MSc. Thesis

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An analysis of the effect of regulation, investment uncertainty and actor network on the investment behaviour of Dutch distribution system operators.

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Executive Summary

This thesis represents the culmination of six months of research into the investment behavior of Dutch DSO's in the context of the energy transition. In the past few years the Dutch distribution grid has experienced increasing levels of congestion in relatively rural areas, which is mostly attributed to the growth of distributed renewable generation projects that are being developed in these areas. The problem has grown by such a margin that it has become a main topic of discussion within the Dutch parliament as far as climate and energy policy is concerned. Solving these problems requires structural grid reinforcement at choke points, along with legal and regulatory changes in the governance of the Dutch distribution system and the development of detailed regional plans for energy assets, according to the ministry of economic affairs. Given that these solutions all lead to a substantial increase in investment levels in the grid, this thesis investigates the effect of the actor network relations, regulation and investment uncertainty on the investment behavior of the Dutch distribution system operators (DSO's). These topics are evaluated using the following main research question:

"How do the factors of regulatory regime, investment uncertainty and actor-network affect the investment behavior of Dutch distribution system operators in a period of energy transition?"

By finding an adequate answer to the above question, this research can help future researchers in further case-studies of the Dutch distribution grid, as well as serve as a basis for policy-makers that require deeper understanding of the congestion-problem on the grid.

Research Set-up: Theory and Methods

This thesis uses theory from two fields of research in particular: "*Regulation of monopolies (In the power sector (Gómez, 2013; Correlje et al., 2012))*" and "*Principal-agent theory (With a multiple principal/agent perspective (Waterman and Meier, 1998; Hancher et al., 2008))*". Using these theories, I analyze the Dutch distribution system from two different angles. Firstly, I use both theories to make a qualitative analysis of the actor network, and its effects on DSO behavior. This analyses is supported through open-ended interviews with experts from the field, and through the careful examination of public documents made available by parties such as the ACM (Autoriteit Consument & Markt, the Dutch regulator). Secondly, I use the annual reports provided by the Dutch DSO's to make a quantitative financial assessment of their investment behavior. The results from this financial analysis are used throughout the thesis in support of the qualitative findings.

Effects of the actor network

Some of the actors have a more clear and more profound effect on the investment behavior of the distribution system operators than others, but the most important takeaway from the analysis of the actor network is the importance of goal alignment. The analyses has shown that mismatched goals cause the DSO's to be caught between two or more principals that want different things (efficiency, climate-focused investing). The following effects were observed in this thesis:

- From the governance level actors, there is a clear push towards realizing the energy transition by sticking to the goals set in the climate agreement (Rijksoverheid, 2019b), whereas the regulator is mainly advocating efficiency, as it has been doing since the introduction of the current regulatory regime. Given that these actors have a significant amount of influence regarding the DSO's (Both are main principals using the DSO as an agent), this "tug-of-interests" is causing the DSO's to be trapped between two directions that both need to be adhered to.
- The relationships with other actors in the network have smaller effects, with regional differences occurring due to for example municipality size. Furthermore, shareholdership of the municipalities was also investigated, but no evidence was found that dividend payouts are hindering the investment rates.

- Lastly, the relationship between the DSO's and the energy producers is of high importance due to the fact that the energy producers are the "adversary" of the DSO with regards to congestion (new assets increase the capacity demand). This relationship is deteriorating as a result of the tug-of-interests, whilst both parties would benefit enormously from a more centrally coordinated effort. Eliminating the investment uncertainty that is caused by the quick development procedures for renewable assets needs to be a part of this.

Regulation in some more detail

The regulatory regime in the Netherlands is one of the major factors with regards to effect on investment behavior. This is mainly due to the strong efficiency incentives that are in place within the current system. This system has not substantially changed over the past decade, whilst the surrounding system is in a state a great change due to the energy transition. Assessment of the discussions between the relevant parties, and the results of the interviews have shown the following:

- There is a clear awareness among the actors that the regulatory system is affecting the investments made by the DSO's, but there is also an appreciation of the effectiveness of the current system with regards to efficiency. Due to this fact, the actors are trying to solve the problems within the bounds of the current system, meaning that the goal mismatch does not seem to be solvable through regulation in the coming regulatory period (starting in 2022).
- One of the options for changing the regulatory system is the introduction of some cost-based elements that give the DSO's some breathing room with regards to efficiency directives. These elements would only be used for investments directly pertaining to the energy transition, and the idea is that these elements also need not be permanent.

Under the current regulatory regime, the DSO is a careful, risk-averse investor, and this does not seem to be changing with respect to the coming regulatory period. Solutions outside of regulation are also needed, and the most mentioned one is the reduction of investment uncertainty.

Investment uncertainty and its effects

Investment uncertainty is mainly caused by the relatively quick development of renewable assets, that have much shorter licensing and development cycles than grid expansions. Because the DSO's are risk-averse investors that will wait until investments are near-certain to have sufficient returns, this uncertainty can be seen as a major cause for the current grid congestion.

Solving the investment uncertainty problem requires more central coordination and clearer spatial planning, and one of the possible solutions can be found in the regional energy strategies (RES). These documents seem to contain the necessary information needed to reduce the investment uncertainty sufficiently enough to allow for earlier DSO investments. However, the documents and programs are still in their infancy and need to be quickly developed and centrally orchestrated if they are to succeed in this role.

Conclusions

Through a combination of interviews, analyses of annual reports and a qualitative analyses based on principal-agent theory, I tried to find the effect of the actor network, regulatory regime and investment uncertainty on the investment behavior of the DSO's. I found that there exists a misalignment of goals within the DSO actor network, with government principals pushing towards realization of the energy transition, whilst the regulator is still mainly advocating efficiency incentives. Because the regulator is in a rather dominant position with respect to the DSO's, these efficiency incentives are causing mainly risk-averse, or tentative, investment behavior. Solving the investment problem requires a change that can be found in two directions, regulation or by tackling the investment risk through a reduction of uncertainty. In my research, I found that the notion of changing the regulation substantially is not viewed as a particularly realistic solution, with parties strongly preferring to keep the current system in place and tweak it as necessary. Therefore, the current solutions target the reduction of uncertainty through the creation of programs such as the regional energy strategies. Less investment uncertainty leads to higher, and easier DSO investments and can serve as a key solution to the congestion problems. By creating a more centrally coordinated approach to the development of renewable energy infrastructure, through programs such as the regional energy strategies, a more open forum of information can be created that could allow the DSO's to make the required additional investments within the bounds of the current system. In the end, this thesis shows how the combination of the uncertain investment climate and the regulatory influences has created a system with very little room to manoeuvre for the Dutch DSO, but that they are actively trying to work on solutions within the bounds of the system.

Preface

This thesis is culmination of a long period of desk-based research done in a time where everything went a bit differently. Writing a thesis during a time of a global pandemic is not something you expect at the start of your academic career at the university, but it is something that happened nonetheless. Even though the set-up of the research had to change a bit to accommodate this, using video interviews instead of live interviews for example, in the end I believe I managed to produce something that I can be proud of.

Over the course of the past year I have wondered what the area of research would be where I would focus my own research efforts, and write the culminating piece of my Master's degree. I knew that I was interested in the sector of energy and the accompanying transition through an internship done at Energie Nederland in the summer of 2019, and as a result I chose to follow a selection of relevant courses to specialise in this field. In particular, the course Electricity & Gas: Market Design and Policy Issues really peaked my interest, and I decided that I would like to do a research piece in this field. In the end, the focus area became the DSO due to the prevalence of problems surrounding the national grid infrastructure, something that I had already noticed during my internship in 2019, and that I became more acutely aware of at the start of 2020.

During my time as a student, I have worked on a multitude of topics, and the start here at the TU Delft as an aerospace engineering student has given me both a thorough understanding of very complex machines, but also a love for complex problems. In the end of my Bachelor's program, I decided that what I really wanted was to broaden my horizon, choosing the Management of Technology program as my Master's direction.

Here I developed a certain appreciation for overly complex, national or international systems such as infrastructure works and energy systems, and this thesis is the culmination of those interests and experiences.

In the end, I would like to deeply thank everyone who has supported me throughout this process, and a few people in particular. Firstly, I would like to thank my friends, family and girlfriend for supporting me throughout the tough times of writing a thesis whilst also being in a situation of partial lockdown. Their support has kept me going throughout the process. Next, I would like to thank my first supervisor and chair, Aad Correljé, for his insights and feedback during the process, and answering the many questions I had during the final couple of months. I also would like to thank my second supervisor, Udo Pesch, for his valuable insights and feedback. Lastly, I would like to thank a few people that helped shape the research in terms of content, my interviewees Huub Halsema, André Jurjus and Paul van Engelen.

I wish you a good read of this thesis.

Lucas C. Kluiters
Delft, Oktober 2020

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1
Introduction

In June of 2019 the Dutch government reached an agreement on how to proceed with the goal of substantial emission reduction. In this climate agreement Rijksoverheid (2019b), one of the key pillars is a system-wide change in energy production, shifting the sector from a coal- and gas-based system focused on large production plants to a sector based on multiple renewable alternatives. Because these renewable alternatives are not a direct substitute for the old generation plants, the electricity grid, which was designed with these high-capacity plants in mind, also requires a system-wide adaptation. These changes have to be implemented through the making of substantial grid investments by the current owners and operators of the grid, the transmission system operator (TSO) and the distribution system operators (DSO's). However, making the required investments is not a case of simply reinforcing the grid wherever possible, given that grid operating firms are subject to a strict system of regulation that requires them to make efficient investments.

