interview permission is asked to make notes, and during the interview little pauses or silences provided time to write. A report of the interview was made the same day, based on the notes and memory. It was then sent to the interviewee to correct, complement and ultimately approve for use in this research.

[Principles of data collection Yin (2003)] to maximize the benefits of data collection, in this case interviews.
(1) Use multiple sources of evidence. Attachment A provides an extensive list of respondents
(2) Create a case study database. All interviews are summarized on the same day, send to the interviewee to correct, complement and approve, and are then kept in a file with 'approved reports'
(3) Maintain a chain of evidence. A clear trail from the question form (prepared as guide for the conversation line during the interview), to the summary of the interview structured following this guide, to the summarizing tables and lastly concluding remarks is apparent.

2.8 Test & Selection

When various design options are created with the parameters in the design space they will be evaluated, first, on what impact they have on the problems resulting from the problem analysis. This result will be compared to an evaluation of the options using the field research. From this it will become clear what trade-offs might exist in preferred options using the theoretical problem analysis approach and the option that shows the highest acceptance by the actors, and what, in the end, will be chosen as the final design option. This option will be compared to the current situation and the necessary institutional changes to the system to implement the final design option will be indicated.

2.9 Reflection

2.9.1 Qualitative approach

The construction of the design space is based on the findings from the application of transaction cost theory to the Dutch electricity system, but is also for a large part composed using creatively combining technical and contractual options. This bears the risk of overlooking important variables or accidently bypassing ways of combining variables into transaction cost efficient options. To reduce this risk, all variables and design options are discussed with transaction cost experts and experts in the Dutch electricity industry.

2.9.2 Evaluation of interviews

The *open ended* approach used in the interviews worked quite well, and resulted (in hindsight) in exactly what Yin (2003) described: "Case study interviews are of an *open ended* nature, in which you can ask key respondents about the facts of a matter as well as their opinions about events. In some situations, you may even ask the respondent to propose his or her own insights into certain occurrences and may use such propositions as the basis for further inquiry. The respondent also can suggest other persons for you to interview, as well as other sources of evidence".

Another interesting effect of the chosen interview approach (taking notes instead of recording), was that the interviewees began talking about the subject without questions being posed, suggesting that this silence provided them the space to add information that was relevant to the research in their eyes, but was not asked for yet. This has provided a lot of valuable information.

3. TRANSACTION COST THEORY

[SubQuestion 1]

What can the application of Transaction Costs Theory tell us about the current and future configuration of the market?

[Ch. 3&4]

To provide this research with a theoretical framework to analyse the phenomena of prosumers in the Dutch electricity system, Transaction cost theory will be used.

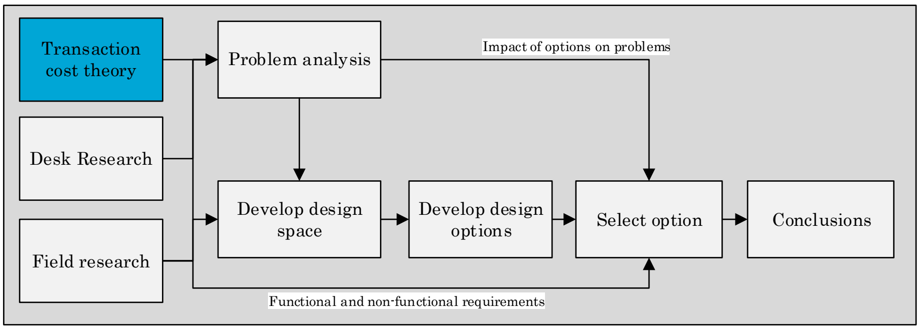


Figure 11: Situation of chapter 3 in the approach

The term 'transaction costs' was first introduced by Ronald Coase (1937). He recognized the costs (transaction costs) involved in running the economic system. Economic actors try to minimize these costs by finding a corresponding 'governance structure' (market or firm) for making the specific transaction. Simply said, economic actors decide what is of least cost: 'make' or 'buy' the entity that the transaction is about. The term 'transaction costs' was further developed into Transaction cost theory by O.E. Williamson (1975) (and many later publications). In contrast to Neo Classical economic thinking where the market is viewed as an ideal and efficient configuration for all economic transactions, Transaction cost theory compares different forms of governance serving different forms of transactions, thereby economizing transaction costs, recognizing that not all market transactions are perfect and aiming to find the most efficient governance structure. In some cases the market can be the most efficient governance structure, in others all transactions are internalized in one firm (Niesten, 2009).

Transaction cost economics is taken as the theoretical basis of this research because it focusses on the transaction as the central unit of analysis. As O.E. Williamson (2003) described: "Transaction cost economics not only takes the transaction to be the basic unit of analysis but views governance as the means by which to infuse order, thereby to mitigate conflict and realize mutual gains". Thus, governance is a means to realize efficient transactions. A transaction occurs 'when a good or service is transferred across a technologically separable interface. One stage of activity terminates and another one begins' (O.E. Williamson, 1985).

This research concerns transactions as such: prosumers both generate and receive electricity from the grid. These transactions and the governance structures to guide the transactions are possibly not set in the most transaction cost economizing configuration. This configuration will thus be analysed using Transaction cost theory, in order to judge its efficiency and to propose possible adaptations. This chapter starts with explaining the relevant concepts of Transaction cost theory. Chapter 4 will apply this theory to analyse the current configuration of the market concerning prosumers. Chapter 5 will search for adaptations in order to improve the efficiency of the transactions concerning prosumers.

3.1 Transaction cost theory in its context

Transaction cost theory is part of bigger framework of economic theories applied on different levels of abstraction. It is important to understand the interrelation of those theories in order to have an idea about the level of analysis of this research and which other levels can be reached out to.

Williamson identified four interrelated layers of economic analysis and institutions (Figure 12). It is argued that institutions (such as the working of the different governance structures) not come about randomly, but that developments are influenced by and build on the interrelation with other layers. Imbalances in relations between layers are likely to cause institutional changes in one or more layers. The four layers differ in their level of abstraction: the first layer is of the highest abstraction and the fourth (lowest) layer focusses on small and practical forms of institutions (Groenewegen & Künneke, 2005).

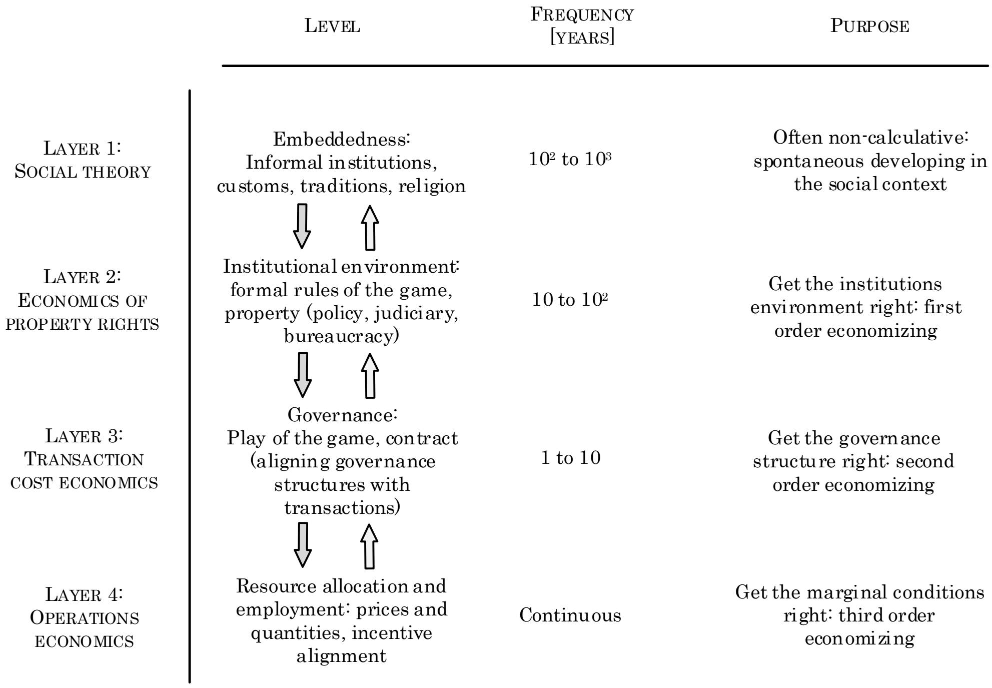


Figure 12: Four layer model of institutions and economic analysis (Williamson, 1998) picture based on Kunneke & Fens (2007)

In total two of the four layers are described within New Institutional Economics; the second layer 'Institutional environment' and the third layer 'Governance'. The Institutional environment is the area of formal governmental policy and legal processes and describes the rules of the game and property rights (also explained in 2.5.3). The possibilities of the alignment of governance structures (third layer) with transactions are set in this layer. This is called 'first order economizing'. Setting the governance structures right (in the third layer) is called 'second order economizing' (O.E. Williamson, 1998). The details of the third layer will be described in the next paragraphs. It serves as the theoretical basis for this research. The second layer (Institutional environment) will be discussed briefly in the next chapter.

Two of the four layers are not taken into consideration: The first layer – Embeddedness – and the last layer: Resource allocation and employment. Embeddedness is developed spontaneously over hundreds to thousands of years. This layer is described by historians and sociologists and consists of norms, customs and traditions that explain the behaviour of managers and governments (Künneke & Fens, 2007). The fourth level is of the smallest scale. It describes market processes and incorporates agency theory (explained in

2.5.2). It is on the level of the individual and its transactions. This level is mostly described by Neoclassical Economic theory (Niesten, 2009).

3.2 Discriminating alignment hypothesis

The key proposition of Williamsons Transaction cost theory is the discriminating alignment hypothesis: transactions (differing in their attributes such as frequency, uncertainty and asset specificity) are aligned with governance structures (differing in costs and competences) in a transaction cost economizing way (O.E. Williamson, 1996) cited in Niesten (2009). The figure below visualizes this. The governance structure rests upon the transaction attributes; the governance structure is set in such a way that it is efficiently aligned with the transaction attributes, which are taken as given. The governance structure serves efficiency purposes and is an ex post way (thus after the contract is signed) of 'keeping the parties to the contract' in case a contractual hazard occurs (due to opportunistic behaviour or bounded rationality; the two behavioural attributes of economic actors).

If governance structures are not well aligned with the transactions they are supposed to guide, incomplete contracts arise and this gives room for economic actors to act based upon their natural behavioural attitudes: **bounded rationality** (limited human capacity to receive, store, retrieve and process information) and **opportunism** (self-interest seeking behaviour combined with dishonesty), resulting in higher transaction costs because this behaviour needs to be monitored and managed.

The discriminating alignment hypothesis will be taken as the central point of analysis in the next chapter, and therefore the attributes (of transactions and of governance structures) where this hypothesis is based upon, will be explained in the next paragraphs.

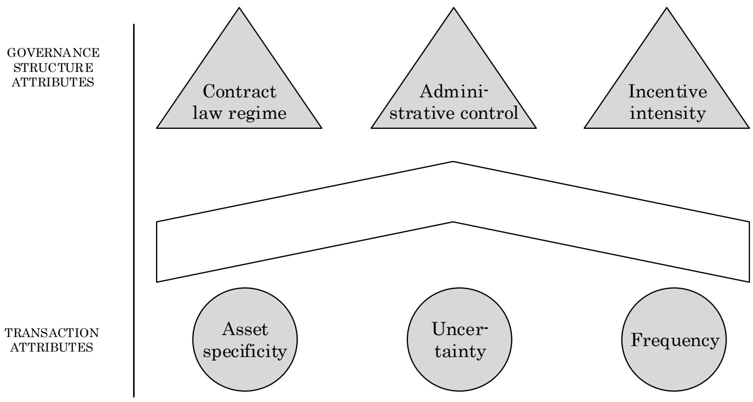
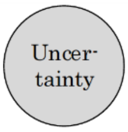


Figure 13: Discriminating alignment hypothesis

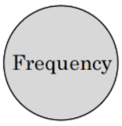
3.3 Transactions

"A transaction occurs when a good is transferred across a technologically separable interface. One stage of activity terminates, another one begins." (O.E. Williamson, 1985). Transactions can be characterized using three attributes: asset specificity, uncertainty and the frequency of the transaction. Those three attributes will be specified to the transaction concerning the prosumer, in order to determine the applicability of the discriminating alignment hypothesis for these transactions.

Asset specificity is 'the degree to which an asset can be redeployed to alternative uses without sacrifice of productive value' (O.E. Williamson, 1996). There are six types of asset specificity (O.E. Williamson, 1985, 1996): site specificity, physical asset specificity, human asset specificity, dedicated assets, brand name capital and temporal specificity. They are explained in Table 3. A high degree of asset specificity, for example the timely response needed to keep the balance in the electricity system (temporal specificity), gives rise to considerations to not rely on others to give this timely response, but to keep the service in house – in the hierarchy of the own firm – in order to avoid physical and financial risks resulting from unbalance.



The risk of actors being opportunistic (by strategic nondisclosure, disguise and distortion of information) creates **uncertainty** in the transaction. For example the supply of gas from unstable countries: certain regimes are known to use the gas dependencies to put political pressure on receiving countries. This uncertainty demands for in house (domestic or European) supply of gas, or the use of renewable energy sources such as wind. This in order to avoid the risk of a reduced security of supply or no supply at all.



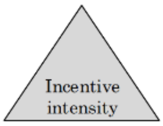
The third attribute is de **frequency** of the transaction. It differs from one-time, occasional to recurrent and it is important because of the effects of reputation and trust (matters more when the transaction is recurrent) and the costs of governance (administration and recovery of costs is easier when there are recurrent transactions between the same economic actors).

Table 3: Asset specificity (Williamson 1985, 1996)

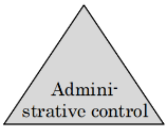
Kind of asset specificity	Explanation
Site specificity	Plants located at close proximity to economize on transport and inventory
Physical asset specificity	Specified inputs to produce a component or product
Human asset specificity	Learning by doing
Dedicated assets	Investments particularly made for a certain purpose that would not have been made otherwise
Brand name capital	Investment in reputation
Temporal specificity	Timely response is crucial to delivering a valuable product

3.4 Governance structures

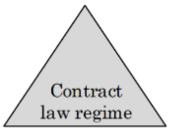
Governance structures are 'the organizational structures that coordinate the transactions between the parties to incomplete contracts' (Niesten, 2009). Two extremes are possible: **the market and the hierarchy. In between is the hybrid**. The hybrid is characterized by the remaining autonomy of contracting parties (as in the market), but the persisting dependency upon each other due to asset specific investments (as in the hierarchy). These three forms of governance are the generic forms; many more are possible in between the two extremes. Which governance structure is applicable when (which form of governance aligns with the transaction in question), depends on the attributes of the transactions. The three forms of governance differ in the position they have on three attributes: incentive intensity, administrative control and contract law (O.E. Williamson, 1991). Those differences in attributes indicate the differences in the way the governance structures guide transactions. The current governance structures concerning prosumers will be analysed and judged using the three attributes in the next chapter. This section elaborates on the exact meaning of the attributes.



Incentive intensity is the degree to which changes in efforts by an economic actor have an effect on the result of the effort. For example the extent to which the consumer saves on the use of electricity when the consumer notices there is no wind or sun outside and turns of the dishwasher at that moment. If that has a significant impact on the electricity bill, then we can speak of high incentive intensity.



Administrative control is the measure of support for the functioning of the governance structure, in other words: does it run by itself or is there much steering and administration? In general the market has/needs few administrative control, because the dynamics of demand and supply provide the incentives to conduct transactions in the most efficient way for the particular transaction. When a transaction has to be done within the firm, for example the in house mechanic that needs to repair a generator in an electricity plant, there is not much incentive to do this fast: the mechanic earns the same salary anyway. Thus, a controlling governance structure has to make sure that the mechanic repairs the defect timely. When an external mechanic was hired (via the market), he or she would have more incentive to act fast, because the mechanic wants to be hired again next time there is a defect. Not much administrative control is needed to make this mechanic do his or her work timely and good.



Contract law regime describes the mechanism that is used to resolve disputes. Three types are apparent: classical contract law, neoclassical contract law and forbearance law. An explanation of these three types of contract law can be found in Table 4 below.

Table 4: Types of contract law (attribute of governance structures) (Williamson, 1994)

Type of contract law	Explanation	Corresponding governance structure
Classical contract law	Most complete and standard contracts, focused on prices and pricing formulas. No dependency between contract parties on short term. When disputes arise, contracts are ended and other contracting parties can be easily found.	Market
Neoclassical contract law	Contracts with a greater deal of flexibility and longer duration. Continuity of relation is valued because of specific assets and thus parties are dependent (but maintain their autonomy). Contracts allow for adaptation to circumstances. Third parties may handle dispute settling or regulation of the contract.	Hybrid
Forbearance law	Implicit contract law. Elastic long term contracts and more adaptation to circumstances possible. Own dispute settling mechanisms within the hierarchy.	Hierarchy

The typical position of the attributes for each of the three governance structures (market, hybrid, firm) is summarized in Table 5.

Table 5: Governance structures and their position of attributes (Niesten, 2009)

	Incentive intensity	Administrative control	Contract law regime
Markets	High	Low	Classical
Hybrids	Intermediate	Intermediate	Neoclassical
Hierarchies	Low	High	Forbearance

3.5 Combining transaction and governance attributes

In the previous section the attributes of both transactions and governance structures are explained. In the next table they are combined in a way that discriminating alignment is secured according to Williamson. The market is the most efficient governance structure to govern non-specific and low uncertainty transactions, both occasional and recurrent (depending on the specific transaction). No specialized procedures (as in the hybrid or hierarchy) are needed, thus bureaucratic costs for this can be avoided. The other extreme, the hierarchy (or unified governance, meaning only one party to the transaction), is efficient for highly uncertain and very specific (idiosyncratic) transactions, both occasional and recurrent (depending on the transaction). Decisions can be made fast within the hierarchy without any dependencies and while mitigating uncertainty. When transactions are intermediate or highly uncertain and make use of mixed or idiosyncratic assets, then the hybrid accounts for the dependence between the contracting parties; it promotes continuation of the relations and shields from opportunistic behaviour. With trilateral governance a third party steps in to assist the contracting parties.

Table 6: Discriminating alignment of transaction cost attributes and governance structures (adapted from Williamson, 1985)

<table>
<tr><th></th><th>Asset-specificity</th><th>Non-specific</th><th>Mixed</th><th>Idiosyncratic</th></tr>
<tr><th></th><th>Uncertainty</th><th>Low</th><th>Intermediate</th><th>High</th></tr>
<tr><td rowspan="3">Frequency</td><td rowspan="2">Occasional</td><td rowspan="3">Market governance</td><td rowspan="2">Trilateral governance (hybrid)</td><td>Trilateral governance (hybrid)</td></tr>
<tr><td>Unified governance (hierarchy)</td></tr>
<tr><td>Recurrent</td><td>Bilateral governance (hybrid)</td><td>Unified governance (hierarchy)</td></tr>
</table>

This is a generalistic way of matching governance structures with transactions. In the next chapter this will be applied to the electricity sector and the transactions concerning prosumers, where more attention will be paid to the specifics of the transaction and their context and a more refined classification of the governance structures.

3.6 Contribution to theory

An interesting angle of analysis is briefly discussed by O.E. Williamson (2003): the suggestion to reverse the discriminating alignment hypothesis.

3.6.1 Reverse discriminating alignment hypothesis

Williamson suggests that the search for matching forms of governance with existing transaction attributes (Figure 13) could be reversed (depicted in Figure 14). Thus, no longer are governance structures the dependent variable (as the existing theory dictates) and the transaction attributes the independent variables. Reversing the discriminating alignment hypothesis implicates that the transaction attributes are altered to match an existing form of governance. They are now the dependent variable 'resting upon' the governance structure being the independent variable (Figure 15).

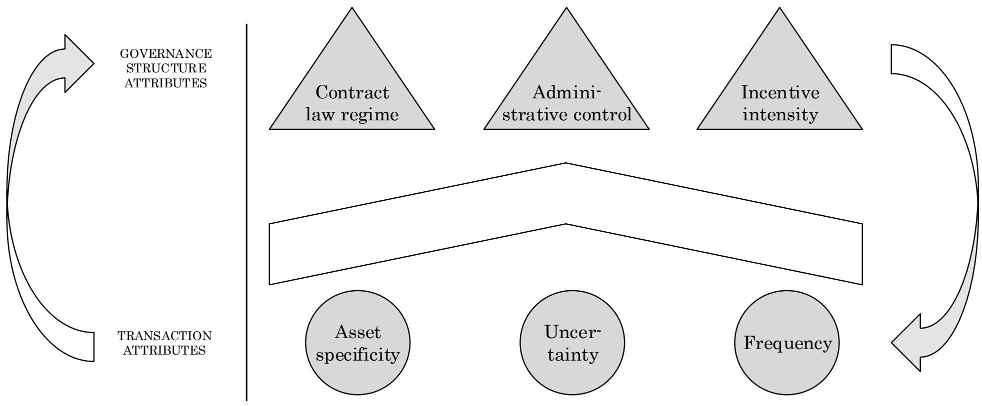


Figure 14: Reversing the discriminating alignment hypothesis

There is no scientific research known about exploring or testing this conceptual idea, not in the work of Williamson and not in other transaction cost research. The reverse discriminating alignment hypothesis will therefore for the first time be explored in this research, where it will be applied to the electricity sector and the transactions concerning prosumers. Scientific recommendations will be given as a result of this exploration.