This thesis aims to evaluate the investment behavior of the Dutch DSO's within this context of an energy transition. Given the key role that the national grids play in the realization of transition policies, and the recent emergence of substantial problems regarding congested local grids (Wiebes, 2019), the research done in this thesis aims to shed light on the influencing, and prohibiting factors of DSO grid investment. This introductory chapter contains a description of the background problems and concepts, details the specific research objectives and research questions, and explains the scope and limitations of this thesis.

Investment in the distribution grid - Background

At the end of February 2020 the larger Dutch DSO's made a call to attention to the fact that they require a substantial increase in financial capital to accommodate the next 10 years of operation and investment (van der Walle, 2020). These investments are required because the Dutch electricity distribution grid is in a state of increasing stress due to the lack of capacity to connect new clients, both from the supply side (Mostly renewable and distributed generation projects) and the demand side (data centers and other customers with a large demand for transport capacity). In order to solve this capacity problem, the grid requires a substantial investment in grid reinforcement and new grid management systems, in the order of 30 billion euros for the largest 3 of the Dutch DSO's, according to Mark van der Linden, CEO at Stedin Groep (van der Walle, 2020).

The existence of capacity problems in the Dutch electricity grid have been acknowledged and discussed in the Dutch parliament over the last two years. According to the former director of the trade association for Dutch TSO's and DSO's, André Jurjus, this increase in awareness is one of the more fortuitous results of years of hard work [Appendix section B.2, p. 101]. It means that solving the grid capacity problems has become a prominent item on the political agenda, and especially so at the ministry of economic affairs and climate (EZK). If one takes a brief look at the ministerial letter to parliament concerning this specific topic, we can identify both a direction and tone with regards to the problems and their possible solutions (Wiebes, 2019). The minister starts with a clear statement of awareness of the problem, mentioning the substantial grid reinforcement that is currently being planned by the DSO's, but also mentioning the fact that the demand for transport capacity is outpacing the this grid reinforcement rate. In other words, the networks are getting congested due to the incapability of the DSO's to reach the required growth rate through new investments.

One of the key issues mentioned by the minister in his letter is the procedure of constructing new grid infrastructure, and the comparatively quick procedure of developing new distributed generation projects. Grid projects, such as a new substation, require a lengthy procedure of approval, including some degree of civilian participation. This lengthy development track was also mentioned during one of the interviews conducted for this thesis, where a Liander portfolio manager mentions the long process of developing a new substation within the Haarlemmermeer-polder [Appendix section B.3, p. 101]. Because of these lengthy procedure, having a solid regional or municipal development plan with regards to renewable generation projects is needed in order for the DSO's to start investment procedures in a timely fashion. In his letter, the minister mentions that these development plans did exist for inland wind-parks, but solar projects did not have a similar supporting documents, or that these documents have only very recently been drafted.

Given that the goals of the energy transition are ambitious, and will keep increasing the demand for transport capacity on the electricity grid, solving the problems of underinvestment and limited grid capacity is one of the major early challenges in the transition period. In his letter Wiebes (2019), the minister mentions long term solution directions and short term solution directions:

1. **Grid reinforcement at choke-points** *(Long Term)* - Strengthening the grid where necessary is the best long term solution for solving grid capacity problems. The minister explicitly mentions the provinces of Groningen and Drenthe, but this can be extrapolated to areas that are close to becoming a choke-point. Current congestion is a strong indicator for investment locations, but because the development procedures take years, the first of the new HV-stations and substation are expected around 2028.

2. **Changing laws and regulations** *(Long Term)* - According to the ministry, the current set of laws and regulations has not been designed for dealing with transport capacity issues. Therefore, new laws and regulations are needed to give the DSO's more room to anticipate new developments.

3. **Adjusting SDE+ subsidy procedures** *(Long Term)* - The current procedure for obtaining SDE+ (Subsidie Duurzame Energie [*Subsidies Renewable Energy*]) do not take into account lack of transport capacity in the area where a particular project is to be realized. By changing the subsidy procedure to prefer projects in areas where capacity is available, the growth of transport capacity demand can be covered more easily by the TSO and the DSO's.

4. **Renewable Energy Strategies (RES) and regional government policies** *(Long Term)* - RES documents contain a lot of the needed development plans for renewable projects, and can help prevent transport capacity issues in the future. The involvement of regional (provincial or a combination of several municipalities) government levels allows for a more localized approach to grid reinforcement.

5. **Use of congestion management** *(Short Term)* - Using congestion management tools is a solution to cover some degree of lack of transport capacity, and the DSO's need to employ these tools where possible to lighten the load on the congested grid.

6. **Changing coding structures for congestion management** *(Short Term)* - Some of the codes that DSO's have to follow when employing grid congestion management tools are not updated to the current situation of transport capacity issues. Changing these codes to accommodate this new reality should make the use of congestion management easier.

From this list of solutions, this thesis focuses on the long term options and the capability of the DSO to invest where it is needed. Looking at the list of solution offered by the minister, the true, structural solution can be found in grid reinforcement. However, in order to accomplish this, the DSO's need to have an enabling context that allows them to make the needed investments. Changes in laws and regulations, changes in subsidy procedures and making better regional plans are some of the factors that create this enabling context, but the details of this context are still vague. In this research, I will show how the current context is influencing the investment behavior of the DSO, and I will present some suggestions for improving this context for the coming period in the transition. In a sense, a goal here is to provide some more substance to the solutions mentioned by the minister.

One of the most important factors determining DSO investment behavior is the regulatory framework in which they have to operate and plan new expansions. This regulatory framework is a subject of interest in research, due to the possibility of creating a more enabling version of a similar framework. Considering the challenges of regulating the sector, one of the most distinguished authors in the field, Pérez-Arriaga (2013) has identified some key issues regarding the wider sector as a whole.

Firstly, he mentions the fact that the regulatory system needs to adapt to the reality of new sustainable energy. The current system, first adapted on a widespread basis during the years of liberalization in the 1990's, is built upon two foundational principles: efficiency and security of supply. Within the new system, sustainability is a required third principle. Adding this principle creates new questions however, namely in the form of what the specific role of the regulator should be. As in, in what way should a regulator be a driving force in the realization of renewable energy goals set by energy transition policy.

Secondly, Pérez-Arriaga describes how this new energy reality creates a challenge in the classical dilemma of regulation: Market forces versus government intervention. What kind of developments can be left to market forces, and where should governments intervene because leaving something to the market leads to non-satisfactory results. Here, he mentions the importance of considering the limitations of energy markets. Whereas the effectiveness of market forces to create an efficient allocation of resources is well known, dealing with uncertainty and long term plans is not something easily solved.

With regards to the distribution network in particular, he mentions the challenge of adapting the regulatory system in such a way that it supports the level of large-scale investments needed for the transition. The system of regulation implemented in the 1990's targets efficiency most of all, and has mostly caused DSO's to reduce their cost substantially over the last two decades. This system has worked well, especially in the Netherlands where we enjoy a very high quality of service and comparatively low consumer prices. In that sense, it is important to understand that the current system of regulation is considered to be a very effective tool by both the regulator and the DSO's themselves. It is within this valued system that environmental sustainability needs to take a major role, and figuring out how that role can be translated to a regulatory framework is one of the key challenges.

Returning to the long term solutions offered by the minister, the creation of detailed energy strategies is seen as one of the major tools needed to enable the DSO's to make investments in anticipation of major renewable energy projects. What is less clear however, is how these plans will impact investment from the DSO perspective. What kind of content do the DSO's need for an adequate investment signal is a question that requires some more investigation, bringing us to the general problem that is central to this thesis.

Exploring DSO investment behavior - Problem Statement

Exploring firm investment behavior is a common topic in economic and financial research fields, where the authors often look at a specific type of firm or firms under a particular set of rules. Where investment behavior of DSO's is concerned, we find a few avenues of research that are actively being pursued.

First among these is research into the investment behavior of DSO's that fall under a particular scheme of regulation. A clear example of this is research into the effects of incentive regulation schemes, of which regimes that have recently experienced a change are of most interest. Cullmann and Nieswand (2016) analyze the investment behavior of German DSO's that have fallen under an incentive regulation scheme since 2009, and find that investments have increased since the implementation of incentive regulation. Furthermore, they also find that there is no explicit difference in the investment behavior of private firms versus public firms. Similarly, Poudineh and Zhang (2013) examine the same case in Norway, and find that under the Norwegian incentive scheme, more investments often lead to higher efficiency gains for DSO's. However, in a further study (Poudineh and Jamasb, 2016), they also find that in general, DSO's respond to investment incentives in the regulatory scheme, but that not all incentives are drivers of said investment. Also, they find that DSO investments are often "corrective" in nature, i.e. they fix flaws in the grid instead of preventing them.

In the same field, Nolting et al. (2019) study a more recent amendment of the German incentive scheme, and prove that some misleading incentives existed in the old-scheme that led to inefficient investments preferring to invest in regulatory base years. They also mention the yardstick competition incentive elements that have already been implemented in the Netherlands as an effective tool to further increase efficiency in future regulatory periods. Matschoss et al. (2019) however, also study the recent German regulation and find that although all grid integration projects were completed, a challenge remains in designing new incentives that consider the future, non-conventional grid expansion, in particular incentives that target the implementation of smarter grids that make DSO's incur higher costs. The authors also state that the German regulatory regime serves as a fine example of successful regulation of DSO's that have to accommodate large scale distributed generation. This last statement, however, is something that can be considered somewhat generalizing due to the differences that exist between the types of distributed generation that different countries try to integrate (Looking back at the Dutch case, the huge investments in solar photovoltaics are a much larger source of grid problems than in-land wind parks).