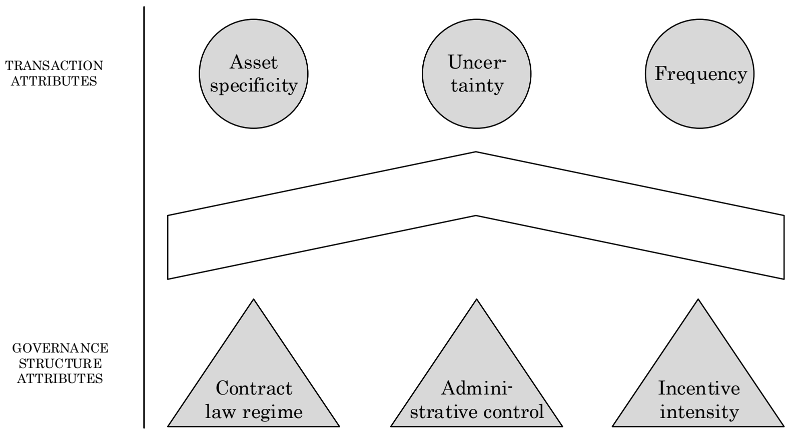


Figure 15: Reverse discriminating alignment hypothesis

First the reverse discriminating alignment hypothesis will be applied to the Dutch electricity sector in the next paragraph, to illustrate whether this sector is suited to explore the idea of reversing the discriminating alignment hypothesis. Then the following paragraph will discuss points of attention when reversing the hypothesis. Chapter 4 analyses the prosumers' transactions from a transaction cost perspective: it will point out issues of misalignment of transaction attributes and governance structure. Chapter 5 will apply the reverse discriminating alignment hypothesis to the subject of this research: technical and contractual governance means will be sought to alter the transaction attributes to align with the 'given' governance structure and create a design space.

The reverse discriminating alignment hypothesis visualization in Figure 15 will be used (and expanded) in the next chapter to analyse the problems in the Dutch electricity industry concerning PV prosumers and in chapter 5 to create a design space.

3.6.2 Application to the Dutch electricity industry

The application of reverse discriminating alignment to the Dutch electricity sector would mean that the governance structure is the given, independent variable. This is indeed the case in the Dutch electricity industry. It is, on the basis of European and national laws, prohibited for electricity firms in the Netherlands to act as one integrated hierarchical firm with generation, transmission, distribution and retail; a market form of governance is imposed on the Dutch electricity sector. Thus, even when the efficient match of transaction attributes and governance structures would be the hierarchy, this would be prohibited. Therefore, given this prohibition, it will be analysed in chapter 4 if the transactions in the Dutch electricity sector are already aligned with a market form of governance. Chapter 5 will then explore if the attributes of the transactions can be altered, in order to make a more efficiently aligning match with a market governance structure.

3.6.3 Consequences of reversing the hypothesis

Williamsons work is focused on finding matching forms of governance to align with given transaction attributes. Therefore much attention is dedicated to fine tuning governance structures and contract forms taking into account the complexities of the transactions in question. Examples are the various 'custom made' hybrid governance structures such as joint ventures and new contracting forms such as long term contracts to cope with uncertainty and asset specificity of the transactions, while maintaining autonomy and avoiding vertical integration and its issues of administrative control.

When reversing the discriminating alignment hypothesis, a previously unexplored area will be entered. No research has been done in how to 'fine tune' the combination of transaction attributes, in order to cope with their complexity and taking into account their uncertainty, while efficiently aligning them with existing governance structures. Bringing down asset specificity and uncertainty using technical and contractual means sounds simple, but it might bring about complexities that Williamson has not accounted for.

Masten (1996), Goldberg (1976) and Oliver E Williamson (1979) do however provide an insight that could be valuable for this research. In uncertain and complex situations where actors are unable to close complete contracts to mitigate uncertainties and cope with complexity, contracts tend to become more 'relational', according to the authors. The contract is not specified in detail, but room is left for flexibility in the length of the relationship between the actors; the continuity of this relationship is governed by the contract. The challenge is to find structures to "encourage rent-increasing adaptations (flexibility) but discourage rent-dissipating efforts to redistribute existing surpluses (opportunism)" (Masten, 1996). This relational focus could be an important feature in the market design options that will be formulated and the result of this research will therefore be discussed in this light in paragraph 10.2.3.

Chapter 4 will first analyse the current configuration of the Dutch electricity sector concerning PV prosumers from a transaction cost perspective and chapter 5 will then provide a design space where means are proposed to alter the transaction attributes. When forming market design options in chapter 6, attention will be paid to the arising complexities when combining several means and how to cope with them (paragraph 6.4).

4. Problem analysis

[SubQuestion 1]

What can the application of Transaction Costs Theory tell us about the current and future configuration of the market?

[Chapter 3&4]

The theory explained in the previous chapter will be applied to the electricity sector and its transactions concerning PV prosumers in this chapter (Figure 16). The analysis will concern if the transaction attributes are efficiently aligned with the governance structure of the market.

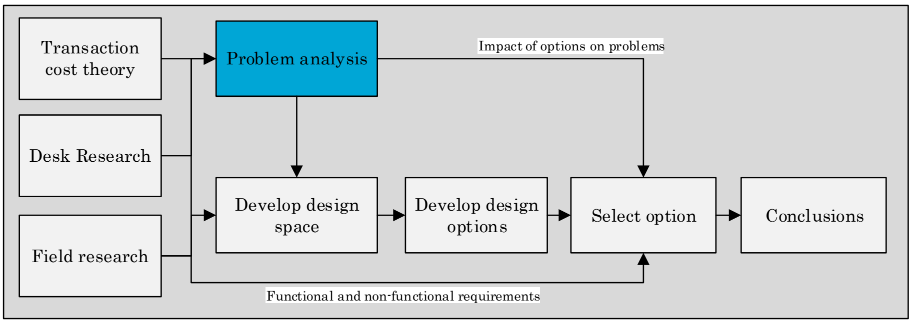


Figure 16: Situation of chapter 4 in the approach

After introducing the current situation of the electricity sector in paragraph 4.1 and the transaction units that are taken as a basis in this research in 4.2, the transaction attributes and governance structure attributes will be analysed in 4.3 and 4.4. Paragraph 4.5 introduces the behavioural attitudes of economic actors relevant for this research. In paragraph 4.6 all information is summarized in one figure, based on the reverse discriminating alignment figures introduced in the previous chapter. The idea to reverse the discriminating alignment hypotheses is further pursued by indicating what changes are needed concerning the transaction attributes, to align them with the governance structure of the market.

4.1 Misalignment in the electricity sector

The liberalization of the Dutch electricity sector followed the directives of the EU of 1996 and 2003 that prescribed vertical unbundling of transmission and distribution from generation and retail of electricity and the introduction of competition in generation and retail and free choice for the consumer to choose their own retailer (thus openness of the sector to new entrants). The idea was to create one single European market and that "Market forces produce a better allocation of resources and greater effectiveness in the supply of services…" (EC, 1996), following Neo Classical economic theories. EU member states were required to adopt new forms of governance in the electricity sector and with the electricity act of 1998 the directives were transposed into Dutch law. Most important was the prohibition of vertically integrated energy (electricity and gas) firms and introduction of competition and market forms of governance.

For reasons stated in the previous chapter, this research takes Transaction cost theory of the Institutional economists as a basis. This leads to applying Williamson's four-layer model to the subject of this research (depicted in Figure 12 in chapter 3). From this it becomes clear that forces in the second layer of institutional analysis (institutional environment) – the EU parliament and council, followed by governments of member states implementing the directives in national law – prescribed the forms of governance that should be taken on at the third level (Governance). Much empirical research applying Transaction cost economics to the electricity sector has been performed (Joskow, 1996; O.E. Williamson, 1976, 1996), concluding that discriminating alignment in the electricity sector consists of vertical integration and regulation; these are the most efficient structures to govern transactions in this sector. Vertical integration and regulation reduce uncertainty and asset specificity because the integrated electricity firms are in control of the whole value chain (supply, transmission, distribution and retail) and therefore their dependence on other economic actors that might act upon opportunism and bounded rationality is minimized. Thus, with vertical integration the governance structure is aligned with the transaction attributes and transaction cost are minimized. But with the prohibition of vertical integration, misalignment of governance and the specific attributes of the transactions within the electricity sector occurs. These attributes include asset specificity and uncertainty, the presence of natural monopolies and externalities in the industry, which are aligned with the hierarchy (Joskow, 1996; O.E. Williamson, 1976, 1996).

4.2 Transaction unit

In this research the transaction units are 1 kWh of electricity, generated by the electricity supplier and transferred through the grid and sold to the prosumer, or generated by the prosumer and 'sold' (via net metering) and transferred through the grid to the supplier. This transaction unit is chosen because, first and most important, it concerns the key change within the Dutch electricity sector: prosumers are supplying 'from the other side of the market' as well and this is not yet optimally accommodated in the market. Second, the choice for this transaction unit provides structure to the analysis: the transaction and governance structure attributes are analysed separately for the two transactions, revealing different problems. Lastly, this small unit of analysis provides the possibility to be 'grouped', which has a significant impact on the frequency of the transaction (trade of 1 kWh with different actors versus a yearly bill from one single supplier with all transactions grouped), more on this in section 4.3.3.

The choice of transaction unit could have a significant impact on the results of the analysis. If the focus would be placed on for example data traffic as the unit of transaction, the results of the analysis would be different: they would be more oriented towards privacy issues, ownership and accuracy of data. Taking the unit of analysis of 1 kWh, this is certainly an aspect within the analysis, but not the main issue. The unit of analysis of 1 kWh provides for a broader view on the various issues in the sector. In chapter 10 this choice will be reflected upon.

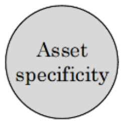
In the next paragraph the attributes of the transactions will be analysed, followed by an analysis of the attributes of the governance structure (4.4). Next the behavioural attitudes of the actors concerned in the transaction are described (4.5) and in 4.6 the discriminating alignment of the transactions and governance structure is analysed.

To analyse the attributes of the transactions under consideration structurally, the issue is stated first, followed by the implication of (for example) the asset specificity and the reason for change. The issues, implications and need for change are based on the researchers own experience in, and knowledge about the sector, on desk research and on the interviews conducted within the 'Field research'. This was also visualized in Figure 16 on the previous page.

4.3 Analysis of transaction attributes

This paragraph applies the concepts about transaction attributes explained in the previous chapter to the electricity sector and particularly PV prosumers. Following the reverse discriminating alignment hypothesis, for each transaction attribute it will be indicated in which direction the attribute should be altered to match with the governance structure of the market.

4.3.1 Asset specificity



The next table shows the issues, implications and reasons for change concerning the current configuration of the electricity sector and prosumers. All the issues are related to the various forms of asset specificity, and are divided between the two transactions that are taken as the unit of analysis; 1 kWh from supplier to prosumer and vice versa. This is done because asset specificity (and other) issues are different for those two different transactions.

Table 7: Analysis of asset specificity of the transactions (other half on next page)

	Issue	Implication	Reasons for change
1 kWh supplier → prosumer	Dedicated assets: Large investment in power plants with a single purpose	Large investment risk	Plants are needed for back up capacity: security of supply. This issue will play a bigger role when decentralized production increases and the volatile nature of most decentra-lized sources becomes more problematic.
	Temporal specificity: suppliers are expected to react fast in case of grid unbalance.	Suppliers need to switch facilities off and on quickly. This is costly and difficult with nuclear and coal fuelled plants. Gas facilities are more flexible.	This issue will play a bigger role when decentralized production increases and the volatile nature of most decentralized sources becomes more problematic.
1 kWh prosumer → supplier	Dedicated assets: relatively large investment in solar panels, done because of the expectation of a certain payback time	Large investment risk	Expected payback time is based on the net metering mechanism (and takes away temporal specificity). This mechanism has an uncertain future.
	Temporal specificity: the prosumer can only supply electricity in accordance with the volatile supply of the sun.	Supply is not always in balance with demand	

Dedicated assets and temporal specificity are the major points of concern for both suppliers and prosumers. Both parties face large (relative to their budget) investments with the risk of changing policies and uncertain future payback. The volatile supply of sun (and other decentralized sources) requires suppliers to react fast in case of unbalance, which is expected to be needed more when decentralized production capacity grows. Net metering takes away similar concerns for prosumers, with the risk of being vulnerable for changing policies making payback uncertain. Concluding, to make a more efficient match with the current governance structure, **asset specificity should be reduced.**

4.3.2 Uncertainty

This section is about uncertainty issues concerning the electricity sector and prosumers – indicated with 'issues', 'implications' and 'reasons for change'. Again there is a division between the two transactions; 1 kWh from supplier to prosumer and vice versa, because also uncertainty issues are different for those two different transactions.

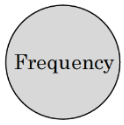
Uncer-tainty

Table 8: Analysis of the uncertainty of the transactions

	Issue	Implication	Reasons for change
1 kWh supplier → prosumer	Inelastic demand of electricity	Demand is inflexible and unpredictable.	When the group of Dutch prosumers grows, the unpredictable switch of demand to supply by prosumers becomes a treat because the balance keeping of the grid becomes more difficult.
	Quickly changing policies influencing suppliers' business case	Cautious investment strategy of suppliers.	Stable investment climate is needed for the required back up capacity.
1 kWh prosumer → supplier	Uncertain government policy concerning the future of net metering and thus their payback time	Uncertain payback time of relatively large investments and under net metering the relatively big tax part of the electricity price is subtracted from the prosumers electricity price. Because of this big price difference (par. 1.3), PV electricity will not be cost competitive without net metering.	A certain payback time or reduction of investment risk is needed for prosumers to make an investment in solar panels

The major uncertainty concerns for this attribute are the unknown future policies, for both suppliers and prosumers that cannot make a certain business case as a result. Physical uncertainty concerns are the inelastic demand that results in inflexible and unpredictable system. Concluding, to make a more efficient match with the current governance structure, **uncertainty should be reduced.**

4.3.3 Frequency



At this point, the unit of transaction between suppliers and prosumers and vice versa is not 1 kWh, but all separate 1 kWh-transactions are grouped on one yearly bill, based on the number on the meter. Thus, many transactions of 1 kWh form one final transaction, resulting in a very low frequency, and each time with the same supplier accounting for easy administration. The next table will indicate the issues concerning frequency in the situation where not only the supplier supplies, but also the prosumer, and where the unit of transaction is 1 kWh, instead of one yearly bill.

Table 9: Analysis of the frequency of the transactions

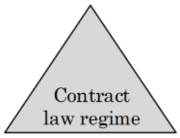
	Issue	Implication	Reasons for change
1 kWh supplier → prosumer	One contract with one supplier, for very frequent transactions of 1 kWh grouped on one yearly bill.	Relatively easy and cheap administration. Trust between supplier and prosumer.	No change needed: good equilibrium.
1 kWh prosumer → supplier	Various collectives of prosumers indicate that they want to trade their surplus electricity with their neighbours et cetera (many to many) to create a more open market instead of only being able to trade with their supplier for a fixed price.	This reduces the frequency of the transaction with one party and it increases the total amount of transactions with different parties.	A breakthrough of this mechanism will cause complex data traffic and administration, bringing about large transaction costs.

The high frequency of the transaction, conducted between the same two actors resulting in one final transaction (bill), makes administration relatively easy. The opposite poses a risk: prosumers that want to trade kWh's with neighbours et cetera (many to many, to create a more open market) accounts for many transactions (same amount of kWh's are traded, but they cannot be grouped into one transaction, they remain numerous different transactions). This could account for complicated administration. Concluding, to make an efficient match with the current governance structure, **frequency should stay more or less at the same level.**

4.4 Analysis of governance attributes

This paragraph applies the concepts about governance structure attributes explained in the previous chapter to the electricity sector and prosumers in particular. Also for the governance attributes it will be indicated if they should be reduced, kept at the same level, increased or else to make an efficiently aligning match with the governance structure of the market. This seems to conflict with the reverse discriminating alignment hypothesis where the governance structure was said to be given and transaction attributes would be altered. However, also the governance attributes could be altered, while still remaining a market governance structure. The room that is still available to do this will be used.

4.4.1 Contract law regime



The next table typifies the contract law regime used in the electricity sector. Since this is the same for both transactions, no division is used.

Table 10: Analysis of the contract law regime of the governance structure

	Issue	Implication	Reasons for change
1 kWh supplier → prosumer & 1 kWh prosumer → supplier	The contract law regime used in the electricity sector (for both transactions) resembles Neo classical contract law. Regulatory oversight and dispute settling is provided by a third party: ACM. There are elastic contracts (with flexible excuse doctrines and changeable (but non-market tariffs) and conditions).	Prosumers are dependent on their supplier for their surplus supply tariffs, this creates an imbalance of risk distribution: the prosumer relies on one supplier for his payback and service, but the supplier has thousands of consumers and is not dependent on a sole dissatisfied consumer.	At this point this is overseen by ACM, but also in the future arrangements need to be in place to account for fair tariffs and no opportunities for abuse of position

Both transactions are guided by Neo classical contract law, characterized by elastic contracts and regulatory oversight and dispute settling by ACM. This makes prosumers dependent on their suppliers' tariffs for surplus generated electricity that can make or break a business case. Suppliers in their turn have a big clientele and are not dependent from one dissatisfied prosumer. Concluding, the governance structure is set, but where possible, **the contract law regime of Neo classical contract law should safeguard risk distribution.**

4.4.2 Administrative control

The next table analyses the administrative control of the governance structure. For this the division between the two transactions is used again, because administrative control is different for the two transactions. Again the issues, implications and reasons for change are indicated.

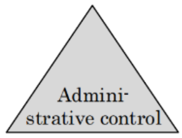


Table 11: Analysis of the administrative control of the governance structure

	Issue	Implication	Reasons for change
1 kWh supplier → prosumer	The transaction is not only about 1 kWh, but about the total costs of a period of time, taking into account costs for infrastructure et cetera. The prosumer pays a bill at the end of the year to the supplier based on the figures on the meter, read out once a year.	Minimal administration. But when the prosumer would trade with not only their supplier, but with neighbours et cetera (many to many), administrative control would increase significantly.	Administration should be simple to let the market function efficiently. Therefore, for this issue, no changes are required. But cautiousness for future developments concerning many to many trade is needed to keep administrative control low and/or well organized.
	The price of 1 kWh is not only subject to its marginal costs. Fixed components to support the infrastructure (paid to the supplier, but put through to the DSO and TSO) and standing charge are part of the final bill as well. Therefore the trade of 1 kWh is about different costs making up the bill.	With a growing part of PV (and other decentralized) production, supply to the grid will come from both sides and questions about the fixed payment for infrastructure use and standing charge will come up. Varying these costs will again bring more complex administrative processes.	A simple cost division mechanism should provide for a fair and clear cost break down to each consumer, taking into account both relative use of infrastructure but also socializing of costs of a national infrastructure.
	Smart meters and their appliances bring about more (needed and useful) data.	In a many to many market, there will be more issues of administration, responsible parties and data.	Administration should be as simple as possible to let the market function efficiently.
1 kWh prosumer → supplier	There needs to be a party that has the responsibility of the supply (of each kWh) of each prosumer. This is called Program response-bility (P.R.). The supply of the prosumer falls within the production portfolio of this program responsible party (mostly a supplier) and this portfolio is communicated beforehand with the TSO in order to balance the electricity grid. The supply profile of small consumers is not based on their real supply, but on averaged profiles.	Today prosumers' supply is small relative to the production portfolio of the supplier and the total Dutch electricity supply and there-fore program responsibility is not an issue. However, if PV (and other decentralized) production grows, this will have an impact on the port-folio, the more since the supply is unpredictable. If a prosumer could supply electricity to neighbours et cetera, the question will rise who will be program responsible.	When the group of PV prosumers grows and it concerns an amount of kWh that is not negligible in the Dutch production portfolio anymore, then institutional changes are needed to arrange for a more detailed program responsibility for this group of suppliers. The more when prosumers could supply electricity to neighbours et cetera.

The physical lay-out of the electricity system is the basis for the complicated administrative processes guiding the transactions. Not only marginal costs, but also costs to support the infrastructure et cetera should be paid. This makes the transaction less about 1 kWh and more about a bill over a longer period of time with fixed costs apart from the kWh's. Future risks lie in the system becoming even more complex (smart meters and many to many trade) with more complex administrative control and, when PV grows, questions about program responsibility, use and ownership of data and the allocation of infrastructure costs. Concluding, the governance structure is set, but where possible, **administrative control should be reduced.**

4.4.3 Incentive intensity

This table elaborates on the incentive intensity of the electricity sector and specifically prosumers. For this last attribute the division between the two transactions is used as well and the structure of issue-implication-change is followed.