Next, some authors have also focused on the Dutch DSO's in particular, giving a good overview of the effect of the Dutch regulatory regime at that time. Haffner et al. (2010) determine that the Dutch regulatory system (incentive based) has encouraged a more professional and rational method of investing, finding no evidence of investment postponement or cancellations due to regulatory pressure. Mulder (2016) explores Dutch yardstick competition in the regulatory scheme and concludes that a yardstick system does foster efficient investments in making smarter grids. However, hindering elements exist in the case of different operational circumstances for the different DSO's, or when externalities influence investment behavior in a significant manner.

All of these studies, focus on determining the effect of the current system of regulation on investment behavior, or whether said investments are efficient or not. What is less studied in literature, is the question of how DSO investment behavior is determined by a combination of factors. What kind of factors make or break efficient investment, especially considering the investment challenge that has been issued by energy transition policy. Through the exploration of investment behavior of the Dutch DSO, one can determine in what way they are influenced by the regulatory regime, what kind of externalities have a significant effect on investment behavior. By exploring these types of questions, this research can help future policy-makers and researchers in understanding what drives DSO investment behavior.

In the end, DSO investment behavior is going to determine the structure and strength of the future grid. Whilst literature has explored the effect of certain regulatory regimes on this behavior to quite some extent, the way in which a variety of factors and externalities influence DSO investment is less clear. With this thesis, I aim to explore the general effect of investment uncertainty, regulatory regime and actor-network effects on DSO investment behavior in the Netherlands.

Research Questions

The specific questions used in this thesis to fulfill the research objectives have been based on observations made in the literature and news sources, and have experienced some adjustment during the execution of the research. To that end, the research questions used in this research are as follows:

Main research question: *"How do the factors of regulatory regime, investment uncertainty and actor-network affect the investment behavior of Dutch distribution system operators in a period of energy transition?"*

This main research question is then supported by the following research questions that focus on a particular topic:

Q1 - How is the current surrounding actor-network influencing investment decisions by Dutch DSO's?

Q2 - How have the Dutch DSO's invested in grid expansion over the past few years?

Q3 - How is the current regulation influencing investment behavior of Dutch distribution system operators?

Q4 - What kind of changes in regulation are needed to enable DSO's to invest more pro-actively?

Q5 - How is the investment uncertainty caused by new renewable projects affecting DSO investment behavior?

Q6 - How can the regional energy strategies be used to reduce investment uncertainty?

All of these questions contain a component of investment and most of the questions have a DSO behavioral theme. Therefore, in this thesis I opted to use financial analysis to map how the DSO investment pattern has changed over the past few years. This gives a simple, historical overview of what happened, and can then be used as a tool during subsequent interviews.

However, the interviews themselves cannot be done on a simple blind premise of investigating the topics mentioned in the research questions. There needs to be a system to the analysis, and some form of theoretical support. This does not mean that the results need to neatly fit into this supporting framework, but it does give a sensible direction for questions. Because the primary relationship between the DSO and the regulator is one of a principal-agent type, I chose to analyse the relational network of the DSO's from this perspective. The specifics of the system used will be discussed in the next chapter, where I will detail key concepts and theories and link them to the larger system.

Topics of considerable interest

During the research performed for this thesis, a couple of topics of considerable interest came up that link into the subquestions mentioned above. These topics were, for example, mentioned in some preliminary discussions regarding the research, and I set out to investigate these topics. Over the course of writing this thesis, I adopted a wider approach, but the topics still merit some specific attention. Therefore, I will shorty discuss these topics here and mention where they will come up in the remainder of this thesis:

- *"The dominant position of the regulator"*: In the Netherlands the regulating authority, the ACM (Autoriteit Consument & Markt) is in a very dominant position (this has grown historically) with respect to tariff design. The specifics of this relationship play a vital role in understanding the investment behavior of Dutch DSO's and need further investigation. Hence, this topic supports the first and third research questions, and will come up in chapter 3 and chapter 4.

- *"The shareholder relationship between the municipality and the DSO"*: The Dutch municipalities are the owners of the DSO's in the Netherlands. In their role as shareholder, there can be some conflicts of interest, and this can impact the investment behavior of the DSO's. This specific relationship is investigated in chapter 3.

- *"The DSO and Risk-Aversiveness"*: One of the main issues that was mentioned often in conversations and interviews on this topic is the presumed risk-aversiveness of the DSO's. With risk-aversive investing, I mean the tentative approach to investment where the investor waits until returns are near-certain before investing. This topic plays a substantial role in this thesis and can provide some answers to the research questions two to six. It is discussed in most detail in chapter 4, but it also mentioned in chapter 5.

- *"Investment plan testing by the regulating authority"*: Testing of investment plans with regards to renewable generation and solving congestion issues before they arise is something that was very recently introduced to the Dutch regulatory system. This topic is interesting for answering the fourth research question on needed changes in the regulatory system, and will be discussed in chapter 4.

- *"The new roles and activities for DSO's and energy suppliers"*: The energy transition is creating new roles and activities for both the DSO and the Energy suppliers. The effects of distributed generation development, but also energy storage, transportation and grid management are all part of the larger discussion surrounding the issues of an overtaxed grid. This topic can provide some answers for the fifth and sixth research question, and will be discussed in chapter 5.

With the topics mentioned above in mind, I performed both the analysis and interview parts of this thesis. Some of the questions asked in the interviews therefore directly pertain to one or more of these topics. When going over the findings of this thesis in chapters 4 through 6, I will present some concise conclusions regarding the topic in the concluding remarks section of the relevant chapters.

Understanding investment behavior - Significance of Research

This study can serve as a basis from which future researchers can continue analyzing distribution grid investments. By building knowledge from a broader perspective of factors, it can give future researchers the information necessary to focus future research on key elements influencing investment behavior. By exploring three elements that have an effect on the investment behavior of Dutch DSO's, this study can contribute to further studies that narrow down on one of these topics in the context of the energy transition.

From a policy and industry perspective, this study tries to present the current grid problems in the Netherlands from a DSO perspective. In that sense, it can be used to make problems that are experienced by Dutch DSO's but are not so abundantly clear to other parties more visible. Energy producers can use this study to gain more understanding of how investment in electricity grid infrastructure develops. Similarly, policy makers can use this study to gain a broader perspective on the grid capacity problems they are trying to solve.

Significance of Research to study program

With regards to my program of study, Management of Technology, this thesis shows how important it is to consider the institutional context of new technologies and how this affects their implementation and use as a whole. A commercial party wanting to develop some new renewable generation technology cannot simply start building assets and expect to be commercially successful in a system as complex as the energy industry. This is a characteristic that is quite particular to complex network industries, but it shows that new technologies are not just limited by their own performance or their market setting, but also by their embeddedness in some type of network, their governance through regulatory schemes and the limitations coming from these factors. As a manager in a firm wanting to develop these types of technology, knowledge of the system is crucial, and this thesis is an example of building such understanding for the electricity sector.

Part of the MOT program is to introduce students coming from engineering backgrounds to the world of management, economics, finance and innovation. This thesis employs skills learned in the courses of Financial Management, Economic Foundations, Technology Dynamics, Research Methods and Inter- & Intra-organizational decision making. It also utilizes some of the skills learned in my specialization program into infrastructure and environmental governance with a focus on energy systems. In the end, I believe this thesis serves as an example of how complex a surrounding context can be for some new technologies, and how careful managers need to be when operating within these confines.

Limitations of this study

The research performed in this thesis is of course subject to a set of limitations that future researchers can improve upon during further research. In this section, I will try to give a transparent overview of said limitations.

The limitations of this research can be categorized in three main groups: Resources, Scope and methodology. Each of these will be discussed briefly:

Resources

In terms of resources, this research is limited by the the typical limitations of a Master's thesis:

- The timeframe during which this research was performed is limited due to the relatively short (from a research perspective, compared to PhD and publishable research) time-span of the Master's thesis in the Management of Technology program of the TU Delft. The official time allocated to this thesis is half a year.

- This thesis research is performed on zero budget, meaning that all sources of data and information need to be publicly available, internal university sources or easily attainable through collaboration with the relevant industry. In this thesis, there was some collaboration with trade associations of grid operators and energy producers as to find suitable interviewees.

Scope
In terms of scope, this thesis is limited to the Netherlands and its particular set of influencing factors. Regulatory regimes, renewable project cycles and DSO characteristics all vary from country to country, so conclusions from this study cannot be universally applied. Countries that employ both a similar regulatory system and have a similar investment environment could be examined using the same factors, but in general the findings from this study should only be used as an input for possible research avenues when using another country as a case study.

Furthermore, this study is focused on the period of energy transition, and it is therefore questionable to apply the findings to time periods where there is no system-wide transition occurring.

Methodology
In this thesis, I employ both quantitative and qualitative methods. The quantitative methods used are limited by data availability, as only public annual reports were available to construct a data-set of DSO investments over the past decade. Therefore, the quantitative analysis in this thesis can contain errors in the data that are inherent to annual report accounting rules.

With regards to the qualitative analysis executed in this thesis, one has to be continuously aware of the subjective nature of interviews. The interviews presented in this thesis are the viewpoints of individuals that have been extrapolated to the viewpoints of organizations. The viewpoints are supported by other primary sources in the form of public documents, but they are still from a qualitative origin.

Thesis Structure
This thesis aims to explore the general effect of regulation, investment uncertainty and actor-network on the investment behavior of Dutch distribution system operators. These effects are presented using the following the following structure:

- **Chapter 1 - Introduction**
  In this chapter the reader of this thesis is given some background information on the topic of this thesis, followed by a detailed problem description and statement. Then, the research questions are presented, followed by a description of the research significance and limitations.

- **Chapter 2 - Key Concepts and Theoretical Framework**
  This second chapter presents the reader with the research design, including the types of analysis performed and how these have been used. Then, the research execution is discussed by presenting a section on data collection and processing (financial data), a section on interview strategy and execution and a section on the processing of interviews and other sources that were used to perform the relevant qualitative analysis. Next, the chapter discusses some key concepts and information that is required for the further understanding when reading this thesis. It will deal with a description of distribution system operators as an organization, followed by a presentation of the Dutch distribution system operators. Next, regulation of DSO's is discussed in a general sense, covering the multiple systems of regulation that exist in the world and how they typically affect general DSO behavior in theory. Then, two theoretical frameworks that are used in the analyses in this thesis are presented. First, principal agent theory is discussed, from basic theory to the version that is employed in this thesis. Added to that, some financial tools used in the quantitative financial analysis of this thesis are discussed, including the Capital Asset Pricing Model (CAPM) and some smaller tools and variables. Finally, all these topics are tied together in a final section discussing the link between regulation, principal-agent theory and my own analyses, leading into the actor network analyses in chapter 3.

- **Chapter 3 - Inter-organizational relationships and their effect on DSO investment behavior**
  This chapter presents the findings of the qualitative analysis with regards to the actor relations in the actor network surrounding the Dutch DSO's. I will cover the effect of government agents on DSO investment behavior, narrowing down to the specific goals that the energy transition policies set for the DSO's to achieve. I will then take a closer look at the municipal level of government, where the fact that municipalities are DSO shareholders causes some tension, but ultimately does not lead to lower levels of investments. I also cover the relationship between the regulator and the DSO from a goal and relation-typology perspective, although a lot about this specific

relation is also covered in chapter 4. Lastly, I discuss the relation between the DSO and the energy producers and consumers. Ultimately, this chapter presents how the differing actor goals create objectives for the DSO that are not necessarily co-achievable, and how a better alignment of these goals could support more pro-active investing.

- **Chapter 4 - Dutch Regulation and its impact on grid investments**
  This fourth chapter presents the first interview results from this study. In this particular chapter, I first discuss in more detail the findings from literature regarding the effect of regulation on DSO investment behavior. Then, I detail the specifics of the Dutch regulatory regime, and link this to the general introduction to regulation presented in chapter 2. Lastly, I present the findings on the impact of regulation on Dutch grid investment from the interviews, financial analysis and other sources. Here, I present the reason why the Dutch regulatory system is currently inhibiting pro-active investing, and I present some comments from the interviewed parties on how this could be adjusted in the future.

- **Chapter 5 - Distributed generation development and pro-active investing**
  In this fifth chapter I zoom in on the uncertainty aspect of investing in a distribution grid, and how the development of new distributed generation projects are further increasing this uncertainty due to short license procedures and easy subsidies. Then, I discuss what this means for the investment behavior of the DSO's that are expected to connect these projects in a timely fashion. Given that these processes are currently a major cause of grid congestion, I also discuss how a more structured approach to planning these types of projects can be a major factor in solving grid congestion. Lastly, I discuss a version of this structured plan as discussed by the Dutch minister of Economic Affairs in his letter (Wiebes, 2019), the regional energy strategy. In this section, the differing views of the DSO's on this document show that the RES is still something that is in its infancy, and that its effectiveness differs from region to region. However, the final product still has the capability to solve a lot of the uncertainty issues currently blocking DSO investment. Therefore, this section ends with a clear conclusion on what a RES should include for DSO's to be able to make more pro-active investments.

- **Chapter 6 - Conclusion and Thesis reflection**
  In this chapter I summarize the results presented in the earlier chapters briefly, followed by a presentation of the piece-wise conclusions made in chapter 4 through 6. Then, I provide an answer to the main research question. Next, I discuss the limitations of the conclusions found in this research in more detail, and I provide some suggestions for future research that can help deepen the understanding of the findings in this thesis, or that can address a particular limitation. Lastly, I provide some critical reflection on the thesis process.

2 Key Concepts and Theoretical Framework

In this second chapter I will present the key concepts and frameworks that are used on a regular basis in this thesis, along with the research methodology. The theories discussed in this chapter provide the point of reference for the reader, as some concepts have varying meanings in different fields of study. To that end, this chapter discusses these concepts and theories in the context of the electricity grid and the regulation there-off. In addition, I provide details on the main theories used during the analyses in this thesis, regulation of electricity sector monopolies and principal agent theory. These two theories are closely linked due to the regulatory relationship being a classical example of a principal agent relationship, a topic that will be extensively discussed at the end of this chapter.

In the first section of this chapter the specific research set-up is discussed, including an explanation of both the qualitative analysis based on interviews and other primary sources, and the quantitative financial analysis using annual reports of the DSO's. Next, I discuss the collection and processing of financial data, including a critical reflection on the use of annual report data (These type of sources are not completely "objective" in the truest sense of the word). Finally, this section discusses the interview strategy and execution, the results of which can be found in Appendix B.

In the second section, I start by presenting the electricity grid from a technical perspective. This introductory section contains a brief exploration of grid design an grid layouts, and places the DSO's investments in a technical context. This section leads in to a discussion of the distribution system operator (DSO) as an organization, detailing the responsibilities and activities that these types of firms typically exhibit. I also shortly discuss a similar type of firm, the transmission system operator (TSO), as to clearly define the boundaries between the two types of organization.

After this general introduction to the distribution system, I discuss the details of this system as it is used in the Netherlands, going over the different firms and their characteristics (Size, area of responsibility). Here, I will also present some typical investment activities performed by the Dutch DSO's as presented in their investment plans, and give an indication of their relative costs. Next, I will present the theory of electricity regulation and what systems are employed throughout the world. I will not go into to much specifics on the Dutch system, as that will follow in the final section of this chapter (as a theoretical overview) and the separate chapter 4 on the Dutch regulatory system.

Following these key concepts, I will present the basic principal agent theory used in the analysis, and I will conclude the section with a brief discussion of the capital asset pricing model (CAPM) and other financial tools used in the quantitative financial analysis.

Lastly, all the theories and concepts mentioned in this chapter are tied together in a theoretical discussion of the Dutch distribution system under regulation, and how this neatly ties into a principal agent framework.

2.1. Research Set-up

The research in this thesis followed a two-step analysis, based on financial analysis and on an empirical analysis through interviews. In this section, I will detail the methodological set-up of both of these analysis.

2.1.1. Basic framework of the financial analysis

The financial analysis of the Dutch DSO's will be done through collection and presentation of accounting variables obtained from the annual reports of the respective firms. In order to obtain a clear view of what has been happening in the past few years, it is preferable to use the reports from at least the last 5 years, if not more. However, some of the firms have experienced severe mutations in operating structure, and thus accounting structure, leading to rather discontinuous data. For this reason, these respective firms will require two separate data sets, or a smaller data set. In a similar fashion, some firms have a rather limited archive of public old annual reports, limiting data availability.

Because of the variability in data, the financial analysis section of this chapter will include a critical reflection on the use of annual report data for the purpose of analysis. From a general analysis point of view, the following structure was used:

1. List the available annual reports, any data discrepancies caused due to limited availability or firm mutations;
2. Show the firm's annual revenue in either table or figure form (choosing the best representative of the two);
3. Show and discuss several accounting variables of interest;
4. Calculate correlations between several of the variables of interest;
5. Perform the earnings beta calculations and present the results.

The complete results of this analysis can be found in Appendix A, with the most important results being used in the results chapters 4 through 6.

2.1.2. Basic framework of the principal-agent analysis

The basic set-up of the principal-agent based analysis is presented in this subsection. The different steps of the analysis are also presented in a schematic overview in Figure 2.1.

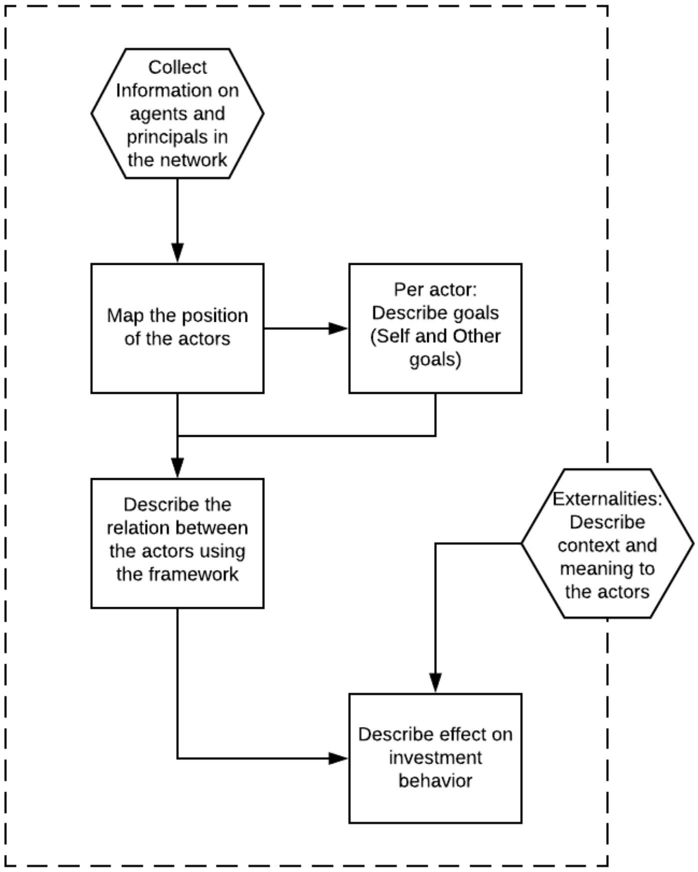


Figure 2.1: Schematic overview of the analysis steps used in the qualitative analysis of the actors.