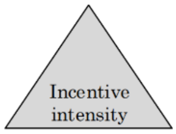


Table 12: Analysis of the incentive intensity of the governance structure

	Issue	Implication	Reasons for change
1 kWh supplier → prosumer	There is no icentifying mechanism that has an effect on prosumers' behaviour and thus their demand.	With no cooperation from the side of the prosumer, it is costly for the supplier and the system to match demand and supply.	Growth of PV prosumers results in even bigger imbalances in supply and demand which are more costly to prevent.
	Suppliers making the effort to supply green electricity do not receive extra rewards, at best extra clients are attracted because of it.	A contribution to the energy transition by suppliers is made for reputation purposes and to attract a small group of renewable energy-concerned consumers, not as a result of a financial incentive.	Suppliers should be motivated to supply green electricity to contribute to the 20/20/20 goals.
	When PV (and other decentralized) production capacity grows, suppliers' facilities are needed less. However, they need to run when demand does not match renewable supply. Currently there is no mechanism to compensate for this 'standing back up'.	Suppliers will have few incentive to keep their production facilities running for back up purposes.	Growth of PV prosumers and thus more reliance on volatile sources results in the need for back up capacity.
1 kWh prosumer → supplier	Under net metering, time of supply or time of use have no financial value (due to virtual offset of prosumers' supply and demand within the net metering mechanism and the fixed tariffs for surplus generated electricity), thus prosumers making an effort to consume (or store) simultaneously with supply (by sun/wind) are not rewarded.	Prosumers do not contribute to make a match between demand and supply.	When the group of PV prosumers grows, the differences between supply and demand grow bigger. Balance keeping will become more difficult and costly.

Both suppliers and prosumers have no incentive to put in more effort; there is no reward for being green or efficient matching of supply with demand. When PV (and other decentralized) production capacity grows, two risks appear: first, there is no incentive to supply the required back up capacity to compensate for volatile resources (there is however a discussion about a capacity market going on (Energieactueel.nl, 2013)) and second, there could be a grid overload when there is a lot of wind and sun supply, caused by the lack of incentive to consume immediately or store. Concluding, the governance structure is set, but where possible, **incentive intensity should be increased.**

4.5 Analysis of behavioural attitudes of economic actors

Misalignment of governance structures with transactions leads to incomplete contracts where room is given to the actors to act upon **bounded rationality and opportunism**. Table 13 analyses bounded rationality of the actors in the transaction

Table 13: Analysis of bounded rationality of actors in the transactions

	Bounded rationality
1 kWh supplier → prosumer 1 kWh prosumer → supplier	Prosumers have limited understanding of the system where they receive electricity from and supply their generated PV electricity to. The system under consideration is characterized by the need for constant balancing of supply and demand and where the infrastructure is not supposed to (small neighbourhoods, remote locations) it cannot process unlimited supply or demand of electricity. Prosumers do not act upon this mechanism because they have little understanding of it.

Table 14 analyses opportunism of the actors that take part in the transactions under consideration.

Table 14: Analysis of opportunism of actors in the transactions

	Opportunism
1 kWh supplier → prosumer	Not applicable due to ACM oversight.
1 kWh prosumer → supplier	Many households do not register their old bidirectional meter and their solar panels because this mechanism ensures them to apply net metering also when regulations might change in the future (interview F). This results in unknown supply to the electricity grid which can become a problem when PV production capacity grows. This may cause problems in balancing demand and supply.

Limited understanding by prosumers of the physical characteristics of the electricity system leads to prosumers not acting upon its limitations and this effect is enlarged because the current net metering policy does not require them to act based on the system characteristics. Next, the foresight of net metering policies coming to an end motivates prosumers to not register their old bidirectional meters and PV system, in order for them to secretly continue net metering, which is a serious risk to the system when PV capacity grows. However, net metering may be changed in 2020 with a transitioning period of at least two years. By that time there will be 100% penetration of smart meters and is opportunism in this area not possible anymore (Hollandsolar.nl, 2014; Kamp, 2014)

In the course of this research, there will not be an attempt to change the behavioural attributes of the actors. They will only serve as points of attention when the options (chapter 6) will be evaluated (chapter 8).

4.6 Concluding analysis of discriminating alignment

This chapter answers sub question 1:

What can the application of Transaction Costs Theory tell us about the current configuration of the market?

To answer this question, the findings of the previous paragraphs are summarized in the figure below and a conclusion about their discriminating alignment in the current configuration is provided after. The arrows and equal signs in the figure indicate the directions in which the attributes should be altered when following the reverse discriminating alignment hypothesis (aligning the transactions with the governance structure of the market).

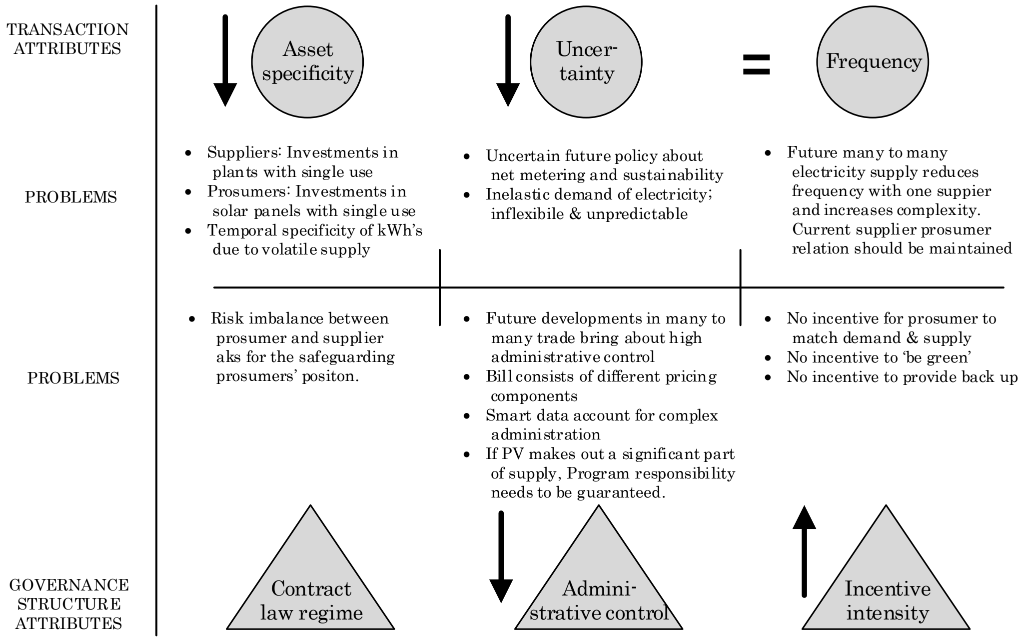


Figure 17: Conclusion of problem analysis

Asset specificity and uncertainty influencing big investment decisions ask for a hierarchical form of governance to reduce the impact of those attributes on financial risk. The current high frequency of the transaction does not reduce those risks, it only makes administration easier, since the transaction is always conducted with the same supplier. Today the governance structure of the Dutch electricity market is that of a regulated market. This is not only different from the 'ideal' configuration, it has also shown to give room for actions based on bounded rationality (limited system understanding) and opportunistic behaviour (for example not registering old bi-directional meters and resistance to smart meters) by prosumers.

The regulated market as a governance structure shows a lack of market dynamics: there are no incentives for both suppliers and prosumers to make an effort towards obtaining better results and to come to efficient market transactions. The physical system characteristics demand high administrative control. The contract law regime results in an imbalanced risk distribution, nowadays overseen by ACM.

As indicated by the arrows in the figure, Uncertainty and Asset specificity need to be reduced and frequency should stay at more or less the same level. Incentive intensity should go up and administrative control down. The contract law regime cannot change, but within this regime risk imbalances need to be safeguarded.

5. Design Space

[Sub Question 2]

What does the design space of the electricity market concerning PV prosumers look like and what options can be formulated?

[Chapter 5&6]

The previous chapter, the problem analysis, concluded with the observation that the transaction attributes and governance structure concerning PV prosumers are not optimally aligned and future risks of the current configuration are significant on several areas. In chapter 3 the idea of reverse discriminating alignment hypothesis was explained. This chapter further pursues the reverse discriminating alignment and therefore, in the course of this research, *it is accepted that the governance structure is set by European and Dutch law, entailing unbundling of transmission and distribution from generation and retail, and the introduction of competition and consumer choice. Within this governance structure, technical or regulatory alterations can change the attributes of the transaction (asset specificity, uncertainty and frequency), and, to a certain extent, the governance structure attributes, in order for them to be more in line with the governance structure.*

This chapter will explore the practical means to change the transaction attributes in the intended direction and explain them shortly (5.1). The room that is still available to change the governance attributes to achieve discriminating alignment will also be explored (5.2). Paragraph 5.3 visualizes and gives an overview of all the means forming the design space. Paragraph 5.4 explains all the means in depth.

The collection of suitable means to mitigate the problems found in the previous chapter is based on knowledge of and experience in the electricity sector, on desk research and on the interviews of the field research. This can be seen in the approach in Figure 18.

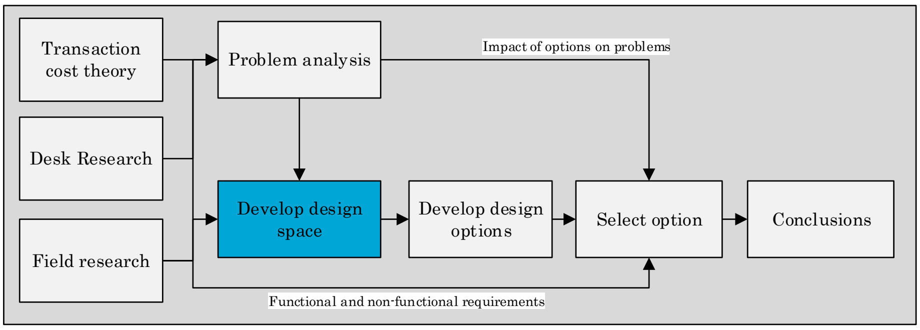


Figure 18: Situation of chapter 5 in approach

5.1 Change transaction attributes

This paragraph takes the analysis of the transaction attributes of chapter 4 to the next level. Several means are proposed to solve or relieve the issues determined in the previous chapter. **A discussion and explanation of the means can be found in paragraph 5.4.**

5.1.1 Reduce asset specificity

To align the attributes of 1 kWh from the prosumer to the supplier and vice versa with the governance structure of the market, the asset specificity of the transaction should be reduced. The asset specificity concerns dedicated assets (investments in plants or solar panels) and temporal specificity (volatile supply of solar energy). The next table sums up the means (second and third column) to mitigate the problems (first column, derived from previous chapter).

Table 15: Means to reduce asset specificity

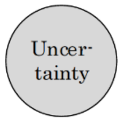
Reduce asset specify of:	Means	
Investments in plants	Back up on bill: different pricing scheme with mandatory back up payment	Bundle offering: different pricing scheme with voluntary back up component in bundle
Investments in solar panels	Lease solar panels	
Temporal specificity	Supply steering	

The risks resulting from the asset specificity of the investments in plants by suppliers can be reduced by compensating suppliers to keep their facilities ready to use for back up (discussion about a European capacity market left aside). The compensation can be mandatory for all consumers and prosumers, or voluntary; the choice to pay for security of supply at all times in a bundle-like pricing scheme[1].

To reduce the risk following from the asset specificity for prosumers, the investment of the prosumer can be lowered via a lease and payback scheme. The temporal specificity of the prosumers supply can be reduced by supply steering. **Supply steering** in the context of this research means making supply of solar panels predictable and dependent of market signals or external control. Since it is impossible to steer the supply of the sun, this implicates storing electricity or releasing stored electricity. Supply steering by using Micro CHP installations is left out of the scope of this research because it uses gas as a resource and not the electricity generated by solar panels.

> [Intentionally left out]
> - Options to finance generation plants are left out because they are not about trading 1 kWh.
> - Net metering and other subsidies to reduce the asset specificity of the investment in solar panels are also not taken into account because they are an external disturbance to the market. For this research an attempt is be made to let the market function on its own.
> - Minister Kamp's intended European capacity market (Energieactueel.nl, 2013)

5.1.2 Reduce uncertainty



To reduce the uncertainty of the transactions, the uncertain future policy that inhibits investments of suppliers and prosumers should be stabilized. On the lower level the uncertainty lies in the inelastic response of prosumers and the dependency of one supplier's tariffs. The next table provides the means to solve these issues.

Table 16: Means to reduce uncertainty

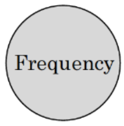
Reduce uncertainty of:	Means
Future policy	N/A
Inelastic response	Demand side management

> [Intentionally left out]
> Options to secure future policy. First because they are not about the trade of 1 kWh. Second because they do not focus on the third layer of Williamson's four layer model (governance) which is the subject of this research, but it has an impact on the second layer: the institutional environment (paragraph 3.1).

The inelastic response of prosumers can be tackled by demand side management, thus giving prosumers incentives to make their electricity needs steerable and predictable. In the context of this research **demand side management** means that market signals or external control result in a lower or higher demand of electricity from the grid.

[1] Despite this being difficult to achieve technically (new smart meters have no 'switch off'-button/relais) this is still proposed to bring down asset specify, assuming that when this would be the final option, technological advancements could make this possible.

5.1.3 Maintain frequency



Maintaining the frequency of the transactions to account for easy administration and low transaction costs can be done by the obligation to have one contract with one supplier (as it is now) so that transactions can be grouped into one transaction on a periodic bill. Or the low frequency can be incentivized by offering attractive bundles of services by suppliers to motivate having all contracts with one supplier. This is summarized in the next table.

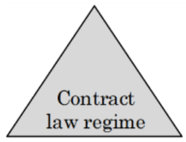
Table 17: Means to maintain frequency

Maintain frequency of:	Means	
Supplier-prosumer relation	One-party contract between prosumer and supplier	Bundle offering

5.2 Change governance attributes

This paragraph takes the analysis of the governance attributes of chapter 4 to the next level. Several means are proposed to solve or relieve the issues determined in the previous chapter. A discussion and explanation of the means can be found in paragraph 5.4.

5.2.1 Contract law

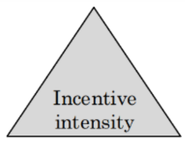


Working effectively with the current contract law regime with the risk of imbalance between prosumer and supplier because of the surplus electricity tariffs can be done by several means (next table). The risk imbalance can be taken away by grouping of clients in the same contract, giving them more power to negotiate or by setting the surplus supply tariffs by market prices or market-wide tariffs determined by ACM.

Table 18: Means to work with contract law

Work with contract law:	Means		
Risk imbalance	Group contracts with supplier	Market pricing for surplus electricity	Market-wide tariffs for surplus electricity

5.2.2 Increase incentive intensity



Areas where incentive intensity is important are a better match of supply and demand, a reward for being green and providing back up to the market (the discussion about a European back up market left aside). The following table summarizes the means that can be used to relieve those issues.

Table 19: Means to increase incentive intensity

Increase incentive intensity of:	Means	
Matching demand & supply	Demand side management	Supply steering
Being green	N/A	N/A
Providing back up	Bundle offering: different pricing scheme with voluntary back up	

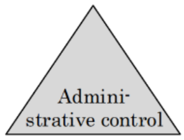
A better match of supply and demand can be achieved by demand side management, with for example real time pricing where the time value of electricity is reflected. Supply steering works the other way around: incentives are provided (for example real time pricing) to provide the generated PV electricity to the grid at times of electricity need and keep it 'in-house' (consumption, storage) when there is an excess of electricity.

To motivate suppliers to have facilities as standing back up, it can be provided to those who want to pay for it. Thus, those who want to pay for 100% security of supply are served at all times, and those who agreed to be disconnected at certain moments pay less (see note 1 on previous page). This could be offered via bundles of services of suppliers. The previous chapter mentioned that this is technologically difficult to achieve, but it is kept as an option in this research because it is assumed that, if chosen as final option, it could be realized.

[Intentionally left out] Subsidies, taxes and portfolio obligations. The market should function with the least possible external disturbances.

Being green could be stimulated by portfolio obligations, green subsidies or grey taxes, but these are all external disturbances to the market and will therefore not be part of the design space for this research. Thus, the motivation to provide or consume green electricity should be intrinsically. When consumers search for a different product on the market such as green electricity for an acceptable price (because they want to contribute to the energy transition, be independent of fossil sources et cetera). The supplier can decide to honour this demand as a business opportunity.

5.2.3 Reduce administrative control



The attribute administrative control asks for means to reduce the growing administrative pressure due to the different bill components and the emergence of a high amount of complex smart data. When the share of PV generation grows and there is a significant PV contribution, the required program responsibility for each point of supply could become an issue as well.

The current situation, where a contract with one supplier (that guarantees program responsibility for the prosumers supply) that groups all bill components in one contract and where data handling is a non-commercial DSO task, is an effective means to keep administrative pressure under control. Bundle offering could be another means, keeping program responsibility within the bundle. The task of program responsibility could also lie with the DSO that can group the data and program responsibility for supply regionally.

Table 20: Means to reduce administrative control

Reduce administrative control:	Means		
Different bill components	Bundle offering	One party contract prosumer/supplier (as it is now)	
Program responsibility	Bundle offering	DSO groups clients regionally	Supplier has program responsibility (as it is now)
Smart data	Bundle offering	DSO groups clients regionally	One party contract between prosumer and supplier, (data handling is with DSO) (as it is now)

5.3 Overview of design space

By reversing the Discriminating alignment hypothesis several means came forward – together forming the design space. Some means serve one attribute, others serve multiple. This is summarized in the figure below, answering the first part of sub question 2:

"What does the design space of the electricity market concerning PV prosumers look like?"

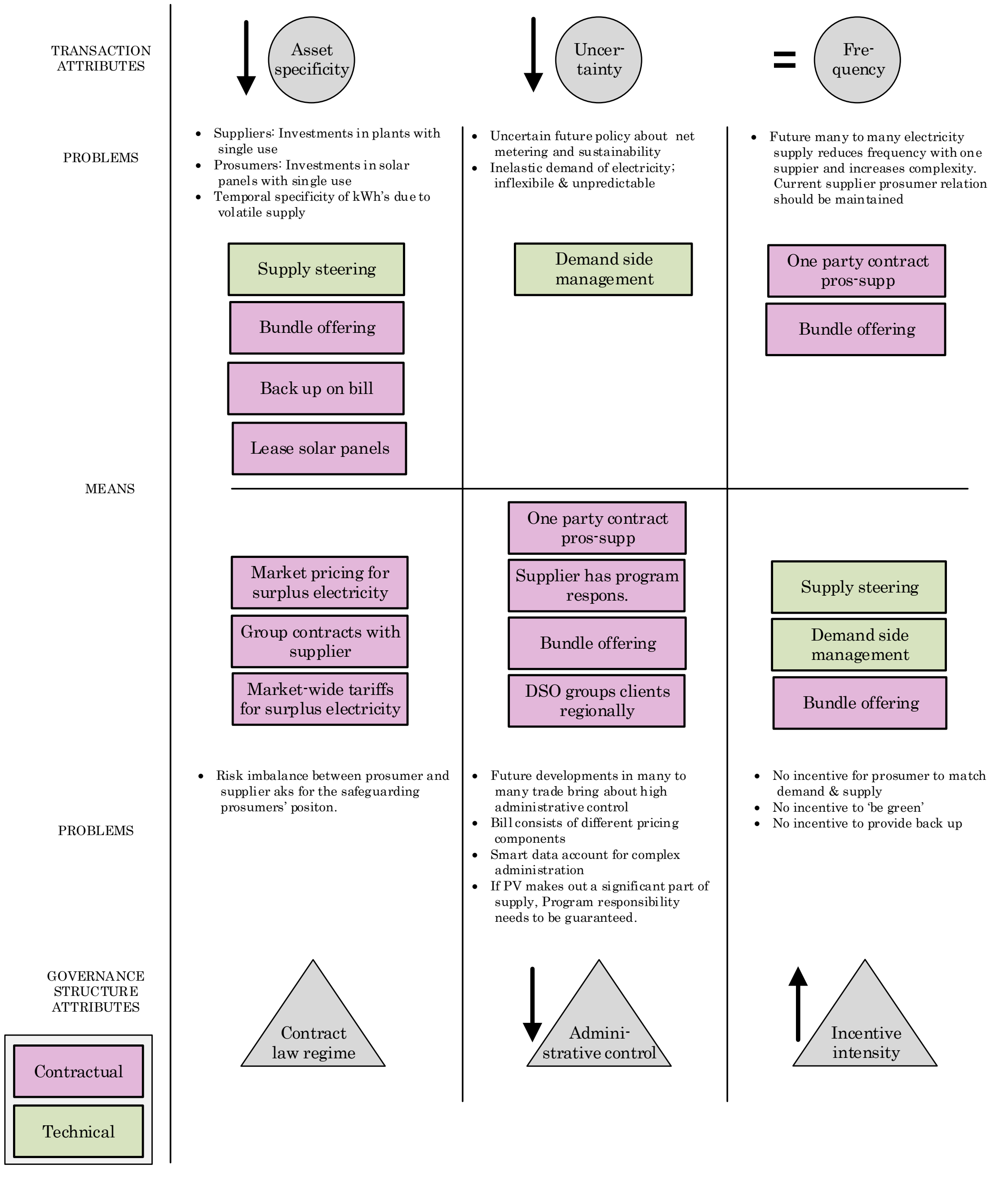


Figure 19: Design space

Figure 19 has the reverse discriminating alignment figure as a basis as well, and the problems that were concluded from chapter 4 are still indicated per attribute (as in the concluding figure of chapter 4). Next the figure is expanded. For each attribute the means that were proposed in the previous paragraphs to alter the transaction attributes in the intended direction are added. They are divided between contractual (pink) and technical (green) governance means because those two groups have an impact on a very different level: the technical governance means are technical options to safeguard the technical stability of the system. The contractual governance means arrange for the relationships between the actors in the system.

The next chapter will devise different options based on the design space, but first the exact meaning of the different means forming the design space needs to be clear and the various possibilities within the means should be listed. This is done in the next paragraph.