1. The first step of the analysis is the creation of an accurate map of all the actors. This includes a short description of the entity and their relative responsibilities as to provide the context needed to support the location of the actor in the map. This step is also where a graphical representation of all the relevant actors will be shown as to increase the ease of examining the network;

2. This next step runs in parallel to step 3, and concerns the goals of all the actors. Using the information gathered, the self and other goals for the different principals and agents can be estimated, as long as a clear goal can be found or logically derived. This information is then used in the next step;

3. As the goal information comes in, the relation between principals and agents can be described, both by the actual typology of the relationship as the category based on the Waterman and Meier (1998) framework;

4. In the next, separate part of the analysis, some external factor that are especially relevant will be introduced and discussed as to provide the necessary context needed for linking these externalities to the agent's investment behavior;

5. In the final step, the goal and relation map and the external factors will be brought together in order to describe their relative effect on investment behavior of the agent.

The results of the analysis will be mostly presented in chapter 3, but some of the more relevant parts with regards to the regulator and the energy producers will also be used in chapters 4 and 5.

2.1.3. Collection and processing of financial data

In this section I will discuss the collection of data for the financial analysis, followed by a presentation of the methodology employed in the processing of the data. Lastly, this section will critically reflect on the use of annual report data as a source for a financial analysis.

Collecting the relevant data

The collection of data was done through the acquisition of annual reports from each of the Dutch DSO's from their respective websites. For all of the seven DSO's, the tables A.2 through to A.8 in Appendix A give an overview of the relevant reports used. In terms of availability of reports, Table 2.1 shows which reports were found for the respective DSO's.

Table 2.1: Overview of the available annual reports per DSO.

Year	Coteq	Enduris	Enexis	Liander	Rendo	Stedin	Westland
2011	-	✓	✓	✓	-	-	-
2012	-	✓	✓	✓	-	-	-
2013	-	✓	✓	✓	-	✓	-
2014	-	✓	✓	✓	-	✓	-
2015	-	✓	✓	✓	-	✓	-
2016	✓	✓	✓	✓	-	✓	-
2017	✓	✓	✓	✓	✓	✓	-
2018	✓	✓	✓	✓	✓	✓	✓
2019	✓	-	✓	✓	✓	✓	✓

As becomes very clear from the table, the availability of annual reports differs quite strongly per DSO, with the larger DSO's usually having a much larger historical database that is publicly available. I tried to contact the firms that had lacking annual reports, but all of them were unresponsive to requests for the provision of older reports.

Processing firm data

For the financial analysis, quite a few variables are of interest, including operating profit & costs, total investments, yearly depreciation, net investments, dividend payouts, and several of the respective ratios. The complete collection of each firm's analysis can be found in Appendix A, and the following list gives a specific description of every considered variable:

- **Total revenue:** Total income from sales, called *"Netto omzet"* in the Dutch books;
- **Gross revenue:** Total income from sales minus the cost of sales (transport costs for DSO's), called *"Voor bedrijfsactiviteiten beschikbaar saldo"* in the Dutch books;
- **Operating Profit:** This variable is taken from the yearly books, and is called *"bedrijfsresultaat"* in the Dutch version of the books. In most of the cases i am using the Dutch version of the respective annual reports due to availability of reports for the specific DSO portion of the holding firm;
- **Operating Costs:** This variable represents the firm's costs without taking into account depreciation. In the Dutch books they are called *"bedrijfslasten"*;
- **Total Investments:** This variable represents the absolute amount invested in new infrastructure. It is taken from the cash flow statement, and is called *"Investeringen materiële vaste activa"* in the Dutch books;
- **Yearly depreciation:** This variable represents the yearly cost of depreciation, and is needed to find the net investments. In the Dutch books these are called *"Afschrijvingen en buitenbedrijfstellingen"*;

- **Net Investments:** This variable is defined as the total investments minus the yearly depreciation, and is calculated using the numbers obtained from the respective annual reports;
- **Dividend Payout:** This variable is the annual dividend payout. It is called *“Uitbetaald Dividend”* in the Dutch books;
- **I/D Rate:** This ratio (Investments over Dividend) gives the relative spending of the firms on new investments and dividend payouts. It is calculated by dividing the net investments by the dividend payout;
- **Net Profit:** This is the final profit as reported on the annual reports, and is called *“Resultaat na belastingen”* in the Dutch version of the annual reports;
- **D/NP Rate:** This ratio shows the relative margin of dividend payout over the net profit, and is obtained by dividing dividend payout by the reported net profit for the corresponding year.

Using annual reports

The use of annual reports as completely objective sources of information is not easy due to the accounting practices of the firms under examination. It is questionable to call annual reports completely objective sources of information, but even though the accounting practices might change the details of the data somewhat due to the yearly interval of the documents (handing over certain expenses to a following year), the reports are good for recognizing trends (Böcskei et al., 2015). Therefore, for building a financial analysis based on trends of certain variables, their use is fair as long as the conclusions drawn do not focus in on the numeric differences seen. In other words, in this thesis, the annual reports will function as trend indicators to see whether certain variables are moving up or down, but I am not going to draw conclusions from the specific values of these variables.

2.1.4. Interview strategy and execution

In order to collect the required information needed to map the complex network of actors, interviews have been chosen as the main data source, to be supplemented by official notes, comments on laws and other, similar sources. Of course, interviews can take a whole range of shapes and sizes, so the first step in determining the right structure and topics was to carefully examine the goal of the interviews. Because the topic of network investments by Dutch DSO’s did not have very clear indicators of the exact causes of a lagging investment behavior, the research variables were still vague in the interview stage. The purpose of the interviews, therefore, was to examine the situation with a couple of experts in order to get a better understanding of the situation. It might lead to clear, concrete variables, or it might lead to more follow-up questions.

Stuctured versus unstructured interviews

With a clear goal in mind, the first step in the design of the interviews was to determine whether the interviews needed a structured approach or not. According to Sekaran and Bougie (2016), unstructured interviews serve the purpose of unearthing issues or ideas that influence a certain problem, without knowing exactly what they are. In that sense, the unstructured interview is ideal for exploratory research, where the discovery of interesting phenomena or variables is a central theme.

In this thesis, uncovering problems, factors and barriers regarding network investments by the Dutch DSO’s is a central theme. Especially regarding the upcoming analysis, this exploratory focus is key. Therefore, the interviews were conducted in an unstructured approach.

Respondent Selection

For the interview respondents, interviewed parties were required to have quite a substantial degree of information regarding the Dutch DSO’s and some of the other interesting subtopics such as regulation, investment planning or the new regional energy strategy (RES) plans. For this reason, the following parties were contacted:

- *Dutch DSO’s* - All of the Dutch DSO’s were contacted for an interview, but the response rate was low, and rather slow. Eventually, I managed to get an interview with a District-Director from the company Stedin, who managed to provide a lot of insights in the viewpoints of the DSO’s regarding regulation and solving the capacity problems. Later, I also interviewed a manager in Grid planning at Liander, which gave a lot of insights regarding the RES programs and the investment planning perspective. For Enexis, the contacted party with expertise in tariff-regulation replied to my questions via e-mail. All of the relevant transcripts can be found in Appendix B;

- *Netbeheer Nederland* - The trade association for the Dutch DSO's is an ideal party to provide the necessary insights in the different relations and parties in the network as they lobby for and against these parties in their daily activities. At first contacting them took some time, but I managed to interview the director of the trade association, which provided a lot of interesting insights. Again, the relevant transcripts can be found in Appendix B;

- *ACM* - Given the role of the ACM as regulator, this party is quite relevant to be interviewed. However, after contacting this party, they refused to cooperate with an interview. They did, however, point towards the official notes regarding the discussion with Netbeheer Nederland, Energie Nederland and the Dutch DSO's regarding pro-active investments in the new regulatory period, and stated that all of their viewpoints can be seen and observed in these documents. After scanning these documents, I agreed with their comments, and thus, these documents have been used to construct a lot of the viewpoints in the analysis. More on this will follow in subsection 2.1.5.

Interview preparation

Preparation for the interviews was done based on the interviewee's area of expertise. First, I used the social platform LinkedIn to note their current responsibilities and have a look at their previous experiences. Using this information, it was possible to focus the topics into areas where the respondent's insight would be especially valuable. This focus was then added on top of the general structure I used for every interview, which consisted of a series of topics that I wished to discuss. These topics were:

- *General introduction* - A quick introduction of my thesis work and the emphasis of the study, as to give the interviewee a notion of where the interview would be heading, followed by an introduction of the interviewee and their experiences;

- *Grid congestion* - I included this more general topic after the first interview, given that the interviewees might mention some facts that would not come up with more specific question lines. I used this topic to establish some rapport and to get a sense of how the interviewee viewed the problems in the Dutch grid;

- *RES programs* - This topic was often the first main topic of the interview, given that it lends itself well to figuring out how the different parties in the network view each other. The topic has collaboration between several actors at its core, and is therefore very useful for the interviews;

- *Regulation* - This topic was saved for the latter part of the interview, although the RES programs and regulation were switched around if the situation called for it (i.e. the interviewee has limited experience with regulation, so quickly I would cover it and move to the next topic). Given the complexity of regulation, the topic can lead to some detailed discussions, and I did not want to fill all the interview time with a detailed regulation discussion.

The order and content of the interview topics was sent to each interviewee before the interview, as to give them ample time to prepare.

2.1.5. Processing of interviews and other primary sources

The other types of sources used in the analysis are primary sources found online at for the relevant parties. The most important among these are:

- Notes from the ACM meeting about the next regulatory period. Within these notes, a very clear picture can be seen on how the parties in the discussion view the regulatory framework with respect to the energy transition. These documents, and other documents from the ACM website, will be used to create the profile for the ACM, and will influence the profiling of the DSO's where regulation is concerned

- Another important source is found at the Dutch government website, and it regards official letter to parliament, research reports and policy documents. These types of sources will be used to profile the more governmental parties in the network, along with the interviews.

2.2. Key Concepts - The distribution system operator

The first step in defining the problem space is the definition of organization itself, the distribution system operator. However, in order to define what constitutes an operator of a distribution network, it is necessary to briefly explore the various parts that make up an electricity network. In Figure 2.2 a general layout of a typical power system is displayed as an example. Note that this figure uses a schematic view in order to show what the typical components of a power system are.

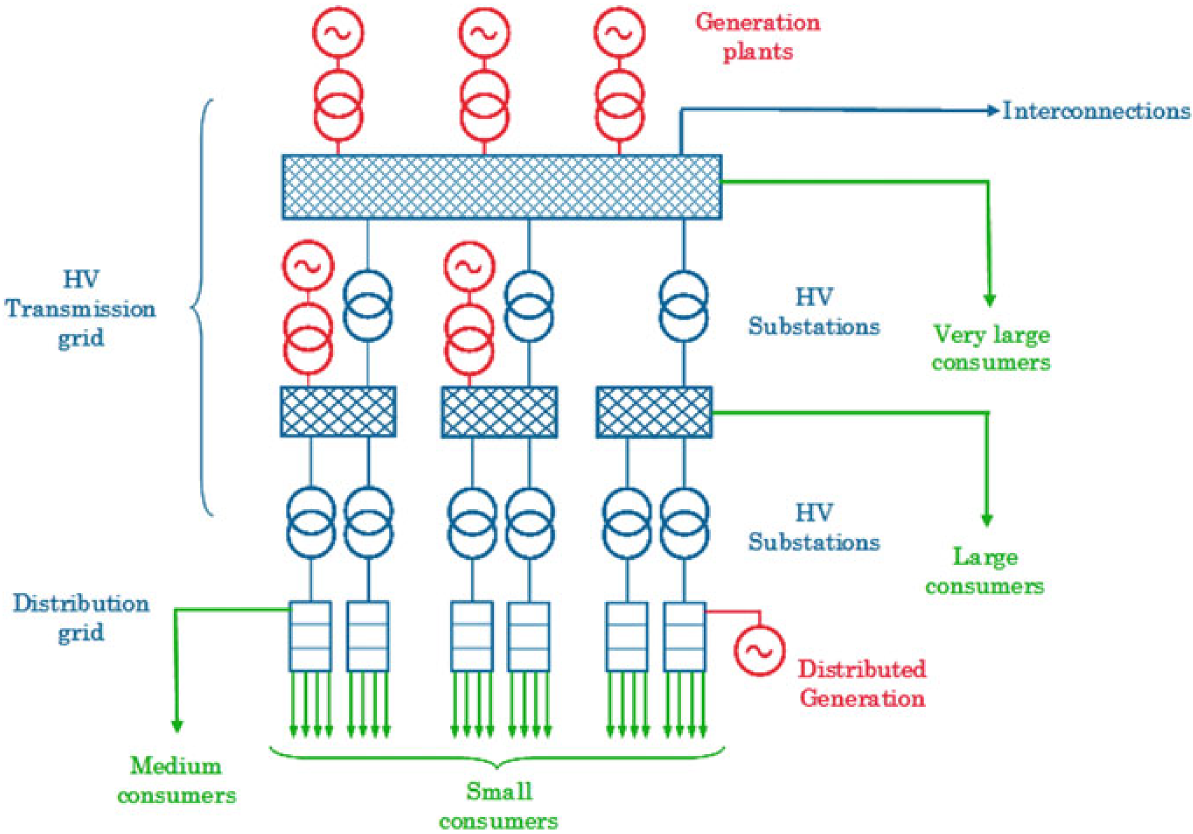


Figure 2.2: Typical layout of power system. Obtained from Laloux and Rivier (2013)

In this layout, electricity is generated at the red sites, both in large quantities at the generation plants that are situated in the HV Transmission grid part of the diagram and the distributed generation part of the diagram. Transmission substations up- and downscale the voltage to the respective transmission grids (of varying high voltage), and finally, the distribution grid (made up of a medium voltage grid and a low voltage grid that leads to small consumers). From a system-change perspective, the energy transition is causing an increase in the distributed generation capacity, meaning that the distribution grid needs to accommodate more and more transport capacity. This is a radical change from the classic top-down or waterfall-esque system (Large generation leading to a high voltage transmission grid that slowly downsizes until it reaches consumer sockets) that can also be seen in the diagram.

Within this system, a distribution system operator is responsible for the operation, maintenance and expansion of a distribution network, or parts of this distribution network. Often, these DSO's are responsible for regional grids, with, for example, 7 DSO's in the Netherlands that each service an area ranging from several provinces to a few municipalities. The high voltage (HV) network is maintained, operated and expanded by the TSO, or the transmission system operator. High voltage networks in the Netherlands are operated by Tennet, and range from 380 kV (Mostly in the south of the Netherlands, including the Randstad), to 110 kV (smaller sub-grids in the northern provinces of Friesland, Groningen, Drenthe and Overijssel).

To give an idea of these types of systems are organized on a local level, Figure 2.3 shows the local grid layout surrounding the Delft University of Technology (TU Delft).

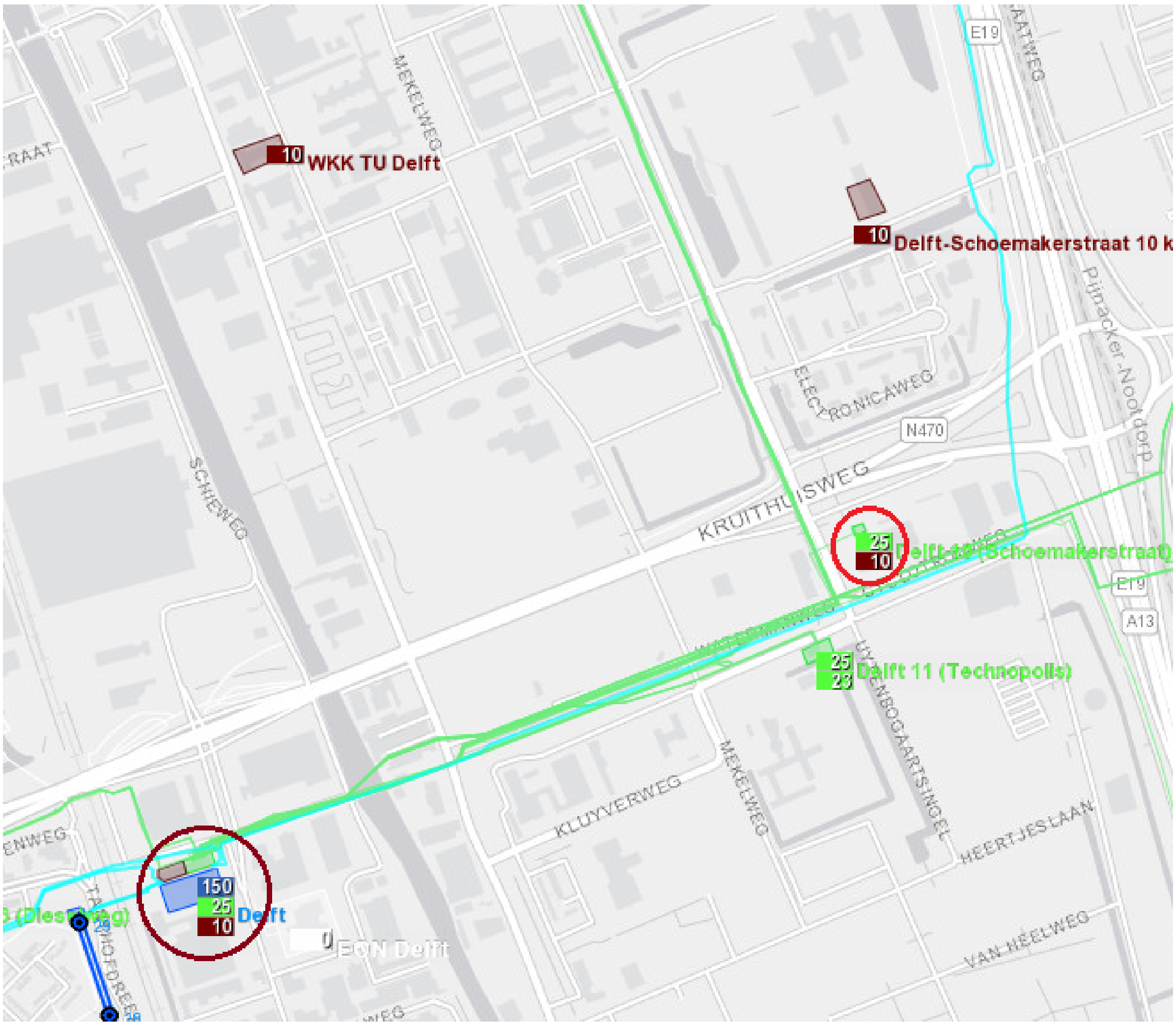


Figure 2.3: Example of a local grid, with a basic overview of the transmission and distribution grid near the campus of the TU Delft. Obtained from (HoogspanningsNet.Com, 2020)

In this figure, the 25 kV distribution grid is shown in the green lines. This particular grid is operated by Stedin, and it connects to the transmission grid at the substation that is circled in the bottom left corner. The blue line close to this substation represents the 150 kV transmission grid, with every dark blue circular marking representing a HV mast. There is another substation circled in the middle of the image, where the electricity is down-scaled to the 10 kV grid that is not visible on this image.

Given that the distribution grid also contains cables that reach the sockets in homes and offices that are on a 230 V voltage, this image only shows the main artery of the distribution grid. However, the principle is similar, with smaller transformer stations gradually bringing the voltage down in smaller parts of the grid until the cables reach homes and offices. Some industrial and similar customers use a higher voltage, and would thus be connected higher up in the grid.