5.4 Discussion and explanation of means and possibilities

This paragraph described the means proposed in the previous paragraphs in depth, in order to have a common understanding of the means. This common understanding is needed to combine the means into market design options in the next chapter.

5.4.1 Explanation and discussion of contractual means

The means have been divided in two categories, corresponding to the different colours of the blocks in the figure on the previous page. The pink means are the contractual means, they arrange the relationships between the transacting parties. Those means are discussed in this section.

- **Bundle offering of different services**
  "Bundling is selling more than one product in a single-purchase package. Typically there is a core product that has value-added services packaged with it" (Eakin & Faruqui, 2000) Instead of a mandatory 'security of supply' bill component, it could be voluntary, combined with other voluntary/variable components (green/grey electricity, tariffs for surplus self-generation to the grid, demand side management, lease of solar panels et cetera), together constituting a bundle for a specified price (e.g. telecom smartphone bundles).
- **Lease mechanism for solar panels**
  Mechanism where prosumers lease their solar panels from the DSO or supplier, which is settled within the electricity bill. This reduces or takes away the prosumers' investment. (Could be part of a bundle)
- **Back up on consumers bill**
  At this point the consumers' bill concerns supply costs per kWh, standing charge and supply costs (fixed) and taxes (fixed, per kWh and %). A fixed 'security of supply' component could be added to account for the standing back up costs of suppliers. (Could be part of a bundle)
- **Market-wide tariffs for surplus electricity**
  Apart from a bundle-scheme, the tariffs for surplus generated electricity could be fixed for the whole sector determined by ACM, or fixed per supplier at the start of the contract.
- **Market pricing of surplus electricity**
  The price for surplus generated electricity could also be a market price, based on a 15-minute (as with the electricity wholesale market) adjusting mechanism following demand and supply forces.
- **Supplier has program responsibility (P.R.)**
  Supply needs to be in balance with demand at all times, and therefore each point of supply should be taken into account for balance planning purposes. Currently the supplier has program responsibility for all its contracted prosumers and uses averaged profiles (for small consumers) to predict demand and supply. This seems like an easy solution since the supplier already has a contract with the prosumer where it has to settle the surplus generated electricity. At this point in time this surplus generated electricity makes out a negligible part of the suppliers portfolio

and does not have a significant impact on the supplier's program responsibility. However, would the contribution of PV to the total electricity supply grow significantly, it would have an impact, making program responsibility a difficult task for the supplier.

- **DSO groups regionally for P.R. and smart data management**
  In case of a significant contribution of PV and thus program responsibility becoming more important, it could also become a DSO task. The DSO has the responsibility for the (regional) distribution grid and could group de supply of prosumers into one regional supply component where it would have program responsibility about. Smart data could be grouped and analysed for the same region, without having a commercial purpose.
- **Group contracts with supplier**
  To strengthen the position of individual consumers and prosumers, they can engage in a group contract with suppliers (or via an ESCO or VPP that negotiates with suppliers) on the basis of a building, street or neighbourhood. A strong negotiation position about for example surplus tariffs is the result. Shandurkova et al. (2012) refer to Bremdal who says that "already with the inception of Automatic Metering Services (AMS) user groups have the means and the power to enforce price changes and to create a negotiating platform that only large scale, industrial consumers have had before."
- **One party contract prosumer – supplier**
  (now) The prosumer continues to have one contract with one supplier that contains provisions for consumption of electricity, for supply of surplus generated electricity back to the grid and program responsibility for this supply. All separate transactions for 1 kWh are grouped into one final transaction (bill).

5.4.2 Explanation and discussion of technical means

The green blocks in the design space correspond to the technical means. They arrange for the technical stability of the system. There are two technical means and they are described in the following section.

- **Supply steering**
  (Focus on supply steering of PV electricity; generation plants and micro CHP out of scope)
  In the context of this research: Make the volatile and supply of the sun predictable as a reaction to market signals or external control by storing electricity or releasing stored electricity. Storage can thus be used to compensate for the possible time lag between supply and demand. The price/performance ratio for storage options is increasing and therefore storage becomes more attractive. (Shandurkova et al., 2012) Storage can be located at the level of the prosumer (at home, with different levels of ownership and control) or DSO (at regional grid level).
- **Demand side management**
  Demand response, demand steering or demand side management is defined (by the US department of Energy cited by Shandurkova et al. (2012)) as: "programs and activities designed to encourage change in consumers' electricity usage patterns in response to changes in the price of electricity or grid state or environmental effects over time designed to induce a changed electricity use at times of high wholesale market prices, when system reliability is jeopardized or when the environment would be more heavily affected e.g. by the CO_2-intensive electric power generation".
  In the context of this research: market signals or external control result in a lower or higher electricity demand from the grid to let electronic devices in the house function. Three levels of demand side management can be distinguished, all driven by dynamic prices of electricity:

(1) Implicit steering using real time pricing, giving pro- and consumers incentives to change their behaviour[2], possibly in cooperation with 3th party, DSO or supplier;
(2) Explicit steering with smart devices (dish washer, washing machine) with user interaction in cooperation with 3th party, DSO or supplier with different levels of control and sharing and ownership of data and devices. Within a certain time span the prosumer indicates when an activities needs to be started and finished and the 'smart' device takes into account dynamic prices to decide on the most cost-efficient time to use the device and starts it then.
(3) Automatic steering (heating, cooling, EV loading) by DSO or supplier. Temperature in house, in fridge and freezer or the electricity load in the EV need to be around a balance figure. An automated system decides on exact moments of cooling/heating/loading taking into account dynamic prices without consumer interference. (Interview K, 2014)

[2] At this point it is not possible for small consumers to react to dynamic prices that are existent on the wholesale market, because they cannot receive information or signals to do so.

6. Options

[Sub Question 2]

What does the design space of the electricity market concerning PV prosumers look like and what options can be formulated?

[Chapter 5&6]

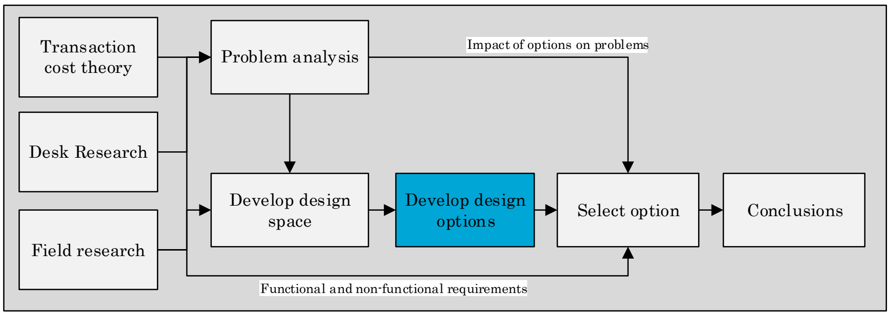


Figure 20: Situation of chapter 6 in approach

Chapter 5 ended with a comprehensive figure of the design space to answer the first part of sub question 2. This figure was created with a step by step method based on the reverse discriminating alignment hypothesis where first the problems of the current configuration of the Dutch electricity market were indicated for each separate transaction and governance structure attribute (chapter 4). Second, means were formulated to address the problems of each attribute (chapter 5). Those means will in this chapter be used to formulate different market design options to answer the second part of sub question 2. This can also be seen in the approach in Figure 20. In chapter 8 the resulting market design options will be reviewed and selected by their impact on the problems of the attributes and using the field research.

In attachment B an analysis of existing Dutch initiatives is provided. It shows that the Dutch electricity sector itself is dedicated as well to find answers to the problems resulting from the transitioning electricity system. However, the existing initiatives have a limited impact on the problems that were concluded from the problem analysis. This study attempts to devise a market design with a holistic system perspective, thus an impact on multiple attributes.

First, the technical means to arrange for the management of the grid (green blocks in design space) will be structured in paragraph 6.1. In paragraph 6.2 the same is done for the means for the contractual arrangements of the system (pink blocks in design space). Lastly, based on the first two paragraphs, market design options for future system configurations will be proposed in paragraph 6.3.

6.1 Technical governance model

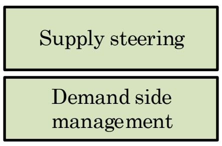


Figure 21: Technical governance means

Two means (the green blocks) concern the technical part of the system; the management of the grid. These are supply steering and demand side management (discussed extensively in paragraph 5.4). Within those means various levels of control and ownership can be distinguished. In paragraph 6.3 they will be combined with the contractual governance models (next paragraph) to devise market design options. The following table concerns demand side management.

Table 21: Technical arrangements concerning demand side management

	Consumer controlled	Semi-automatic	Automatic
Demand side management	Real time pricing (indicated by for example in house screens) motivate to change electricity consumption.	Appliances such as washing machines are 'smart', taking into account real time pricing and deciding when to work, within a consumer decided time frame.	Automated smart balancing of climate control system, fridge, EV

Within supply steering two possibilities are distinguished, explained in the following table.

Table 22: Technical arrangements concerning supply steering

	In house	Neighbourhood level
Supply steering	A mechanism taking into account own consumption and real time pricing decides between supply to the grid or to use in house storage capacity and consume this stored electricity later or release it to the grid at a later point in time.	Storage is DSO owned and operated for balance keeping purposes (no commercial use) and is located at neighbourhood level. When more surplus electricity is released to the grid then is needed within the neighbourhood or when there is a risk of imbalance, the surplus electricity is stored, and is released later.

6.2 Contractual governance model

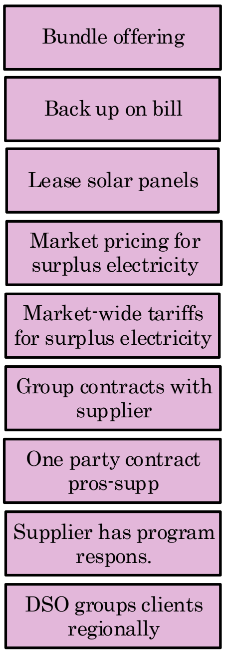


Figure 22: Contractual governance model

To arrange for the contractual part of the system, nine means (the pink blocks) are identified. They are put together in four arrangements differing along two axis (table below). The horizontal axis makes a division between the prosumer transacting with a single actor or multiple actors. The vertical axis divides the contractual options using real time (15 minute[3]) pricing or a fixed tariff. Those two axis are used because the resulting four arrangements together incorporate all nine means. Other axes, such as program responsibility with DSO or with the supplier, or variable bundles versus fixed contracts, did not provide this broad framework for all the proposed means.

Table 23: Contractual arrangements

		ACTORS	
		Single	**Multiple**
KWH €	**Real time pricing (15 min)**	1. Bundle: ▪Bundle offering (+back up, lease) ▪One party contract prosumer – supplier ▪Supplier has program responsibility ▪ Group contracts with supplier	2. Many to many market: ▪DSO groups consumers regionally for program responsibility
	Fixed tariffs	3. Current model: ▪One party contract pros. –sup. ▪Supplier has program responsibility	4. Many to many regulated ▪DSO groups consumers regionally for program responsibility

The four arrangements are explained in the next section.

[3] Large consumers in the Dutch electricity market already use real time pricing on a 15 minute basis. The same timeframe is proposed for the real time pricing options in this research.

1. The first contractual governance model uses real time pricing and the prosumer only trades with one actor: the supplier. The prosumer bases its choice of supplier on the contract form (long-term vs short-term et cetera) and the content of the bundle. Within this bundle the supplier can offer lease of solar panels, group discounts, back up (depending on the capacity market developments), services (contractual and technical) et cetera. Suppliers could engage in partnerships with ESCO's (Energy Service Companies) that offer prosumers services that can be chosen within the suppliers bundle and are settled on the bill with the supplier.
2. The second contractual governance model also contains real time pricing. A many to many market allows trade with multiple parties. The framework where the many to many trade takes place consists of two layers: one where the technical functioning of the system is secured by the DSO (that has no commercial role) and program responsibility is secured per region by the DSO as well. The second layer is the competitive domain: prosumers can trade themselves with whoever they want. Actors can also offer attractive business propositions to prosumers, such as bundles, services (for example to trade on behalf of the prosumer), group contracts, et cetera.
3. The third contractual governance model resembles the current model: with fixed tariffs and an exclusive contract between prosumer and supplier. The DSO is concerned with the technical governance in the non-commercial domain.
4. The fourth and last contractual governance model uses fixed tariffs with multiple actors in the transaction. It resembles the current model, with the exception that the contract is not exclusive; the prosumer can trade with multiple actors via a DSO operated framework and the DSO has regional program responsibility. This contractual model will not be used in the constitution of market design options, because when using fixed tariffs, there is no value added by trading with multiple actors; the economical result is the same while only using more transactions.

6.3 System configuration options

The previous two paragraphs explained the options within the technical and contractual governance model. This paragraph combines them into market design options. Each design option uses one of the arranged contractual models and combines different forms of demand side management and supply steering. In total three market designs are proposed that take into account the analysis of the actors' capabilities and limitations, performed in chapter 7, by only proposing combinations that are feasible in terms of the possibilities of the actors. In short the market design options are:

1. *It's all in the bundle:* Exclusive supplier – prosumer relation using bundles
    a. Contractual: (1) Real time pricing/single actor
    b. Technical: Demand side management & supply steering using real time pricing consumer controlled, storage in house
2. *One for all, all for one:* Many to many trading platform with technical layer operated by DSO and competitive domain for trade between multiple actors.
    a. Contractual: (2) Real time pricing/multiple actors
    b. Technical: Demand side management semi-automatic, Supply steering using real time pricing, Storage within neighbourhood
3. *Today and beyond:* Current supplier – prosumer trading model with technical governance additions
    a. Contractual: (3) Fixed/single actor
    b. Technical: Demand side management and supply steering automatically controlled, Storage in house.

The next section will elaborate on the market design options by first explaining them, then indicating the concerned actors in the transaction in a table and lastly explaining the market design option from the point of view of the prosumer.

6.3.1 Market design 1: It's all in the bundle

In this first market design only the prosumer and supplier take part in the transaction, using real time pricing. This pricing mechanism and bundle structure give the prosumer the possibility to trade economically efficient, thus both choosing a suitable bundle (containing required services and attractive conditions) and engaging in the balancing of the grid by responding to the real time pricing with demand and supply adjustments. All bundle components and corresponding transactions are grouped on one monthly bill (as in the telecom industry), possibly containing external bundle elements from the supplier's partner ESCO's. The actors taking part in the transaction are marked in the table below.

Table 24: Market design 1

MARKET DESIGN 1: IT'S ALL IN THE BUNDLE			Actors in transaction			
			Prosumer	DSO	Supplier	ESCO's
Contractual	1. BUNDLE		X		X	(X)
Technical	**Demand**	Consumer controlled with real time pricing	X		X	
	Supply	In house storage	X		X	

For the prosumer this would mean that there is still only contact and contract with one supplier and one bill that needs to be paid including transport and taxes. This bill will be made up monthly so that the prosumer has a frequent overview of the transactions and can decide to adjust the bundle components. Also bundle components of partner ESCO's of the supplier are on the bill, examples could be the lease of solar panels or storage, a specialized energy management device or service et cetera. The prosumer can choose to act upon the real time pricing himself using a device that indicates 'cheap/expensive times', or choose bundle components to help with this. Supply steering is done via in house storage, which works with a mechanism that takes into account consumption, real time pricing and storage capacity to decide to release electricity to the grid or use storage.

6.3.2 Market design 2: One for all, all for one

This market design is a many to many trading framework using real time pricing and prosumers can trade with multiple actors. The framework consists of two layers:

1) A technical layer facilitated by the DSO. To keep the balance of the grid under control in this complex framework the DSO makes use of neighbourhood storage to steer supply, and semi-automatic steering of demand, which can develop towards appliances that are automatically steered. And – if well executed – it can lead to lowered transport tariffs in successful neighbourhoods because the DSO would have lower costs of maintaining and operating the regional distribution grid.
2) A competitive layer where electricity is traded. Prosumers, cooperatives of prosumers, suppliers, et cetera can trade electricity with whoever they want.

The next table visualizes the actors taking part in the transaction.

Table 25: Market design 2

MARKET DESIGN 2: ONE FOR ALL, ALL FOR ONE			Actors in transaction			
			Prosumer	DSO	Supplier	ESCO's
Contractual	2. MANY TO MANY		X	X	X	X
Technical	**Demand**	Semi-automatic	X	X		
	Supply	Storage at neighbourhood level		X		

The prosumer trades electricity on a network with those who need it and are willing to pay an acceptable price. This can be done by active prosumer involvement, but also using prosumer customized settings that close deals automatically. On the network prosumers could also choose to join aggregated groups managed by ESCO's, et cetera. At the same time the prosumer cooperates with the DSO by allowing an agreed degree of demand side management and makes use of the DSO controlled storage facilities.

6.3.3 Market design 3: Today and beyond

The third market design is an adapted version of the current model. For the prosumer the tariffs are not real time; they are fixed in the contract with the supplier. Thus the prosumer – supplier relation is exclusive, but in cooperation with the DSO automatic demand side management and supply steering by means of in house storage is realized to optimally balance the distribution grid. The supplier could take up the lease of storage and solar panels as a commercial activity. All transactions are between prosumer and supplier on a yearly bill, as is the case now. This can be seen in the table below.

Table 26: Market design 3

MARKET DESIGN 3: TODAY AND BEYOND			Actors in transaction			
			Prosumer	DSO	Supplier	ESCO's
Contractual	3. CURRENT MODEL		X		X	
Technical	**Demand**	Automatic control	X	X		
	Supply	In house storage	X	X		

The prosumer is, like today, still only in contract with the supplier, which can offer the prosumer services according to what the suppliers seams fit for its business model. However, the DSO is more involved with the prosumer that it is now. By agreeing to a certain degree of automatic control by the DSO of climate systems, fridge/freezer, EV loading, storage, et cetera, the DSO can regionally bring down transport costs and the supplier can therefore lower transport costs on the bills of prosumers in certain regions, because the supplier has to pay less to the DSO in this region. In house storage serves a means for supply steering, but in this case in cooperation with the DSO.

6.4 Complexity of market design options

For the 'normal' discriminating alignment hypothesis, Williamson talks about specific contractual structures to govern a wide variety of transactions and their complexity. Thus when a governance structure is 'created' on the basis of the attributes of transactions, Williamson speaks of specific contractual structures to make those complex governance structures work. This was also discussed in paragraph 3.6.3. For the reverse discriminating alignment hypothesis, that is the basis of this research, Williamson does no such thing as describing contractual structures to make the complex combination of transaction attributes work. There are no ready-to-use contractual structures to let the combinations of means in the market design options work, simply because Williamson did not attempt to use the reverse discriminating alignment hypothesis. The next section describes the consequences of this deficit in the reverse discriminating alignment hypothesis.

6.4.1 Combination of market design options

In chapter 5 a design space was created following the reverse discriminating alignment hypothesis. Means were proposed to solve individual problems (of misalignment with the governance structure of the market) of individual transaction and governance structure attributes. Those means are thus point solutions: they have an impact on one or a few particular problems. In this chapter they have been combined in three market design options. While this has been done on the basis of the (institutional and technical) capabilities and limitations of the actors and attempting to create logical combinations of means, still the combinations are quite simply put together, changing the transaction and governance structure attributes and creating a complex market design, assuming that those market designs can be implemented and work without experiencing any difficulties and do not need specialized contractual structures.

For each market design the following sections explain the complexities that have emerged as a result of the combination of means into market design options. Those complexities call for innovative contractual structures and it is recommended (also in chapter 9: conclusions and recommendations) that future research fine tunes the market design options by focusing on these complexities and governing contract structures.

6.4.2 Complexity of market design option 1: It's all in the bundle'

The wide variety of bundle elements offered by different actors could account for complexity as does real time pricing and the required smart meter that are the basis of supply steering and demand side management.

- Because of the wide variety of possible bundle elements, a very loose and flexible contractual framework is needed, that can incorporate very different business propositions, while still securing availability, affordability and acceptability of electricity. The balance between providing room for innovating bundle components and the protection of these 'electricity values' could become a complex contractual framework. The more because bundle elements can also be offered (via the supplier) by partner ESCO's, thus the supplier is in contract with two parties (consumer and ESCO) for the same bundle element. It could be a challenge to keep this complex contractual framework transparent and understandable for all involved actors.
- The smart meter (that will be installed in all Dutch households before 2020) generates detailed, complex and large quantities of data that is valuable and/or required for different actors. Detailed contracts need to be designed to specify what (part of) the data is available to which actor and for which purposes to be used.
- Real time pricing requires a constant stream of data about prices to and from different actors in the system. These prices reflect the value of electricity at that point in time, but the prices are also subject to regulations about for example price ceilings and bottoms, market power et cetera. This complex system of price determination and communication requires an innovative contractual framework.

6.4.3 Complexity of market design option 2: One for all, all for one

The many to many market design option results in a complex framework as well, due to the two layers (technical layer and competitive domain on top of it) with a large quantity of different participating and transacting actors and the data needed for and resulting from smart meters and real time pricing.

- The competitive layer of this market design option must be able to connect a variety of actors: the individual consumer, aggregators, suppliers, cooperatives, et cetera. The great differences between them lead to a complex map of actors transacting with each other that requires a custom made way of handling them in the system. For this different contracts are required adapted to the actor in question.