The information given by Figure 2.3 is key for understanding what grid reinforcement (and investment) entails. When a DSO needs to create a higher transport capacity, it either needs to expand this network of main arteries in the 50 or 25 kV grid (often requiring a new substation), or it needs to increase the amperage in the cables by increasing cable thickness (although cable material could theoretically also be changed). Just increasing cable thickness is not often not enough though, as this new, higher capacity connection also needs to be able disperse this power onto the rest of the grid. This could mean reaching a certain substation, building a new substation or other solutions that enable this power dispersion. In the end, all of the above means that grid reinforcement is expensive, and should not be done without care for efficiency, as that could lead to runaway costs.

2.2.1. Overview of the Dutch DSO's

In the Netherlands, there are seven distribution system operators that own and operate parts of the electricity distribution network. In addition to the electricity network, the same firms also operate a gas network, although the areas of responsibility do not always neatly align (i.e. there are some areas where the firms for electricity and gas differ). In Table 2.2 an overview can be found of the seven DSO's in the Netherlands. Within this table, each Dutch DSO is described on the basis of area of responsibility and an approximation of annual revenue. This last descriptor serves as a proxy for the firm size, as to give an indication of the type of DSO (small and regional versus large and national).

Table 2.2: Overview of the distribution system operators in the Netherlands.

* *Area of responsibility is an approximation as the regions do not perfectly correspond with province borders;*
** *Enduris is operationally independent from Stedin, although financial reports for the company have been included in the reports of the Stedin group from 2018 onward.*

Company Name	**Primary area of responsibility* - (Gas & electricity differ, see figure 1.1 for details)**	**Approximation of annual revenue - (Reported for the holding companies in 2018 annual report)**
Liander N.V. - Part of Alliander N.V.	Provinces of Noord Holland, Flevoland, Friesland and Gelderland	€1.9 billion
Stedin - Part of Stedin Groep	Provinces of Zuid Holland and Utrecht	€1.3 billion
Enexis Netbeheer B.V. - Part Enexis Groep	Provinces of Groningen, Drenthe, Overijssel, Noord Brabant and Limburg	€1.4 billion
Coteq Netbeheer B.V.	Part of Overijssel	€40 million
N.V. Rendo - Part of N.V. Rendo Holding	Part of Drenthe	€31 million
Westland Infra Netbeheer B.V. - Part of N.V. Juva	Small part of Zuid Holland	€83 million
Enduris** - Part of Stedin Groep	Province of Zeeland	*Part of Stedin Groep Revenue; Firm total revenue for 2018: €120 million*

Observing the table, we can identify three main DSO's in Liander, Stedin and Enexis that own and operate the lion's share of the distribution grid. Enduris is a large regional operator, and the final three DSO's, Coteq, Rendo and Westland are much smaller in size, closer to a municipality or two. As stated earlier, the firms also operate a gas network. In this regard, Coteq and Rendo are larger, regional firms, but for electricity we can consider them small. In Figure 2.4 the corresponding areas of responsibility can be viewed in more detail.

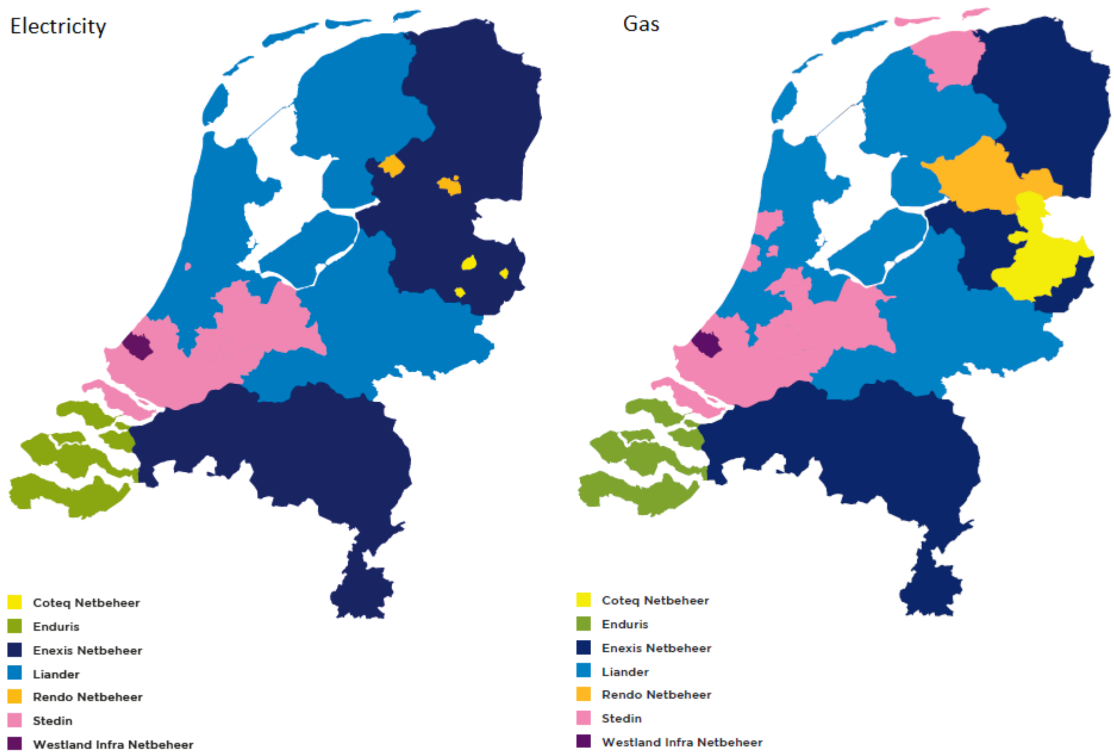


Figure 2.4: Graphical overview of the areas of responsibility for the Dutch DSO's; (Netbeheer Nederland, 2020).

Investments of the Dutch DSO's

DSO investments can be categorized in two types: expansive investments that add new assets to the DSO's portfolio, or replacement investments that are meant to replace assets that have reached the end of their life cycles. One of the challenges in the coming energy transition is that the need for expansive investments is increasing rapidly, leading to escalating levels of investment. This can also be seen when consulting the investment plans of the Dutch DSO's. As an example, some figures from the investment plan of the DSO Liander (Liander N.V., 2020b) are provided here:

- **Regular investments (<25kV):** Liander discusses the investments into their medium and low voltage grids in some details for the years 2020, 2021 and 2022. For these years, the amount of replacement investment is €160.9 million in 2020, €154.7 million in 2021 and €153.6 million in 2022. The majority of these replacements are either small transformers (approximately 30%) and connections and meters (approximately 40% to 50%). In terms of expansive investments, the following numbers are given: €278.5 million in 2020, €289.6 million in 2021 and €316.1 million in 2022. Here, the majority of the expansion is in the form of new cables (approximately 70%) and new connections (approximately 20%). Notice the steep increase in these investment costs as compared to the replacement investments.

- **Major investments (>25kV):** These type of investments mainly come in the form of new substations and major new cable networks. Due to the reliance of the location of these assets on the regional energy strategies, the information in the plan is less concrete. However, the following numbers are mentioned: approximately €60 million in 2020, €140 million in 2021 and €160 million in 2022. Clearly these types of investments are rapidly increasing as well.

Now that it is more clear how the Dutch DSO's are organized and how their investments are increasing, it is important to establish how these firms are governed through regulation. The next section will discuss their economic operation under a regulatory scheme, as well as present some of the commonly used schemes of regulation.

2.3. Key Concepts - The DSO as a regulated monopoly

The daily business for a DSO lies in the operation, maintenance and expansion of a large piece of network infrastructure. This last point changes the DSO from a typical firm to a special case, known in economics as natural monopolies. Because of the inherent difficulty of introducing competition to such a large infrastructure network, there is often only one firm as the sole monopolist in their part of the larger network. It is, after all, inefficient to have multiple and parallel electricity grids. From Joskow (2007), we find the formal definition of a natural monopoly to be when it is less costly for a single firm to produce a certain product or output compared to a similar situation with two or more firms. From a purely economic point of view, monopolies produce output at a level that is less than the social optimum, often leading to what is known as dead-weight loss. If one translates this back to an electricity network firm, this would mean relatively high prices for a relatively low quality of service. Therefore, government intervention is required in order for these types of firms to produce at a level that is seen as socially desired.

Government intervention often takes the form of a regulatory scheme, which will be discussed in the next section of this chapter. However, first, the ideal version of regulation is discussed based on neoclassical economic theory as described by Joskow (2007). In this idealized world, the regulator has all the information it needs to set efficient prices. In other words, in this idealized version there is no information asymmetry.

Let us first consider a firm that is in a regular monopoly position to provide some comparison. This firm can be described by its characteristic curves as shown in Figure 2.5.

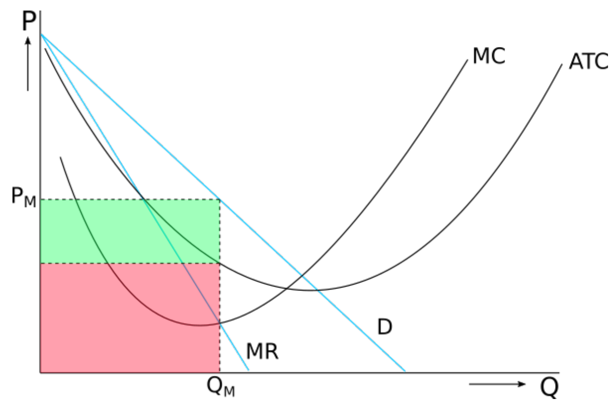


Figure 2.5: Price-Output diagram for a regular monopoly

In this figure, the monopoly produces where its marginal revenue (MR) equals its marginal cost (MC). As shown, the respective level of output then becomes the point where a vertical line down intersects the Q-axis at Q_M, and the corresponding price is the point of intersection between this vertical line and the demand curve D, giving price P_M. Because the average total cost for this firm at output level Q_M equals the point of intersection with the vertical line and the average total cost curve (ATC), the monopoly is making economic profit equal to the green square in the figure.