- Not only the variety of actors transacting with each other on the competitive domain, but also the transactions themselves account for numerous links in this complex system. One time transactions between actors from the same or different groups, the settlement of the transactions and the interrelation with the technical layer managed by the DSO results in a complex settlement framework.
- The functioning of the technical layer is the responsibility of the (non-commercial) DSO. In this market design the DSO works together with the consumer to adjust supply and demand. For this detailed contracts, possibly different for each individual consumer (that wants different things concerning demand side management and supply steering), have to be created that determine a certain amount of control over appliances that will be transferred to the DSO.
- Smart meter: as in 6.4.2.
- Real time pricing: as in 6.4.2.
- Moreover, the interconnection of smart meters, real time pricing, the competitive layer and the technical domain is of crucial importance in this market design. Data issues, responsibilities and limitations have to be determined and clear to all participants.

6.4.4 Complexity of market design option 3: Today and beyond

The market design option 'Today and beyond' builds on the current situation that is already contractually managed. Additions to the current situation are supply steering and demand side management in cooperation with the DSO, of which the complexities concerning control and smart meters have been discussed in the previous sections.

- Transfer of control to DSO: as in 6.4.3.
- Smart meter: as in 6.4.2.

As discussed in 6.4.1, it is recommended that the complexities named in the previous few paragraphs are the basis of the fine tuning of the market design options in further research.

7. FIELD RESEARCH

[SubQuestion 3]

What option can be selected as sketch of an adapted market constitution?

[Chapter 7&8]

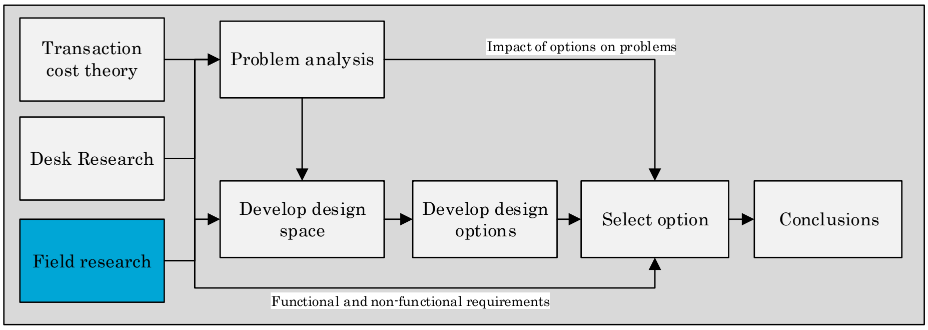


Figure 23: Situation of chapter 7 in approach

This chapter will give an overview of the performed field research that will serve, together with an analysis on what impact the proposed market design option have on the problems found in chapter 4 (see also Figure 23), as the basis of the answer to sub question 3. The field research brings clarity in which actors are concerned with PV prosumers in the Dutch electricity market, what their capabilities are and what they want in terms of 'functions' and 'constraints' of the market design. The list with interviewed actors and the interview questions can be found in attachment A.

[Functions] or functional requirements: 'what the system must *do*'. (Dym & Little, 2009)

[Constraints] or non-functional requirements: 'how the system must *be*'. (Dym & Little, 2009)

This chapter first discusses the important actors according to their (current) function in the system, their capabilities and their limitations by law (MinEZ, 1998). Then a comprehensive overview of the functions (7.2) and constraints (7.3) is given.

7.1 Actors

This paragraph describes the actors important for this research. First they are listed in Table 27, then visualized in the system (Figure 24) and lastly a few actors that have a stake in the system but are not visualized in the system in Figure 24 are discussed.

7.1.1 Description of actors

The following table summarizes the important facts about the actors concerned with prosumers in the Dutch electricity system. This table is based on the researcher's knowledge about the sector and the interviews with actors. It is also used as background knowledge in the combining of the market design options in the previous chapter.

Table 27: Actors concerned with prosumers in the Dutch electricity system

	Function	Capabilities	Limitations
Prosumer	Consume and generate electricity	Adjust demand, supply, but: bounded rationality!	Someone should cover program responsibility. Differences between consumer groups account for different preferences.
DSO	Construct, maintain and operate distribution grid, connect consumers and prosumers	Data handling and analysis, physical balancing when prosumer feed in becomes substantial part of electricity	Commercial activities are prohibited, as is unfair pricing of transport
Supplier	Deliver electricity and related services to prosumer, program responsibility	Generation and/or retail of electricity to prosumer, cooperate with prosumer	Vertical integration with distribution, unfair pricing of electricity
TSO	Maintain and balance high voltage transmission grid	N/A: transmission grid is outside scope of this research	N/A: transmission grid is outside scope of this research
ACM	Regulator, legislative function	Determines maximum tariffs for transport, connection and system tasks. Sets conditions for the (inter)national wholesale market. Legislative function. (ACM, 2014)	N/A
Min EZ/ Min Fin	Policy & law maker, tax office	Adapt institutional environment, create, adapt or remove stimulation policies	N/A
Experts	Informed opinion	N/A	N/A
Interest groups	Point of view	N/A	N/A

7.1.2 Power & Money flow

The next picture visualizes the position of the actors in the system, in terms of power (kWh) and money flow. The picture is followed by an explanation.

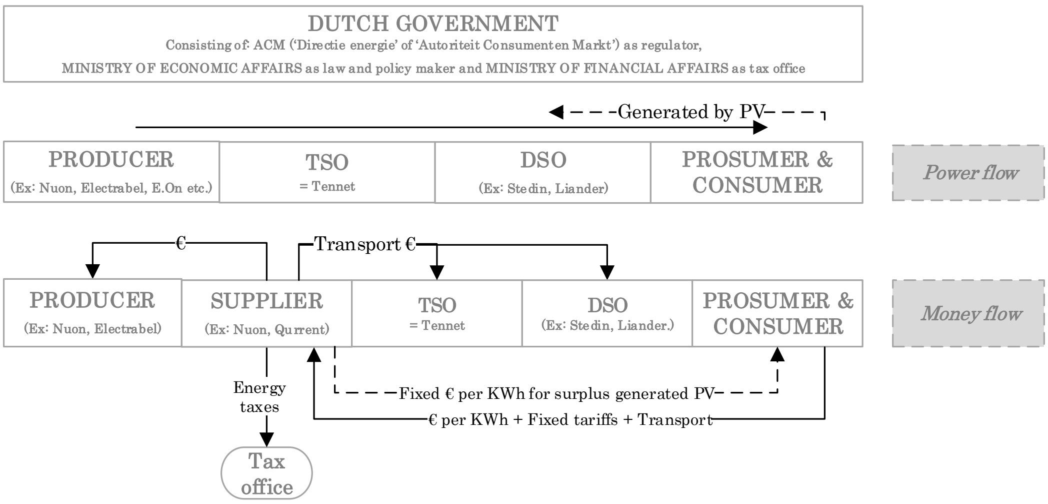


Figure 24: Position of actors in the system

The power flow part of the picture above visualizes power that is fed into the grid by a producer. The high voltage grid is operated (= balance keeping and system management) by the TSO (Tennet in the Netherlands). In case of substantial feed in of prosumers this could become a regional task (on the low voltage distribution grid) of the DSO as well. The DSO has the capabilities to take up this task (Interview F, 2014). It is the low voltage distribution grid that is connected to consumers and prosumers. When a prosumer produces electricity, it is fed into the low voltage grid where it is distributed to wherever it is needed.

When it comes to the money flow, the Supplier appears. This is the actor that the consumer has a contract with and pays to for the consumed electricity. The supplier pays to the producer (however, supplier and producer can be the same actor as with Nuon, Essent et cetera who own their production facilities). The supplier also pays energy taxes in the name of the consumer to the tax office and pays to the DSO and TSO for their transport services. Prosumers that generate more than they consume (net generation) get a fixed tariff per kWh from their supplier. The tariff the prosumer gets for the net generated kWh's differs per supplier, but has to be a 'reasonable compensation' (overseen by ACM).

7.1.3 Other actors

Program responsible parties (PRP's) cooperate with the TSO in balancing the system. They notify the TSO one day up front about the electricity that will be fed into and drawn from the grid. Therefore each electricity producing and consuming entity must be either a registered PRP itself, or be within the responsibility of a PRP. The PRP of the prosumer is their supplier. For those small prosumers the supplier uses averaged profiles to predict the power flows, no actual measurements are needed. EDSN is not listed as well. This is the 'datacenter' of the electricity system, it receives and gives information from/to the DSO's and suppliers. Lastly ESCO's – Energy Services Companies – can exist in various forms with various functions. They can have business models based on energy management, smart energy related product development et cetera.

7.2 Actor values from interviews

Attachment A provides two tables with the actors and their individual functional and non-functional requirements, **including an explanation of each term**.

7.2.1 Functional and non-functional requirements

The next two tables give an overview of the requirements. They have been ordered and colour coded according to how many actors have mentioned them. Three groups are used: Most important (dark blue, will count 3 times), important (middle blue, will count 2 times) and other (light blue, will count 1 time) (non-) functional requirements. Those three groups will be used in the next chapter where the design options will be evaluated and a weighted average will be constituted (separately for functional and non-functional requirements).

	FUNCTIONAL REQUIREMENTS
1	Incorporate an efficiency incentive
2	Provide flexible demand and supply
3	Have connection & control within system
4	Act as a predictable system in terms of demand and supply
5	Provide room for experimentation
6	Trade back up within the market
7	Act as a smart system

	NON-FUNCTIONAL REQUIREMENTS
1	Sustainability
2	Profitability
3	Free market
4	Transparency
5	Understandable for all actors involved
6	Budget neutrality
7	Processability of data
8	Network stability
9	Fair (tariffs)
10	Affordability

7.2.2 Scoring method

For each requirement it will be indicated if the market design fulfils this requirement or that is not possible to determine if the market designs fulfils the requirement. For the functional requirements a five step colour coding method will be used (because variations of fulfilling a function a bit to completely exist), for the non-functional requirements a three step colour coding method is used (because the system is or is not).

For the functional requirements:

--	-	+/-	+	++
Not	Slightly not	Impossible to say	Slightly yes	Yes

For the non-functional requirements

-	+/-	+
Not	Impossible to say	Yes

8. Option selection

[Sub Question 3]

What option can be selected as sketch of an adapted market constitution?

[Chapter 7&8]

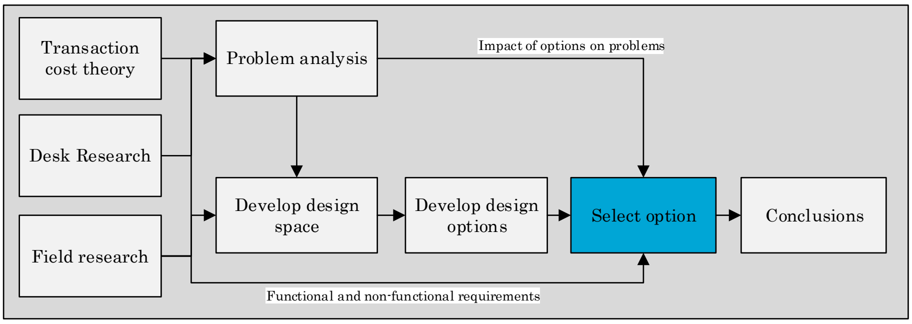


Figure 25: Situation of chapter 8 in approach

The options devised in chapter 6 will be evaluated in this chapter on the basis of their impact on the problems that followed from the problem analysis in chapter 4 and the field research in the previous chapter. This approach is visualized in Figure 25.

8.1 Impact of market designs on problems

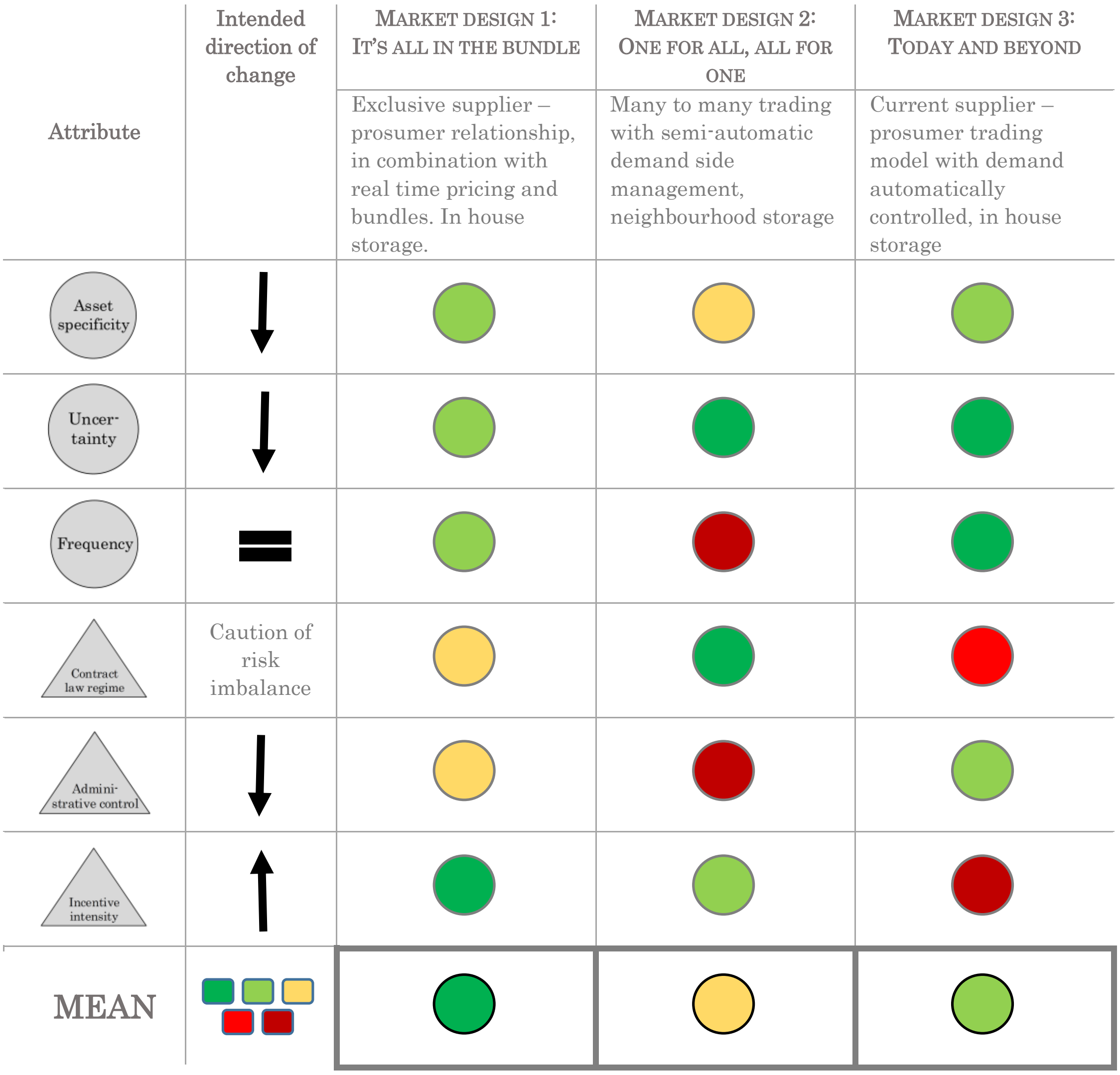
In chapter 5 a design space was created following the reverse discriminating alignment hypothesis. Means were proposed to change the transaction attributes (and to a limited extend the governance structure attributes) in the intended direction, in order to match the governance structure of the market. The means were focused on the problems found concerning the specific attributes in the problem analysis in chapter 4 and they were in chapter 6 combined into three different market design options. This paragraph will assess the impact of the market design options on the problems found in the problem analysis.

In the table on the next page each attribute of each market design is colour coded according to the intended direction of change – dark green being the most change in the intended direction, dark red indicates change in the undesired direction. In between are lighter colours of green and red, and in the middle yellow indicating no significant change of the attribute. The motivation for the colour coding can be found in attachment C.

The impact of the market designs on the problems that resulted from the analysis in chapter 4 is the biggest for market design option 1 ('It's all in the bundle'). Market design option 2 also shows change in the right direction, but not as much as market design option 1. The average change of market design 3 is neutral. Thus, none of the three designs has a negative impact on the problems, which is logical, since the market designs are only composed out of means that were initially proposed to change the individual attributes in the right direction. However, unlike the first market design, the second and third design do have individual attributes that have a negative impact (for design 2 frequency and administrative control, for design 3 contract law regime and incentive intensity).

On the basis of the theoretical analysis performed in chapter 4 and the reverse discriminating alignment hypothesis that provided a method to align the transaction attributes with the governance structure instead of the other way around, market design option 1 ('It's all in the bundle') is the most suited market design. From the three market designs it performs best in mitigating the imperfections created by the misalignment of governance structure and transaction attributes in the current configuration.

Table 28: Evaluation of market designs on problems



The next paragraph will compare the theoretical perspective with the findings from the field research to evaluate the acceptability of the theoretically preferred design option, and the other two market design options.

8.2 Actor perspective on market designs

In this paragraph the three market designs are measured against the functional and non-functional requirements on the system derived from the interviews with important actors.

8.2.1 Evaluation of functional requirements

In the table on the next page the three market designs are evaluated using the functional requirements from the field research (chapter 7). As explained in the previous chapter, they are colour coded using five steps. For the computation of the weighted average of each market design, the upper (dark blue) requirements have more weight (3x) than middle blue (2x) and light blue (1x).

All three market designs show a mean positive outcome on the functional requirements. However, the second and third design perform a little better than the first market design (opposite of previous paragraph!). It is important to note that the function viewed as most important, the efficiency incentive (mentioned by the most actors) is not apparent in market design 3 because with automatic control, the prosumer has still no incentive to be efficient because it is taken out of his hands.

Table 29: Evaluation of market designs on functional requirements

Functional requirement	MARKET DESIGN 1: IT'S ALL IN THE BUNDLE Exclusive supplier – prosumer relationship, in combination with real time pricing and bundles. In house storage.	MARKET DESIGN 2: ONE FOR ALL, ALL FOR ONE Many to many trading in easy access framework, with semi-automatic demand side management, neighbourhood storage	MARKET DESIGN 3: TODAY AND BEYOND Current supplier – prosumer trading model with demand automatically controlled, in house storage
Incorporate an efficiency incentive	(dark green)	(light green)	(red)
Provide flexible demand and supply	(light green)	(dark green)	(dark green)
Have connection & control within system	(yellow)	(light green)	(dark green)
Act as a predictable system	(light green)	(light green)	(dark green)
Provide room for experimentation	(yellow)	(yellow)	(yellow)
Trade back up within the market	(yellow)	(yellow)	(yellow)
Act as a smart system	(light green)	(dark green)	(dark green)
MEAN	(light green)	(dark green)	(dark green)

8.2.2 Evaluation of non-functional requirements

The non-functional requirements are evaluated using a three level colour code, because they *are* or *are not* apparent, or (yellow) it is impossible to say. Again, to compute the mean of each market design, the dark blue non-functional requirements are weighted heavier than middle blue than light blue. The results can be found in the table on the next page.

For the non-functional requirements, the first and second market design show a positive mean (but the first design much more positive than the second). The third market design shows an overall negative result on the non-functional requirements. The first design shows no individual negative results, where the second design does: it is not transparent and understandable for all actors because it is semi-automated and storage is regionally organized. This makes it less important for prosumers to actively engage in the system and understand it (and for DSO and supplier there is no incentive to make it understandable for prosumers).

It is important to note that for both the functional and non-functional requirements, some were impossible to measure (yellow). In this research they were counted as zero, thus having no positive and no negative impact. The discussion (chapter 10) will elaborate further on this deficit, proposing that more detailed market design options should be composed that *can* be measured along *all* requirements and that certain requirements *must* be met or else actors will not engage in the new market design.

Table 30: Evaluation of market designs on non-functional requirements

Non-functional requirement	MARKET DESIGN 1: IT'S ALL IN THE BUNDLE Exclusive supplier – prosumer relationship, in combination with real time pricing and bundles. In house storage.	MARKET DESIGN 2: ONE FOR ALL, ALL FOR ONE Many to many trading in easy access framework, with semi-automatic demand side management, neighbourhood storage	MARKET DESIGN 3: TODAY AND BEYOND Current supplier – prosumer trading model with demand automatically controlled, in house storage
Sustainability	green	green	green
Profitability	yellow	yellow	yellow
Free market	green	green	red
Transparency	green	red	red
Understandable for all actors involved	green	red	red
Budget neutrality	yellow	yellow	yellow
Processability of data	green	yellow	green
Network stability	yellow	green	green
Fair (tariffs)	yellow	green	yellow
Affordability	yellow	yellow	yellow
MEAN	green	green	red

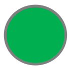
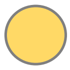
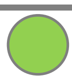
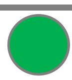
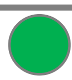
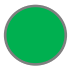
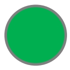
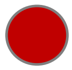
8.3 Comparison of evaluation results

On the basis of the problem analysis performed in chapter 4 of this report, market design option 1 (It's all in the bundle) is the most suited market design for the future electricity market where prosumers are trading there surplus generated electricity, because it has the most positive impact on the problems following from this problem analysis. This can be seen on the first row ("impact on problems") in the table on the next page.

This table also shows this result compared to the result on the preferences (in terms of functional and non-functional requirements) of the actors in the system. The evaluation on the functional requirements indicates that a (minor) trade-off has been made: in terms of the functional requirements market design 1 is not the best option, because the other two designs are more suited in terms of the flexibility and predictability of demand and supply (they are steered semi automatically and automatically in design 2 and 3). The non-functional requirements come to the same result when they are used to evaluate the market design options; design 1 is also most suited according to this method.

Thus, Market design 1 is performing slightly worse (but not negative) on the functional requirements, but this is viewed as a trade off towards the positive impact on the problems resulting from the problem analysis and the positive results on the non-functional requirements. Concluding, on the basis of the criteria used in this research, market design 1, 'It's all in the bundle' (an exclusive supplier – prosumer relationship with a combination of real time pricing and bundle offering), is the recommended market design.

Table 31: Combined evaluation of market designs

	MARKET DESIGN 1: IT'S ALL IN THE BUNDLE	MARKET DESIGN 2: ONE FOR ALL, ALL FOR ONE	MARKET DESIGN 3: TODAY AND BEYOND
	Exclusive supplier – prosumer relationship, in combination with real time pricing and bundles. In house storage.	Many to many trading in easy access framework, with semi-automatic demand side management, neighbourhood storage	Current supplier – prosumer trading model with demand automatically controlled, in house storage
IMPACT ON PROBLEMS			
FUNCTIONAL REQUIREMENTS			
NON-FUNCTIONAL REQUIREMENTS			

9. Conclusions & Recommendations

[Main Research Question]

How can the institutional configuration of the electricity market be adapted in order for PV prosumers to contribute optimally to a sustainable electricity system?

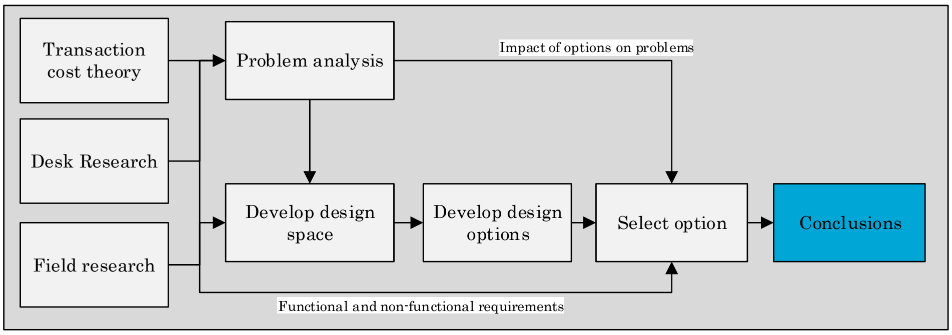


Figure 26: Situation of conclusion in approach

The main research question will be answered following the approach used throughout this entire research (visualized in the figure above), thereby answering the sub questions and ending with the main conclusions and system recommendations. Subsequently, academic recommendations will be given and lastly also relevant findings for Innopay will be shared.

9.1 Conclusions

The uncertain future of net metering, fixed tariffs and lack of incentive to contribute to a match of demand and supply, have led to an analysis of what an adapted market configuration for the Dutch electricity market could be, in which PV prosumers can optimally contribute to a sustainable electricity system.

[Sub Question 1] What can the application of Transaction Costs Theory tell us about the current and future configuration of the market?

Transaction cost theory is used because of its focus on transactions and overarching governance structures to efficiently govern the transactions. The theory allowed us to decompose the system in transaction and governance structure attributes. Those attributes were used to structurally analyse the problems concerning their discriminating alignment: to what extend do the Dutch electricity sector, and PV prosumers transacting in it, make an efficient match. This lead to the finding that in this sector asset specificity as a result of the investments in solar panels and generation plants and the critical system balance time dependency and volatility of supply should be reduced. Uncertainty (due to future policy and inelastic demand) should also be reduced, as well as administrative control (program responsibility needs to be guaranteed for all prosumers, more and more complex smart data follows the national introduction of the smart meter, the different bill components such as taxes, transport and kWh's and the possible emergence of a many to many market and its complex functioning). The frequency of the transaction should ideally stay at the same level (transactions grouped into one on a periodic bill) and incentive intensity should increase (to motivate prosumers to match demand and supply, to produce and consume sustainable energy and to motivate suppliers to provide back-up capacity). Lastly within the contract law regime the focus should be on the current risk imbalance between prosumer and supplier.

[Sub Question 2] What does the design space of the electricity market concerning PV prosumers look like and what options can be formulated?

The proposed means, meant to adapt the attributes in the intended direction to efficiently align them with the governance structure of the market, are divided in two main categories: technical governance means (such as demand side management and supply steering) and contractual governance means (amount of parties to the contract, real time or fixed tariffs, flexibility in the contract). Those means have come forward on the basis of desk research and are validated in actor interviews, together they constitute the design space.

The governance means are then structured along <u>two axes</u>: the prosumers transacts with one single or multiple actors and the tariffs are real time or fixed. This results in <u>four contractual governance arrangements</u>. They are combined with the technical governance means, varying in automation level of demand side management and modes of supply steering. The technical and contractual governance means are combined in <u>three market design options</u>:

4. *<u>It's all in the bundle</u>*: Exclusive supplier – prosumer relation using bundles, real time pricing and in house storage;
5. *<u>One for all, all for one</u>*: Many to many trading platform with a technical layer and a competitive domain for trade between multiple actors, real time pricing, semi-automatic demand side management and storage on neighbourhood level;
6. *<u>Today and beyond:</u>* Current supplier – prosumer trading model with demand automatically controlled and in house storage.

Sub question 3 is concerned with the evaluation and selection of the market design options.

[Sub Question 3] What option can be selected as sketch of an adapted market constitution?

The three market design options are evaluated on the basis of their impact on the problems discovered using the transaction cost theory analysis. For each market design options it is evaluated if the attributes change in the intended direction. Market design option 1 ('It's all in the bundle') comes out best. One trade off that should be made by selecting this option, is that it does not significantly bring down administrative control (because of the possibly complex bundle arrangement) and the risk imbalance stays unchanged (because the exclusive supplier – prosumer relation stays intact). Compared to the other two market designs it has the most impact on incentive intensity (real time pricing influences demand and supply directly) and it maintains the current frequency of the transaction (exclusive supplier – prosumer relation retains the possibility to group transactions on a periodic bill). It also has a positive impact on asset specificity and uncertainty (price elasticity is increased and temporal specificity of the volatile supply reduced). Market design 2 ('One for all, all for one') did not turn out to be the preferred market design option because it has a negative impact on frequency (many to many trade increases the transaction frequency because grouping on a periodic bill with one supplier is not possible) and on administrative control (many to many trade brings about more and more complex administrative processes). Market design 3 ('Today and beyond') was not preferred because it has a negative impact on incentive intensity (fixed prices and automatic demand side management, with no prosumer intervention) and within the contract law regime the prosumer is still dependent from one single supplier.

The result of the evaluation on the impact on the problems is compared with and validated through the field research. This reveals whether the option resulting from the theoretical analysis also shows the most acceptance by the concerned actors. On the basis of functional and non-functional requirements and their weighted average, the second market design ('All for one, one for all') is most preferred. However, the first market design (that resulted as preferred option from the theoretical analysis) also shows a positive result on the requirements. This market design only is less predictable and flexible in terms of the demand and supply relative to the second market option, because it is based on prosumers' reaction of real time pricing, and not semi-automatically steered. Thus, the preferred market design of the theoretical analysis ('It's all in the bundle') is evaluated as an acceptable market design option by the actors.

[Main Research Question] How can the institutional configuration of the electricity market be adapted in order for PV prosumers to contribute optimally to a sustainable electricity system?

To answer this question the starting point is that when an optimal match of transaction and governance attributes is achieved, this economizes on transaction costs. Thus the challenge is to find an institutional configuration for the electricity market that efficiently governs PV prosumers' transactions and is evaluated by the actors as acceptable as well.

The market design 'It's all in the bundle' does just that: it changes the transaction and governance attributes towards better alignment with the governance structure of the market (using the reverse discriminating alignment hypothesis) and is evaluated as acceptable by the concerned actors. This market design is defined by the preservation of the exclusive supplier – prosumer relationship, where bundles are offered consisting of choices to optimally align the contract with the personal possibilities and preferences of prosumers and where real time pricing is used to let prosumers contribute to a better match of demand and supply, also using in house storage.

This market design does not change the contractual relationships of the actors in the system significantly in terms of the amount of interfaces and relations prosumers have. The content of the contract however will experience changes (such as net metering and the bundle structure) and this market design option also has a significant impact on the complexity of the settlement of the system, due to the real time pricing. Lessons from the wholesale market, existing pilots and projects abroad where real time pricing are already used, can be used to optimally design this part of the market. The bundle structure of the contract between the prosumer and supplier requires change in the existing contract as well, but it is up to the individual supplier how much choice to give and how complex this structure will become. Here the telecom industry could serve as an example.

9.2 Goal of research

The objective of this research was twofold:

1. *Gain insight in the institutional configuration of the current electricity system concerning the feed in and settlement of privately produced PV electricity, from a transaction cost perspective.*

   The transaction cost analysis and actor interviews gave this insight in the problems and possibilities on how to mitigate the imperfections in the Dutch electricity market concerning PV prosumers.

2. *To devise a design of a future, transaction cost efficient configuration, tested against the values of all involved actors.*

   Structurally devising a design space on the basis of the transaction and governance attributes and their intended direction of change provided a comprehensive set of arrangements. This set, consisting of technical and contractual governance means, was the basis for three market design options. These options were then evaluated on their impact on the theoretical problems and this evaluation was compared to the requirements of the actors, resulting in one preferred market design option.

9.3 Recommendations

This paragraph discusses the recommendations following from this research from three different perspectives: the recommendations for the system under consideration, the academic recommendations and the recommendations for Innopay that provided the opportunity to execute this research as a graduation internship.

9.3.1 System recommendations

The results of this research can be used as framework-to-be-fine-tuned to set-up an innovative market model for the Dutch electricity sector to handle the two-way transactions of PV prosumers, which can also be used to accommodate 'regular' consumers in the Dutch electricity sector. Thus, the actors in this market (policy makers and regulators, suppliers, DSO's, 3th parties, et cetera) could use the results to critically review the current system and consider an adaptation of the market design towards a new configuration. In the discussion in chapter 10 more detailed and elaborate recommendations on further research on system level will be provided, such as taking a broader perspective than only PV prosumers, the suggestion to further work out the second market design ('One for all, all for one') as well and to place more focus on consumer acceptance and production costs.

9.3.2 Academic recommendations

In paragraph 3.6 the proposed adaptation of the electricity market concerning PV prosumers was typified as 'reverse discriminating alignment': not the governance structure followed from the transaction attributes, but the governance structure is set and the transaction attributes should be changed to make an efficient match. **In this research it is confirmed that for the case of the Dutch electricity market it is possible to adapt the transaction attributes, just like O.E. Williamson (2003) suggested, using technical and contractual governance means**. But not *only* were the transaction attributes changed, also within the governance structure attributes was room to manoeuvre and therefore also there adaptations took place as a result of the technical and contractual governance means.

Nowadays European and national laws are often defining what governance structures should look like in order to achieve an efficient (European) free market. In line with this, it might be important to endorse at academic level that not *always* governance structures follow transaction attributes, but that reversing this mechanism is possible as well. The exact possibilities and constraints to this reversal of the discriminating alignment hypothesis should be underpinned more in depth in both theoretical and practical sense, by dedicating more research towards this idea and analysing what complexities arise as a consequence of reversing the discriminating alignment hypothesis, that were not described by Williamson, and what contractual structures are needed to cope with those complexities.

9.3.3 Value and recommendations for Innopay

Innopay has initiated this research out of interest in changing markets, where two-way transactions are replacing one-way transactions. Innopay also wanted to become more familiar with the dynamics of the electricity sector and possibly identify business opportunities. This business opportunity could lie with the second market design option ('One for all, all for one') where a many to many market would need a collaborative platform in the competitive domain and cooperation between all actors to make this work would be crucial. This is Innopay's area of expertise and Innopay could make a great contribution in this field with its knowledge about other many to many markets and electrification of payments. The discussion (paragraph 10.3 specifically) will elaborate on this opportunity.

Short term and more practically would be taking part in the USEF project (attachment B) that attempts to devise a framework to make a many to many market possible. This framework is still in a very early stage of development and contains many abstractions and unknowns, which could be clarified by an Innopay-like party.

10. DISCUSSION

This chapter will take a broad and critical perspective towards the content of the research and the results and looks further than the scope. The points of discussion will be:

- 10.1 – Choice of transaction unit;
- 10.2 – The constitution and selection of the market design options;
- 10.3 – The potential value of the many to many market design option;
- 10.4 – The market design options from a prosumers/consumers perspective taking into account consumer segments and production costs;
- 10.5 – The potential use of other economic theories for the analysis and research;
- 10.6 – The generalizability of the results.

10.1 Choice of transaction unit

The transaction unit of 1 kWh provided this research with a clear scope and resulted in a structured approach to analyse the problems in the electricity sector. It also created the opportunity to analyse the 'extra' transaction unit separately (1 kWh coming from the prosumer), revealing different problems than those concerning 1 kWh generated by the supplier. The transaction unit proved to have a broad reach in the very different problems that were found, but those problems could at the same time be pinned down very specifically. This specificity was then used to find solutions that are custom made for each separate problem and combined into market design options. The transaction unit was thus chosen on logical and pragmatic grounds.

However, this transaction is part of a chain of transactions and does, in reality, not stand alone. This complex chain consists of the investment in solar panels, in back up capacity, control, measurements, data et cetera, which also influence each other. In addition these elements have a different impact in terms of (relative) costs and risk on prosumers and suppliers or DSO's. This report analyses these interdependencies when they relate to the transaction unit of 1 kWh in chapter 4 and explains about the complexities of the design options resulting from the interdependencies in paragraph 6.4. However, the total chain of transactions and their interdependencies has not been the central focus of this research. Further research can build on the methods used in this research and the findings concerning the transaction unit of 1 kWh, but should take on a broader perspective to analyse the impact of other transactions and processes in the market as well.

Moreover, the trade is never about 1 kWh, but about a 'bundle' of these transaction units. Would the trade be really about 1 kWh, then the frequency of the transaction would be enormous and possibly every few minutes a measurement would be send to the supplier and a payment of approximately € 0,25 made, causing high transaction costs and complex administration. Instead, today the kWh's are grouped on a yearly bill (the resulting transaction), derived from a yearly (bidirectional meter) or two-monthly (smart meter) measurement (Liander, 2014), resulting in transactions with a lower frequency. This grouping of transactions on a periodic basis would happen in market design 1 and 3. Market design 2 (the many to many market) will come closer to actual transaction of 1 kWh, but for efficiency reasons the transaction will most likely be grouped into for example a daily consolidated overview (kWh use of a 2 person household is approximately 10 kWh/day (Nibud, 2014)) which could be settled with an account that can be linked with a bank account or credit card and settled on a direct or monthly basis. This however still requires very frequent measurements.

10.2 Options and option selection

This paragraph discusses the influence of technological advancements on the formation of the market design options, it reflects on the market design options as three extremes on a continuum and it discusses the selection of the market design options.

10.2.1 Technological progress in the sector

Just like in the telecom sector, technological progress has accounted for big changes in the electricity sector and has influenced the market governing the transactions. Advancements such as internet, wireless communication and – specifically for electricity – smart grids have resulted in different products and transactions that were not apparent before and require innovative governance structures. However, the same advancements are also needed for the market design options proposed in this research. Without those advancements, it would not have been possible to 'change' the attributes of transactions in the intended direction as proposed. A few examples: advanced technologies, smart grids and detailed data are needed for automatic demand side management and to enable contracts with bundles or make a many to many market possible. Thus, the starting point of the research, technological advancements, has also been very important in composing the proposed market design options.

10.2.2 Final market design option

Market design option 1 ('It's all in the bundle') was chosen as the preferable market design option because it had the most positive impact on the intended direction of change of the attributes and is accepted by the actors. However, the three evaluated market design options were three extremes, chosen because of the clear differences between them and the logical combination of means within each of them. In reality, the three market designs are a combinations of points on two continuums (control and amount of actors in trade) and the overarching choices of fixed/real time tariffs and storage in house or on neighbourhood level. This choices for the three market design options on these continuums and the overarching layers are visualized in the next figure.

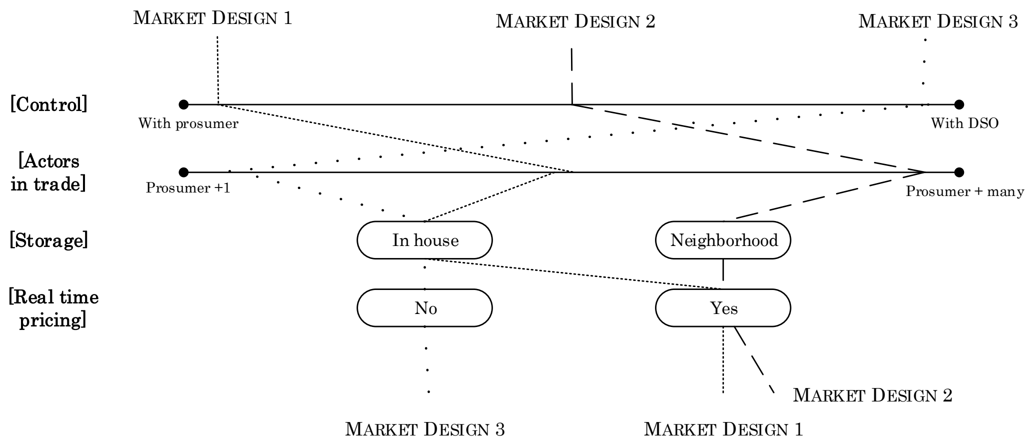


Figure 27: Continuum of options

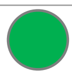
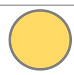
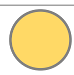
It is possible that a hybrid between the market designs proposed in this report is even more suited for the Dutch electricity market, for example neighbourhood storage within market design option 1, or automated demand side management instead of changing prosumers behaviour on the basis of real time pricing. The next step for this research would be to fine tune market design option 1, so that it will suit the Dutch electricity market. To do this, there are two aspects one should take into consideration. First of all, there needs to be a broader focus than the two evaluation points used in this research; impact on attributes and acceptance by the actors (more on additional evaluation criteria later in this discussion). Secondly, an even more holistic system perspective of the Dutch electricity market should be considered, which takes into account the impact of growth of small scale supply, wind energy, foreign supply, European capacity market, energy cooperatives, security of policy et cetera.

10.2.3 Relational contracts

Paragraph 3.6.3 introduced the concept of relational contracts to cope with complexity and uncertainty. Instead of specifying contracts in detail, the contracts in complex and uncertain situations should focus on the continuity of the relationship and provide flexibility within the arrangements between the actors. The table below indicates how well the market design options incorporate this concept of relational contracts already.

Market design option 1 does this best, because the bundle structure itself provides for this flexibility; bundle elements can be changed and therewith the contract changes in the interest of one or both actors, but no actor would be worse of, since mutual agreements would change the bundle combination in the contract. For market design 2 this would be difficult to achieve because of the transactions with many different actors (but not impossible, for example if the prosumer choses an ESCO that helps with the trade on the longer term, then such a relational oriented contract could be an option). Market design 3 resembles the current model and nowadays such flexible constructions are not in place. But since the prosumer – supplier relation is exclusive, this would not be difficult to incorporate.

Table 32: Possibility of relational contracts in market design options

	MARKET DESIGN 1: IT'S ALL IN THE BUNDLE	MARKET DESIGN 2: ONE FOR ALL, ALL FOR ONE	MARKET DESIGN 3: TODAY AND BEYOND
	Exclusive supplier – prosumer relationship, in combination with real time pricing and bundles. In house storage.	Many to many trading in easy access framework, with semi-automatic demand side management, neighbourhood storage	Current supplier – prosumer trading model with demand automatically controlled, in house storage
RELATIONAL CONTRACTS			

10.2.4 Binding requirements

The functional and non-functional requirements in this research have been translated in a weighted average, indicating a final 'acceptance' level. But it could be that certain requirements *must* be met, or that certain features *may not* be a part of the final market design, such as 'network stability' or 'security'. Such binding requirements were not taken as boundary conditions in this research but may very well turn out to be when implementation of a new market design is considered.

Moreover, in chapter 8 it became clear that many of the requirements were impossible to measure for the current market design options. The options were not defined this way or were not set in such detail. This research was focused on analysing the problem and exploring the possibilities to solve or mitigate these problems. A future study should be a design oriented study that has the goal to create more detailed market designs and should take, while designing, the requirements into account already (Verschuren & Doorewaard, 2010). The current research is in contrast with such a design oriented study, because the structured design approach on the basis of transaction cost theory resulted in market design options that in hindsight could not be evaluated with some of the requirements that the actors indicated.

10.3 Potential value of many to many market design option

At the beginning of this research the expectation was that the many to many market design option (Market design option 2: One for all, all for one) would turn out to be the preferred option. This expectation was based on the many orienting conversations on the subject with various actors in the field, including Innopay, who sought for an open market where literally everyone could be producer and consumer, making full use of the emergence of internet and relating smart solutions, in order to accelerate (the decentralized contribution to) the energy transition.

10.3.1 Drawbacks according to Transaction cost theory analysis

The reason the many to many option did not turn out as the preferred option (paragraph 8.1), was its impact on the attributes of frequency and administrative control. On the basis of the transaction unit of 1 kWh (see also paragraph 10.1) it was said that with many to many trade the frequency of the transaction would be enormous, since the transaction could not be grouped into one bill paid to one supplier anymore. Moreover administrative control would go up and become very complex as a result of the many actors in the transaction. Compared to market design 1 (it's all in the bundle) the negative impact of the many to many market design option on those two attributes led to the conclusion that this market design option is probably not the one that most efficiently aligns the market design option structure with the given governance structure. Thus, this market design option would bring about more transaction costs than the more preferred market design option 1 (It's all in the bundle).

However, one could raise the question if this increase in frequency and administrative control is indeed such a burden and brings up transaction costs significantly in light of the current technological advancements in smart and connected systems. In other sectors where many to many trade takes place (or is emerging) the open market increases competition, lowers prices, increases the amount of available information and does not bring up transaction costs significantly. Examples are Marktplaats, Uber, Airbnb, et cetera. The basis for the success of these many to many platforms is the internet as a transactional channel and the collaborative platform facilitating competitive propositions.

10.3.2 Innopay's expertise

Innopay's expertise[4] lies in managing complex stakeholder fields and finding common ground in creating innovative collaborative platforms on which competition can take place. On these platforms the focus is on transactions in the online world.

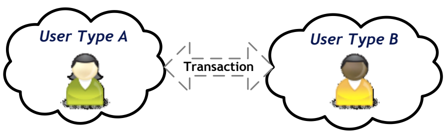


Figure 28: Two-sided market

A special category of a many to many market is the (so called) 'two-sided market'. This is an economic network with two distinct user groups with members that each play on distinct role in transactions (Figure 28). A platform or network brings together the user groups (Figure 29), causing (mainly) positive network effects (user benefits from growth on the same side of the network and/or on the other side, possibly leading

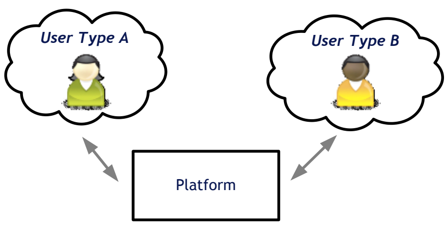


Figure 29: Two-sided market connected by platform

[4] Information and pictures in section 10.4.2 are all from presentation "Vision on two-sided markets" from Chiel Liezenberg on September 19th 2014

to a 'tipping point' – the moment the platform reaches a critical mass to be successful). Such a platform or network can come about using two different market strategies:

- Exclusive 3-party model with central, powerful, service provider (examples: American express, DigiD, Microsoft's Windows operating system, Facebook). Different networks with the same services can exist, introducing competition on network level. Economic optimisation and network effects may lead to a single network that connects all users, although this brings concerns regarding economic principles of competition;
- Inclusive 4-party model with de-central service providers collaborating to create an open level playing field trading platform where they can offer their business propositions (examples: credit cards, iDeal, WWW). More than one party can offer their own value added propositions within the same network. All benefit from network growth (which leads to economic network optimisation) and economic power is distributed over the network. A common set of agreements is needed to create a 'cooperative domain' and a 'competitive domain'.

10.3.3 One for all, all for one

As described in paragraph 6.3, market design option 2 (One for all, all for one), should consist of at least a technical domain to let the market function physically, and a competitive domain to trade electricity with the many possible actors (Figure 29). From the two possible market strategies the inclusive 4-party model is the logical choice, since it creates an open level playing field and is in line with free market principles. What a 4-party model for the electricity sector could look like is visualised the next figure.

In this model different roles can be defined: Producer (producing electricity centralized or decentralized with PV), consumer, acquirer or issuer (ensure that producers and consumers can trade on the competitive domain), system operator of the technical domain and facilitator of the cooperative domain.

- The producer role (top left block) can be undertaken by suppliers and prosumers;
- The consumer role (top right block) can be undertaken by regular consumers or prosumers (thus prosumers can switch roles!);
- The role of acquirer or issuer (bottom blocks) can be taken up by suppliers (also switch roles!), ESCO's or aggregators;
- The system operator for the technical domain (one of the middle blocks) would be a logical role for the DSO;
- The role of facilitator on the competitive domain (other one of the middle blocks) would be taken up by the cooperating acquirers and issuers.

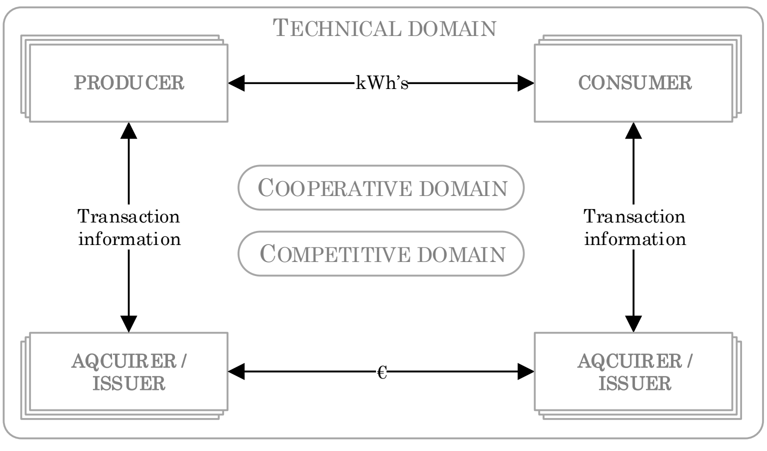


Figure 30: 4-party model for the electricity sector

In this market model the prosumer (in the role of producer, top left) decides to trade with a neighbor (in the role of consumer, top right). The prosumer indicates this transaction to his acquirer (left bottom, an ESCO, supplier or aggregator that the prosumer has trusted to handle the transaction with) that settles the trade. The acquirer settles the trade with the issuer (right bottom). It could be that the neighbor is engaged with the same ESCO, supplier or aggregator (now in the role of issuer, right bottom), which makes the trade easier and economizes on transaction costs. Otherwise the acquirer settles the trade with the issuer that the neighbor has trusted. This can be an ESCO, supplier or aggregator.

The underlying technical domain is logically operated by the DSO. The DSO secures the balance of supply and demand within this domain. The prosumer can thus work with the DSO to take part in this balance of supply and demand on the individual level. The DSO becomes a partner in demand side management and supply steering.

10.3.4 Business proposition from Electrified

To illustrate the 4-party model for the electricity sector, let us take the start-up Electrified as an example. This (fictional) start up recognised the business case they could make within the newly emerging many to many market in the Netherlands by taking up the acquirer/issuer role. In the figure above this means that Electrified would 'be' the left bottom block when they function as an acquirer 'their' prosumers and settle transactions for them, and they would be the bottom right block when they settle transactions for their consumers (or their prosumers that are taking the role of consumer). Once the competitive domain (as described in the previous paragraph) was established, Electrified went all out campaigning for their business proposition, in order to immediately gain market share.

Their target group are PV prosumers: households that have solar panels on their roof and want to trade within a broader range of actors than only a conventional supplier, but do not have the time or expertise to engage on the competitive domain themselves. Electrified connects all those PV prosumers with each other, in order for them to be a self-supporting group. If supply and demand cannot be matched (during night-time or cloudy days), Electrified has an attractive deal with a conventional supplier such as Nuon, which can supply electricity at low times. This deal is evaluated each year and compared to contracts with other suppliers in order to get the best deal. Electrified makes a profit on this mass deal with the conventional supplier. Also regular consumers, that do not have solar panels, can choose Electrified as service provider. Since these consumers do not supply to the self-supporting group, they pay a small percentage over each kWh they consume within the group. This added value is then divided between Electrified and the PV prosumers. The regular consumers also make use of the mass deal that Electrified was able to close with a major supplier such as Nuon or Essent. The added value for all concerned actors in this business proposition is summarized in the table on the next page Table 33.

Future business opportunities for Electrified could be, first, engaging different sources of generation in the self-supporting group to be less dependent on sunlight and the conventional supplier. Second, Electrified could close contracts with similar services providers that have the same business proposition but with CHP or small private wind mills. Together they could act as joint-ventures that have a joint self-supporting group. The self-supporting group thus gets bigger and the volatile supply is averaged out by the different generation methods, resulting in reduced need for external supply. Lastly Electrified could divide the self-supporting group regionally and give the households in this regional group the choice to engage in a program to lower their bill by taking part in steering programs in cooperation with Electrified and the DSO. Taking part in this program is not required for all households in the regional self-supporting group. Households can also choose to remain a 'regular' prosumer instead of an 'active' prosumer taking part in demand side management and/or supply steering.

Table 33: Added value for concerned actors in business proposition

ADDED VALUE	
Electrified	**Prosumer**
• Profit on mass deal with conventional supplier; • Profit on percentage paid by regular consumers; • Profit on sale of (PV related) appliances and services (for example to engage in demand side management and supply steering); • Profit on sale and maintenance of solar panels, or on the deal that Electrified closes with an ESCO that specializes in this.	• Engage and trade within like-minded group; • Consume PV electricity also when own production is not sufficient; • Contribute to self-supporting group, make a joint effort to lower electricity bill; • Profit on electricity sold to regular consumers; • Engage in Electrifieds mass deal with conventional supplier; • Make use of Electrifieds PV expertise.
Regular consumer	**DSO**
• Possibility to consume PV electricity without investing in solar panels; • Engage in Electrifieds mass deal with conventional supplier; • 'Try out' this arrangement before becoming a PV prosumer within the self-supporting group.	• These kind of aggregated groups allow for more precise predictions and if within regional groups demand side management and/or supply steering would be implemented, this aggregated form of steering could have a significant impact on the total regional portfolio.

10.4 Consumers and prosumers

In this research it was analysed what the problems and solutions could be concerning prosumers' transactions, from a transaction cost perspective. A very crucial point when implementing a future market design would however also contain the acceptance of the market design by the consumers and prosumers. This is dependent from various factors such as the credibility of future policy, return on investment and the variations in preferences of consumers. Transaction cost theory focusses solely on the transaction and does not incorporate such issues. Thus, as a result of the choice for this theoretical perspective (motivated earlier), this research did not analyse consumer and prosumer acceptance of the different market designs and did not calculate the economic value of the market design options for prosumers. Also, it did not concern stimulation or compensation policies for consumers (such as net metering). These points are important for future research and for designing a detailed version of one of the proposed market designs. The next section will discuss the variety of consumer segments and the production costs that are an important factor for prosumers and consumers as well.

10.4.1 Consumer segments

This report talks about consumers and prosumers as it were a uniform group with clear preferences and actions. The different market design options propose various contracting forms and different possibilities and degrees of supply steering and demand side management, ignoring the possibility of prosumers and consumers not accepting these features. This generalization of consumers served as a clear scoping decision in this research, but it might also lead to market design options that are only acceptable for a few consumers.

In the research "Understanding consumer preferences in energy efficiency" Accenture (2011)identified six consumer segments, based on their preferences for different components of energy management programs (impact on your electricity bill, utility control, your environmental impact and self-action required). Those consumer segments with their corresponding percentages in Dutch society are:

- Proactives (14%)
- Eco-rationals (7%)
- Cost conscious (8%)
- Pragmatics (18%)

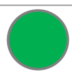
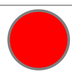
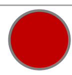
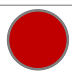
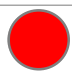
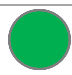
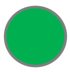
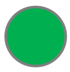
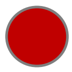
- Skepticals (35% - much higher than worldwide average of 21%)
- Indifferents (18% - higher than worldwide average of 13%)

The skepticals, representing more than 1/3 of Dutch society, are characterized by their low acceptance of utility control, as are the Pragmatics. Added up those two groups represent over 50% of Dutch consumers. Utility control is exactly what market design 2 (One for all, all for one) and 3 (Today and beyond) propose. Thus it would be a difficult process to engage more than half of the Dutch consumers in market design 2 and 3 (first row of the next table).

The Indifferents and Cost conscious together account for a quarter of all Dutch consumers. For both groups bill complexity and time commitment are potential inhibiters, causing lower acceptance (second row of the next table). These are points of attention for market design 1 (It's all in the bundle) and market design 2 (One for all, all for one).

The fragmentation of consumers in the six segments tells us that implementing one uniform solution would be naïve. It suggests that consumers want different things. A future market design option should thus provide room for those different consumer segments in order for them to be handled as they please. Market design 1 and 2 provide this flexibility in terms of the different bundle elements (market design 1) and the different actors that can be traded with and the possibility to engage different ESCO's to take over certain tasks or deliver services (market design 2). The third market design does not provide this room: it is based on automatic DSO control and the prevailing supplier – prosumer relationship. This is visualized in the third row of the next table.

Table 34: Important acceptance factors for consumers and prosumers

	MARKET DESIGN 1: IT'S ALL IN THE BUNDLE	MARKET DESIGN 2: ONE FOR ALL, ALL FOR ONE	MARKET DESIGN 3: TODAY AND BEYOND
	Exclusive supplier – prosumer relationship, in combination with real time pricing and bundles. In house storage.	Many to many trading in easy access framework, with semi-automatic demand side management, neighbourhood storage	Current supplier – prosumer trading model with demand automatically controlled, in house storage
UTILITY CONTROL			
BILL COMPLEXITY AND TIME COMMITMENT			
ALLOWS FOR CUSTOM MADE SOLUTIONS FOR DIFFERENT SEGMENTS			

10.4.2 Production costs

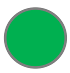
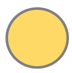
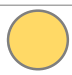
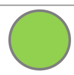
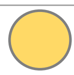
As already emphasized, this research takes on a transaction cost perspective and has the (reverse) efficient alignment of transaction attributes with governance structures as a point of focus. The premise is that efficient alignment results in lower transactions costs (more on this in chapter 3). However, when transaction costs are low, this does not necessarily mean that consumer is better of: the transaction costs will need to be enormously lowered to match the (at this point) very high costs of for example storage.

Arrow (1969) defines transaction costs as 'the costs of running the economic system' and O.E. Williamson (1985) emphasizes the distinction between those costs (he calls them the economic equivalent of friction in physical systems) and production costs. Production costs are the costs that neoclassical analysis is preoccupied with and concerns the actual costs that the proposed market design would result in for consumers and prosumers (storage, smart appliances, extra services). The simplest solution to combining those two distinct categories of costs is to sum them up for each market design and present the one with the lowest total costs (transaction + production costs) as the preferred market design.

Production cost can be quantified. However, the difficulty is that transaction costs are always evaluated in a 'comparative institutional way' (O.E. Williamson, 1985):. Modes of contracting are compared and it is not so much the 'amount' of transaction costs that matters, but the relative difference. Directly measuring those costs is not a common practice. "The question is whether organizational relations (contracting practices; governance structures) line up with the attributes of transactions as predicted by transaction cost reasoning or not" (O.E. Williamson, 1985). When assessing the market design options on both transaction costs and production costs, one can therefore only make a reasoned trade-off, not an absolute comparison. For each of the market designs the following section explains points to take into account when assessing transaction and production costs together. It is assumed that today (situation zero) production costs for prosumers are zero. Only new costs for smart appliances, storage and solar panels are taken into account and only production costs for the prosumer are evaluated. The results are summarized in the next table, followed by a conclusion.

- Market design option 1 (It's all in the bundle)
  - Production costs: Investment in in-house storage needed, but this might be arranged with a lease contract within the bundle with the supplier (applies also to the solar panels).
  - Transaction costs: This is the preferred market design option in the comparative analysis of the three market design options using the impact on the problems from the problem analysis as the evaluation criterion. The basis for the problem analysis was transaction cost theory, therefore it is assumed that the options with the biggest impact is the option with the largest reduction in transaction costs.
- Market design option 2 (One for all, all for one)
  - Production costs: Neighbourhood storage thus no costs for prosumer/ consumer. Smart appliances/solar panels could be leased.
  - Transaction costs: least favourite market design option from the evaluation on the impact on the problems from the problem analysis.
- Market design option 3 (Today and beyond)
  - Production costs: In-house storage, might be in cooperation with supplier.
  - Transaction costs: Second best market design option resulting from impact problems from the problem analysis.

Table 35: Production vs. Transaction costs

	MARKET DESIGN 1: IT'S ALL IN THE BUNDLE	MARKET DESIGN 2: ONE FOR ALL, ALL FOR ONE	MARKET DESIGN 3: TODAY AND BEYOND
	Exclusive supplier – prosumer relationship, in combination with real time pricing and bundles. In house storage.	Many to many trading in easy access framework, with semi-automatic demand side management, neighbourhood storage	Current supplier – prosumer trading model with demand automatically controlled, in house storage
IMPACT ON PROBLEMS (= COMPARATIVE TRANSACTION COSTS)			
PRODUCTION COSTS			

All market design options have production costs higher than zero, because all options are based on storage and/or smart appliances. All of them can reduce (or spread) these costs via different contractual structures (bundles in market design option 1, choice of preferred actor for lease or other constructions in market design option 2 and an arrangement with the own supplier in market design 3). The production costs for market design 2, which works with neighbourhood storage, is however lower than the other two, since no in house storage and investment or lease constructions are required. Market design 2 works with smart appliances, but the extra costs for this is negligible compared to storage.

Focussing on production costs, market design 2 (One for all, all for one) is the preferred market design for prosumers. When designing, choosing and implementing a market design option, it is advisable to take these production costs into account as well.

10.5 Other economic theories

In section 2.5 it was described what defined agency theory and property rights theory, and why they were not chosen as the central theoretical framework for this research. However, in the Economic Institutions of Capitalism, O.E. Williamson (1985) says "Given the complexity of the phenomena under review, transaction cost economics should often be used in addition to, rather than to the exclusion of, alternative approaches." Following Williamsons valuable advice, this discussion takes the same approach as Kim and Mahoney (2005) in their comparison and application of property rights theory, agency theory and transactions cost theory to oil field unitization. This section will take the remaining two theories (Property rights and Agency theory) to sketch what results could have been expected when using those theories. Also transaction cost theory is described again, to give a quick overview of the differences. The next table describes for each of the three theories the unit of analysis, the focal dimension, the focal cost concern, the contractual focus and the (possible) result of the research.

Table 36: Application of other theories (inspired by and adapted from Kim & Mahony (2005))

	TRANSACTION COST THEORY	AGENCY THEORY	PROPERTY RIGHTS THEORY
UNIT OF ANALYSIS	Contractual transaction of 1 kWh from supplier to prosumer and vv	Principal agent contractual relation and its incentives: Supplier/DSO (principal) – prosumer (agent) relation	The viability of the institution of the current net metering mechanism (or the viability of a future to-be-implemented mechanism) with respect to total social costs, including public policy and the political environment
FOCAL DIMENSION	Misalignment of transaction attributes with the predefined governance structure	Incentives of prosumers diverge from suppliers/DSO's. How to align to maximize aggregate economic payoffs of supplier/DSO&prosumer?	Imbalance and non optimal total economic result due to volatile supply and inelastic demand and free use of infra-structure (negative externalities and rent seeking) resulting from net metering
FOCAL COST CONCERN	Transaction costs resulting from misalignment, due to behavorial attitudes of bounded rationality and oppurtunism	Cost of monitoring the prosumer, residual loss from imperfect or non existing incentive alignment	Ex ante property rights allocation over prosumers/suppliers/DSO's and ex post distributional conflicts between the same actors
CONTRACTUAL FOCUS	Analysis of current (mis)alignment and design using the reverse discriminating alignment hypothesis: proposing a combination of means to mitigate the misalignment of transaction attributes with the governance structure	Analysis of current incentive alignment and design of contractual structures to (ex ante) align (and make productive use of) incentives with regard to demand and supply	Analysis of total social welfare in current situation (net metering) and how it came about and design to maximize social welfare by (ex ante) efficient property rights allocation in order to avoid profit maximizing incentives for suppliers, DSO's and/or prosumers resulting in imbalance or negative joint social welfare. Ex post: mitigating distributional conflicts resulting from the critical infra-structure and volatility of supply and inelastic demand
(POSSIBLE) RESULT OF RESEARCH	Proposals for market designs that reduce the misalignment of transaction attributes and gover-nance structures, consisting of technical and contractual means (as proposed in this research)	Proposals for payoff structures for prosumers that are in line with the economic and balance keeping goals of suppliers and DSO's. Example: cooperation contract between supplier and prosumer, that gives the prosumer bigger discounts the better he/she follows the suppliers 'wishes' about times of demand and supply.	Proposals for institutions in order to increase total social welfare, meaning an acceptable institutional design for concerned actors and the broader environment such as politicians. Example: a version of net merting that takes the time value of electricity into account. And/or ex post design of structures to mitigate distributional conflicts between for example DSO and supplier over transport costs for the 'net metered' kWh's

From this table it becomes clear that, although it has a single transaction as unit of analysis, the transaction cost approach provided a holistic market analysis and served as a basis for a market design that incorporated conceptual forms of property rights and principal agent structures. Agency theory and property rights theory analyse (and for this research) design more detailed structures, focused on a specific feature of the contract (aligning incentives for agency theory and rules of ownership, use et cetera for property rights theory). This could be a very valuable addition to this research.

10.6 Generalizability of results

In the introduction, this research quickly scoped to PV prosumers and their transactions in the Dutch electricity market. This paragraph will discuss the generalizability of the results as a consequence of this scoping.

10.6.1 Other decentralized energy sources

More sources of decentralized renewable energy that prosumers might use apart from PV are available today. This research focused on electricity from sunlight (and therewith took its small scale and volatility into account), but for the resulting market design options it does not matter what the exact source is; it could also be wind, micro CHP et cetera, because it concerns the same type of kwh's and therefore the same resulting transactions with the other actors in the system. At this point in time, they also make use of the same net metering mechanism.

10.6.2 Cooperative generation

When taking into account Cooperatives generating electricity from these same renewable energy sources, the market design options do not apply one on one. In this case innovative governance structures need to be designed (concerning taxes, transport and actual kWh's) that make it possible to connect the larger scale 'cooperative generation' to the location of the prosumer and the individual transactions of the prosumer with (in case of market design option 1 and 3) the supplier or with (in case of market design 2) the actors and resulting settlement in the competitive layer of the many to many framework.

10.6.3 Future growth

When private PV generation will grow more than the figures stated in the introduction (which were said to be no problem for the grid), or when growth would be significantly unbalanced (in certain streets, neighbourhoods, cities more than in others), or when we consider an even more long-term perspective instead of only 2020, PV generation might still become a problem. This research lacks the various scenarios just indicated and does not quantify the impact on the grid. Before implementing one of the proposed market design options or one of its variations this is an essential point of research.

10.6.4 Foreign markets

The Netherlands is not the only country that faces a changing electricity market and trying to find suiting market designs. The proposed market designs could also be of use for other countries, but it should be taken into account that the starting point of these countries might be different. They might do not necessarily have net metering policies, but variations on net metering or other stimulation policies. The current institutional structure and contractual arrangements within the market might be different and can lead to necessary small or large adjustments of the proposed market design options.

11. Reflection

The reflection consists of two distinct parts: a reflection on the research itself and a more personal reflection from the researcher on the graduation process.

11.1 Reflection on research

This section reflects on the research process and on choices concerning scoping, methods, theory, the design process and the resulting options.

11.1.1 Choice of research and scoping

From the initial conversations about the subject with members of the graduation committee, I realized that, even with the focus on prosumers producing from 'the other side of the market', the system was so complex that scoping would be the first priority. This realization and resulting focus gave me a head start: I could immediately explore the system with the right perspective. I in my opinion it has been good that the scope was set narrow in the beginning because it provided the opportunity to broaden the scope during the research (towards market design options that concern the market as a whole) without making the research too complex.

11.1.2 Methods

The research approach provided excellent guidance and structure. In a logical way it combined theory, desk research and field research. The only struggle was the field research, since it had an indirect influence on other parts of the research as well, where it was not intended to have this influence in the approach. The actor interviews had started quite early on in the research and the problems and ideas mentioned by the actors already had an impact on the introduction and on choices in the design space. While 'officially' they would not have this impact because the field research should have been done later in the process. This research could only be executed in a limited amount of time and planning issues were on the basis of this intertwining of the field research and earlier parts of the research. To reduce this intertwining to a minimum, all problems and ideas that have been used early on, are also verified by means of desk research.

11.1.3 Use of theory

In my opinion, the strong point of this research is the interconnection between theory and practice. These are not two stand-alone parts, but are intertwined throughout the whole research. This was possible because of the excellent applicability of Transaction cost theory to the subject of this research, and the repeated use in different part of the report. Not only is the theory explained and then applied in the problem analysis, the theory was also the basis for creating the design space, with practical means specifically applicable to the attributes and the intended direction of change. Then the practical means were combined to market design options, which were evaluated using the same theory centred approach focusing on the impact of the market design options on the attributes.

11.1.4 Design process and options

A difficult step within this research was to structure and combine the complex design space into logical market design options. First the means were structured in two governance arrangements, one on the technical part of the system, the other on the contractual arrangements. It has been difficult to get a grip on the complexity and clearly see the division in those two arrangements. However, when this analytical stage was passed (by means of discussions, drawings et cetera), everything fell into place.

Then the technical and contractual arrangements needed to be logically combined. This could be done in four (contractual arrangements) times three (control of demand side management) times two (location of storage) equals 24 combinations, let alone the hybrid forms in between. The choice for the three market design options is made on the basis of the logical combination of arrangements into market design options and the mutual complementing of the arrangements within the options, as well as the extremity in between the three designs. Further research should clarify if hybrid options are more suited for the Dutch electricity market, on the basis of more selection criteria than only the impact on problems and the field research (see also paragraph 10.2).

11.2 Personal reflection

This section explains about personal struggles and wins. It illustrates what the important personal insights in the process of the research have been.

11.2.1 Team work

This research project made me realize how much value working in a team has. Discussions on how to attack the various sides of a research project give fresh insights or confirmation and motivates to continue and deliver within agreed deadlines. This research project was not only bigger than ever before, the team to execute it with was also missing. I struggled with this in the first period of the research, but was then able to set strict deadlines for myself as well and asked for support and feedback from the people around me more often.

11.2.2 People management

From the acknowledgements in the beginning of this report it becomes clear that many people were involved in this research. It has been difficult to manage all those actors, but it has also been a lot of fun to have a lot of people involved and interested in the research. I have not experienced this as a barrier. In hindsight I would ask for help and guidance from the supervisors earlier and more often and I would (when more time was available) interview more actors and take more time for the interviews, to collect all their important and interesting insights and ideas. But after all this has worked out fine.

11.2.3 Research approach

The determination of the structured research approach early on in the research, and in general lines sticking to it to the end (with fine tuning it repeatedly), feels like the most important part of this research. It resulted in clear to-do's and logical story lines. I am convinced that without this early determination, I would have been vulnerable to major delays, because I know that a lack of structure causes me to block.

11.3.4 Internship

Another important point is the execution of this research within an internship. This has given me strong motivation to deliver an excellent graduation project and it provided me with a good working schedule. Moreover, Innopay's interesting and interested colleagues kept me motivated and enthusiastic about this research and Innopay has given me a lot of room to decide on the direction of the research. This gave me the opportunity to dive into subjects that interest me and combine them with an academic point of view.

11.3.5 Use of theory

The use of theory's to analyse a real-life case is not my strongest point. I find it difficult to think conceptually and I have the habit to dive into practical operationalization immediately. The strong guidance of Transaction cost theory forced me to go out of my comfort zone to learn about the theory and apply it. I feel that throughout this research I have become better in understanding and applying the right theories in the right way and also making choices when not to apply, or further apply, certain theories.

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ATTACHMENTS

A. INTERVIEWS
B. EXISTING DUTCH INITIATIVES
C. OPTION SELECTION
D. LIST OF FIGURES
E. LIST OF TABLES

A. INTERVIEWS

A1 Interview respondents

As was explained in chapter 2, the actors for the interviews were chosen because they correspond to the actors concerned with PV prosumers (chapter 7), or because they have knowledge of or interest in the subject. For some sectors, interviews have been conducted with more than one actor (DSO's, Suppliers and Experts) because the opinions within the actor group vary significantly.

Table 37: Interviewed actors

Which actor?	From?	Who?	Referred to as…
Government	ACM	Machiel Mulder	Interview A
	Ministry of Economic Affairs	Mark Streefkerk	Interview B
TSO/DSO's	Tennet	Erik van der Hoofd	Interview C
	Netbeheer Nederland	Martijn Boelhouwer	Interview D
	Alliander	Martijn Bongearts	Interview D
	Enexis	Roelof Dijkstra	Interview F
Producers/ Providers	Energie-Nederland	Ineke van Ingen	Interview G
	Nuon	Jochem van de Hoofden	Interview H
	Qurrent	Denis Slieker	Interview I
	Greenchoice	Sierk Hennes	Interview J
	Essent	Erik Woittiez	Interview K
	Eneco	Floor Hooijman	Interview L
Experts	ECN	Michiel Hekkenberg	Interview M
	Quintel	John Kerkhoven	Interview N
	Pluk de zon	Joost de Valk	Interview O
Interest groups	Holland Solar	Erik Lysen	Interview P
Political parties	CDA (no interview)	Visie lokale energie 2014	CDA, 2014

A2 Interview questions

The interviews with the actors concerned with prosumers in the Dutch electricity system followed a clear structure, to come to the issues with the current configuration of the market, and functions and constraints of a future market configuration. All interviews resembled more with interesting conversations about the subject, than with strictly structured question posing. During the interviews it was checked whether all questions were answered already, and if not, only the remaining questions were posed. First the introduction of the interviews is stated, followed by the questions and the follow up. All respondents spoke Dutch, therefore the next section is in Dutch.

Introduction of research (in Dutch)

Dit afstudeeronderzoek gaat over het huidige model waarin prosumers hun opgewekte electriciteit salderen met hun verbruik, en het systeem hieromheen. Op dit moment is er onzekerheid over de toekomst van deze constructie door de uitspraken die minister Kamp hierover heeft gedaan. Dit wil ik aangrijpen om het huidige systeem onder de loep te nemen en met de betrokken actoren te bespreken of het huidige model voor de lange termijn haalbaar blijft, en wat een eventuele toekomstige verandering van het model en de verhoudingen in de markt wat betreft terugleveren zouden kunnen zijn.

Interview questions

1. Introductie, waar staat het bedrijf, wat doet de geinterviewde
2. Is er een duidelijk probleem met het huidige systeem?
3. Hoe ziet een nieuw systeem eruit? Wat is hierin belangrijk en mogelijk?

4. Wat zou een nieuw systeem mogelijk moeten maken? Wat moet het kunnen uitvoeren, verwerken, hoe moet het functioneren etc?
5. Waar moet zo'n nieuw systeem minimaal aan voldoen? Welke beperkingen zijn er? Wat moet er vermeden worden?

Follow up

- What other research can you recommend me to follow up on?
- Who could give me a relevant view on this subject? New contacts?
- I will sent the worked out interview within a few days to you by e-mail, would you please verify the information, correct it and complete it where needed?

A3 Interview results

For each interview a report is written, which is verified and approved by the interviewee. Then the functional requirements and the non-functional requirements were filtered out of the interview reports.

Functional requirements

The functional requirements of the future system concerning prosumers are derived from the answers to three questions:

1) What do you think of the current system configuration of electricity market concerning prosumers? – many answers came down to: "I think that the current system does not perform X and X, which it should" (functional requirement) or "I think that the current system is not enough Y" (non-functional requirement).
2) What do you expect of a future system configuration? – from the answers to this question both functional as non-functional requirements were gathered.
3) What functions should the system perform? – this was asked so directly to avoid forgetting important functions that did not come out naturally in question 1 and 2.

Functional requirements		Flexibility	Efficiency incentive	System connection and control	Predictability	Room for experimentation	Smart	Back up within market	Many to many
Government	ACM		X						
	Min EZ	X	X			X			
Facilitators	Tennet	X		X					
	Netbeheer NL	X				X			
	Enexis		X						
	Alliander		X						
Suppliers	Nuon	X		X	X				
	Energie Nederland				X	X			
	Greenchoice				X				
	Essent	X	X	X				X	
	Qurrent								
	Eneco			X				X	X
Experts and interest-groups	ECN			X	X	X	X		
	Pluk de Zon								
	Quintell								
	CDA (vision document)						X		
	Holland Solar								
Total		5	5	5	4	4	2	2	1

Figure 31: Source of functional requirements

The overview above shows the functional requirements, ordered left to right according to how many times they were mentioned by the actors, and color coded into three groups indicating categories of decreasing importance for the selection procedure in chapter 8. The last requirement, ‘many to many’, will not be taken further into consideration because it was mentioned by only one actor. The following table explains all the terms in the table.

Table 38: Description of functional requirements

FUNCTIONAL REQUIREMENTS	
Trade many to many	The generated electricity can be sold and ‘delivered’ to a variety of takers, private and commercial. *Only indicated by one actor, therefore not be taken into consideration.*
Work with dynamic prices	Consumers do not pay uniform price for 1 kWh at every point in time, but pay a time-dependent tariff, icentifying smart electricity use
Provide flexible demand and supply	The supply and demand within the system must be flexible to make a cost efficient match of demand and supply.
Incorporate an efficiency incentive	The market must provide an incentive to generate and use electricity efficiently.
Have connection & control within system	The region, the neighbourhood, the street, the household and the applications within the household must be part of a connected system and controlled as a system.
Act as a predictable system	The flows in the system must be predictable to be able to keep the system stable and make efficient use of available capacity.
Provide room for experimentation	Regulations and policies should leave room for experimentation.
Ensure profitability of large generators	Large generation facilities should be profitable because they are still needed in the near future when there is no supply of renewables and storage is not sufficient.
Facilitate demand side management	Not only supply can be adjusted to the demand at a certain point in time. Demand should also be able to adjust to supply
Act as a smart system	Electricity should be smart by using a layer of ICT over the physical network, so it can automatically adjust supply and demand.
Trade back up within market	Back up capacity should not be an unconditional right provided by regulated bodies, but traded for its value in the market.

Non functional requirements

The same is done for the non-functional requirements or constraints. They are filtered out of question 1 and 2 (see above) and the fourth question: What should be avoided?

Non functional requirements		Sustainability	Profitability	Free market	Transparancy	Understanding of system by actors	Budget neutrality	Processability	Network stability	Fairness of tariffs	Affordability	Availability	Responsibility	Security	Longterm security of policy
Overheden	ACM			X	X	X									
	Min EZ	X				X	X								X
Facilitators	Tennet					X			X				X		
	Netbeheer NL														X
	Enexis			X					X					X	X
	Alliander			X			X	X							
Suppliers	Nuon		X		X										
	Energie Nederland	X	X	X	X						X	X			
	Greenchoice	X	X												X
	Essent	X	X	X											
	Qurrent		X	X	X					X	X				X
	Eneco	X													X
Experts and interest-groups	ECN	X		X				X							
	Pluk de Zon	X			X	X									X
	Quintell	X	X			X	X	X	X						X
	CDA (vision document)	X	X		X										X
	Holland Solar	X	X				X			X					X
Total		10	8	7	6	5	4	3	3	2	2	1	1	1	10

Figure 32: Source of non functional requirements

The figure uses the same procedure as with the functional requirements; ordered according to the frequency of them being mentioned by the actors and colour coded into three groups indicated decreasing importance for the chapter of option selection. The last requirement ('Long-term security of policy') will not be taken further because paragraph 5.1.2 explained that it is outside the scope. The three requirements that were mentioned only once will also not be taken further. The next table explains all the terms.

Table 39: Description of non-functional requirements

NON-FUNCTIONAL REQUIREMENTS	
Sustainability	The sustainable 20/20/20 goals must be achieved (concerning production, energy-efficiency and exhaust).
Profitability	The production of renewable energy must be profitable for big and small producers
Availability	Electricity must be available at all times for everybody. *Only indicated by one actor, therefore not be taken into consideration.*
Affordability	Electricity must be affordable at all times for everybody.
Network stability	The electricity network must be stable in terms of matching demand and supply at all times.
Budget neutrality	Policies, regulations, subsidies et cetera must be neutral in their budget.
Process ability of data	The data generated and needed by the system must be processable taking into account time, money and ICT performance limits.
Free market	The market must be free of disturbances and open to actors reacting to market incentives.
Transparency	The functioning and dynamics of the system must be transparent for all actors.
Long-term security of policy	Policies concerning renewable energy and prosumers must be clear, long term and reliable. *Out of scope (paragraph 5.1.2).*
Responsibility	All power flows must fall under an actors' formal responsibility (program responsibility). *Only indicated by one actor, therefore not be taken into consideration.*
Security	The system must be robust to hacking and may not show disturbances or failures. *Only indicated by one actor, therefore not be taken into consideration.*
Fairness of tariffs	Tariffs should be based on actual use and take into account sustainability
Understanding of system by actors	All actors must be able to understand the dynamics of the system in order to behave efficiently within it.

B. Existing Dutch initiatives

In the next table the existing initiatives to find answers to the problems arising as a result of the transitioning Dutch electricity sector are described.

In the second table, the same five initiatives are classified using the means proposed in chapter 5 and in the same table it becomes clear that those existing Dutch initiatives have a limited impact on the problems indicated in chapter 4; mostly they focus on one or two sole attributes using one or two means, instead of taking on a system perspective and tackling multiple attributes.

Table 40: Explanation of existing Dutch initiatives

	What?	Who?
1 ASC Powermatcher	Powermatcher agents are installed inside household appliances and help the consumer to optimize their electricity system by automatically taking into account the electricity price in the decision to turn an appliance off or on. Examples are the fridge, freezer, EV's, and electricity generation systems such as solar panels and micro CHP. Thus, ASC powermatcher intervenes automatically to have an impact on demand (Liander, 2010).	Liander
2 Jouw energiemoment	Test in Zwolle and Breda to explore the flexibility of consumers and prosumers concerning electricity use, using a smart appliance (Wendy) that 'negotiates' with the supplier about tariffs and time of use. The Wendy appliance communicates to consumers and prosumers when to use their household devices in order to consume cheapest and/or use green electricity. Thus, Jouw energiemoment counts on changing consumers behaviour and its impact on demand and does not intervene automatically (Flexicontrol, 2014; Jouwenergiemoment, 2014)	Enexis, Greenchoice, Flexicontrol Eneco, e.a.
3 USEF	Sustainable ICT framework offering flexible market access with maximum freedom to all participants and addressing privacy and security issues that may arise both now and in the future. The framework describes roles, responsibilities and tasks, and the basics of new possible services and the underlying processes and contracts. Prosumers can trade with an aggregator who works with a Program responsible party, DSO and ESCo's. (USEF, 2014).	Essent, Alliander, IBM, ABB, Stedin, e.a.
4 Energymanager	Software (now) only for horticulture that takes into account multiple factors (predicted consumption, weather, energy prices) and chooses the most lucrative options to buy, generate and trade electricity (buy gas or electricity, generate electricity, combined heat producing, et cetera). Possibility to trade automatically or with intervention of prosumer (Houtekamer, 2014).	Agro Energy / Eneco
5 Smart storage	Test in Etten Leur to store electricity on district level operated by the DSO (Enexis, 2013).	Enexis, Alliander, TNO

Table 41: Classification according to means and impact of existing Dutch initiatives

	Means used	Impact on attributes	Impact on problems
1 ASC Power-matcher	• Demand side management (automatically controlled) • Market pricing for surplus electricity	• Reduced uncertainty • Increased incentive intensity	• Demand is more predictable and flexible • Incentive for prosumer to match demand & supply
2 Jouw energie-moment	• Demand side management (consumer controlled) • Market pricing for surplus electricity	• Reduced uncertainty • Increased incentive intensity	• Demand is more predictable and flexible • Incentive for prosumer to match demand & supply
3 USEF	Framework could make use of multiple proposed means, but a concrete configuration of USEF is not available yet.	When combined optimally, all attributes could be optimized.	Impossible to define yet.
4 Energy-manager	• Demand side management (consumer controlled or automatically) • Supply steering	• Reduced asset specificity • Reduced uncertainty • Increased incentive intensity	• Demand and supply more flexible and predictable
5 Smart storage	• Storage	• Reduced asset specificity	• Electricity is less temporal specific, it can be used at a later point in time

C. OPTION SELECTION

C1 Motivation of colour coding

The following tables contain the motivation for the colour coding of the attributes of the design options in chapter 8.

Table 42: Motivation of score market design 1

MARKET DESIGN 1: IT'S ALL IN THE BUNDLE		Result
Asset specificity	Temporal specificity brought down by storage, lease of panels and storage within bundle reduce investment risk for prosumers resulting from asset specificity, but investment risk resulting from asset specificity of suppliers is not reduced. (Capacity payment in bundle is a possibility but left aside because of the European capacity market discussion)	+
Uncertainty	Inelastic demand is made elastic by real time pricing, but still demand is a bit uncertain; there is no automatic control over demand. Supply is made less uncertain by means of storage and an automatic mechanism to regulate it.	+
Frequency	Stays approximately the same – transactions are grouped into a limited amount of transactions (monthly bills) with the same supplier	+
Contract law regime	Choice in bundle components reduces risk imbalance somewhat, but contract is still with only one supplier, making the prosumer dependent from this one party.	+/-
Administrative control	Contract with one supplier keeps administrative control at acceptable level, although the different bundle components (working with smart data) may cause complexity in the contract and control.	+/-
Incentive intensity	Real time pricing provide incentive to prosumers to adjust demand. Capacity payment may be included as a bundle component, increasing incentive intensity for suppliers.	++

Table 43: Motivation of score market design 2

MARKET DESIGN 2: ONE FOR ALL, ALL FOR ONE		Result
Asset specificity	Asset specificity of supplier and prosumers is not brought down. Temporal specificity is reduced by neighbourhood storage, thus to store surplus electricity locally and take away the time dependency of supply.	+/-
Uncertainty	Semi-automatic demand side management makes demand less uncertain, and supply is steered by means of storage on the level of the neighbourhood and DSO controlled for the whole neighbourhood, making supply on the neighbourhood level very predictable. .	++
Frequency	High, many separate transactions with different actors.	--
Contract law regime	Prosumer is not dependent from one supplier anymore; risk is more balanced.	++
Administrative control	Many to many trade brings about high administrative control for what kWh needs to be billed where and the control of smart data analysis.	--
Incentive intensity	Semi-automatic demand side management on the basis of real time pricing results in increased incentive intensity.	+

Table 44: Motivation of score market design 3

MARKET DESIGN 3: TODAY AND BEYOND		Result
Asset specificity	Storage takes away temporal specificity, but asset specificity of the investments of suppliers is not reduced, that of prosumers could be, by the lease of the solar panels.	+
Uncertainty	Automatic control of demand and supply by the DSO takes away uncertainty	++
Frequency	Stays the same – all transactions are grouped into one yearly transaction with the same supplier.	++
Contract law regime	Contract is still with only one supplier, making the prosumer dependent from this one party.	-
Administrative control	Contract with one supplier keeps administrative control at acceptable level	+
Incentive intensity	Automatically controlling aspects of demand and supply by the DSO gives no efficiency incentives to prosumers.	--

D. LIST OF FIGURES

E. List of tables