Given that the monopolist firm has no market power, new firms entering the market will push the price down and drive the output up until firms are producing the socially optimum level of output at $MC = D$. Hence, a regular monopoly will only stay in a monopolist position when it enjoys some measure of market power. This type of market power can come from economic barriers such as economies of scale, large up-front capital requirements creating a large barrier to entry, or technological advantage leading to a lower marginal cost curve. Sometimes, legal barriers such as patents and intellectual property rights can also be a source of monopoly power.

This is a different story when a natural monopoly is considered. If we return to the definition as stated by Joskow (2007), in a natural monopoly it is less costly for a single firm to produce a certain output compared to multiple firms. This means that the fixed cost of such a firm is rather high, but the marginal cost, and hence the average total cost, is very “spread out”, i.e. it doesn’t take much resources to supply one more unit of output. Such a situation is depicted in Figure 2.6.

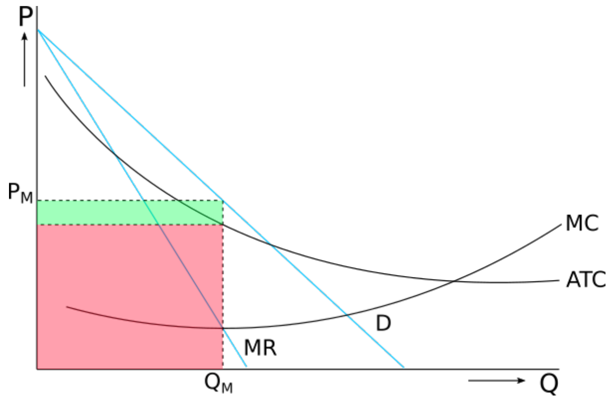


Figure 2.6: Price-Output diagram for a natural monopoly

In this new situation, any new firm entering the market would have to deal with the very high fixed cost and would not be able to outperform the larger, incumbent firm. Hence there is no natural development of competition. On the contrary, a single large firm produces closer to the social optimum than a handful of smaller firms all bearing the large fixed cost. Utility industries such as water, natural gas and electricity are all textbook examples of these natural monopolies (Gómez, 2013; Joskow, 2007), and require regulation in order to produce outputs close to the social optimum.

However, setting a regulated price at the social optimum leads to a situation where the natural monopoly is making an economic loss, and will exit the market in the long run. If one foregoes the notion of subsidizing for now, a better strategy would be to price the good in such a way that the natural monopoly produces at its average total cost intersection with the demand curve, as shown in Figure 2.7.

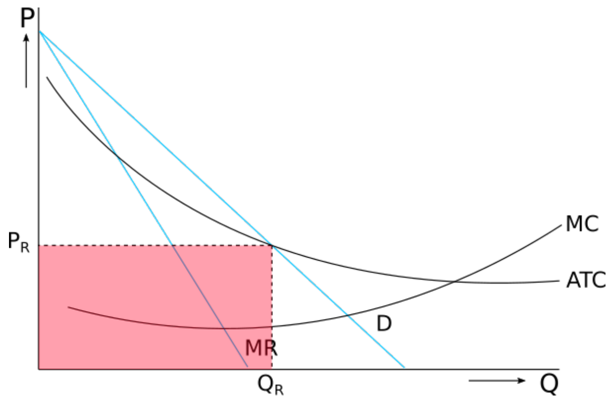


Figure 2.7: Price-Output diagram for a natural monopoly under regulation

Now the firm is producing the good at the level of average total cost, meaning that the regulator should not be pushing the firm out of the market, and the level of production is as close to ideal as possible without subsidizing the good. Whilst this is all very clean and neat from this theoretical perspective, the key assumption lies in the knowledge of the firm's average cost curve. For the regulator to set the price at this level, perfect knowledge of the monopolies' costs is needed, and this is not the case in reality. Hence, without this information, a regulator might price the good too high, leading to less output and less welfare, or too low, leading to firm exit. Therefore, a different scheme of pricing is needed in order to approach this ideal pricing as much as possible. The next subsection will discuss regulatory schemes used over in the world in the regulation of grid operating firms.

2.3.1. Systems of regulation

Regulation of utilities has been commonplace since the concept of regulating certain industries in order to limit market power or to ensure social welfare has been around. Over the years, several systems have been used all over the world, the most common of which are shortly discussed in this chapter.

Regulation schemes have a double objective that are conflicting in nature. This is, in essence, what makes regulation such a difficult and complicated subject. Gómez (2013) describes the two conflicting objectives that these types of regulatory schemes must have:

- On one hand, they need to ensure productive efficiency, meaning that the regulator must try to make the utility provide the good at the lowest possible price;
- On the other hand, the regulator needs to ensure the continued existence of the utility by making sure that set prices are economically and financially viable.

Given the fact that investments in networks are often lumpy and very much up-front in a lot of cases (Gómez, 2013), the role of the regulator in facilitating the right returns on investment is very significant. If prices are too low, the incumbent firms will not even invest the amount needed to cover demand growth. Hence, the regulator should not focus solely on operating costs and efficient production if a long term viability is a goal. However, allowing the regulated firm too much leeway in their return on investments leads to inefficient pricing and might hurt the consumer. To combat this, very specific schemes of regulation have been used in monopoly regulation over the years, of which rate of return regulation and incentive regulation are the most commonplace.

Rate of return regulation

One of the classic schemes of regulating DSO's is known as rate of return regulation (also known as cost of service regulation). In this type of regulation the DSO is allowed a certain income that allows it to both cover its operational costs and provide a high enough rate of return on investments (Correlje et al., 2012). This allowable income is negotiated with the regulatory authority, with these negotiations taking place during set intervals (the regulatory period), or more often, when requested by a DSO (Gómez, 2013). From this allowable income, a second stage of this system determines the tariff structure that is to be used in order to achieve set income. The allowed costs as determined can be seen in Figure 2.8

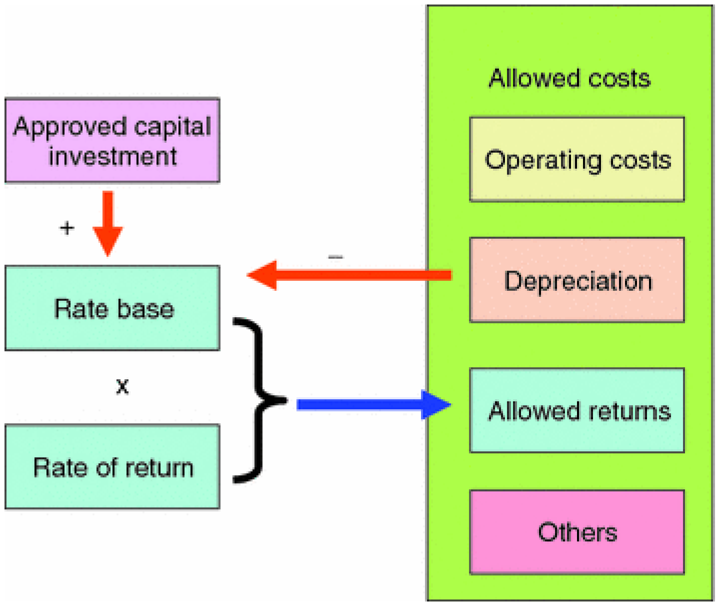


Figure 2.8: Overview of the build-up of allowed revenues under rate of return regulation; from Gómez (2013)

One of the key problems with this type of regulation is the lack of open information in the determination of the costs as presented in Figure 2.8. There is no complete knowledge of the incumbent firm's costs, and thus the review sessions do not necessarily lead to a more efficient price. Gómez (2013) describes the so-called *Averch-Johnson* effect when these calculations are not accurate. When a firm is allowed a too high return, the firm is incentivized to invest more than necessary, and conversely, when the allowed return is too low, the firm is incentivized to invest much less then needed. Both of these investment activities lead to unnecessary costs, and thus the *Averch-Johnson* effect makes rate of return regulation very sensitive to information asymmetry.

Furthermore, Correlje et al. (2012) discuss the lack of incentives for the incumbent firm to behave more efficiently under such a system, arising mostly from the fact that incurred costs are guaranteed to be covered. Because of these shortcomings, a different scheme of regulation called incentive regulation has been employed over the past decades, and a variant of that system is still in effect in the Netherlands.

Incentive regulation

Under incentive regulation schemes, regulated firms are given a specific revenue path that they are expected to follow, designed to incentivize cost reduction and thus a profit increase. These revenue paths are set for periods of approximately 4 to 5 years, depending on the specific country. After this regulatory period, the revenue setting procedure is thoroughly reviewed and a new path is set for the following period. In general, this revenue path is downward sloping, requiring the regulated firms to become more efficient over time in order to meet the regulatory goals.

One of the key benefits of such a system lies in the fact that the regulated firm is allowed to keep some of the efficiency gains it makes during the regulatory period. If a firms over-performs with regards to cost savings, and manages to get costs lower than the allowed revenues based on these costs, any gains can be kept by the firm for the remainder of the regulatory period. Under the above rate of return regulation, any notion of cost saving would lead to lower prices immediately, removing any incentive to actually reduce costs. This period of firm benefit is usually followed by a systematic review where a new base is set for the firms, passing the efficiency gains to the consumer. This principle is illustrated in Figure 2.9. Note that after the regulatory period, the new starting level for the expected improvement is at the level of the actual improvement. So, firm benefits are passed to the consumer after the period, and firms will have to over-perform again to get new benefits.

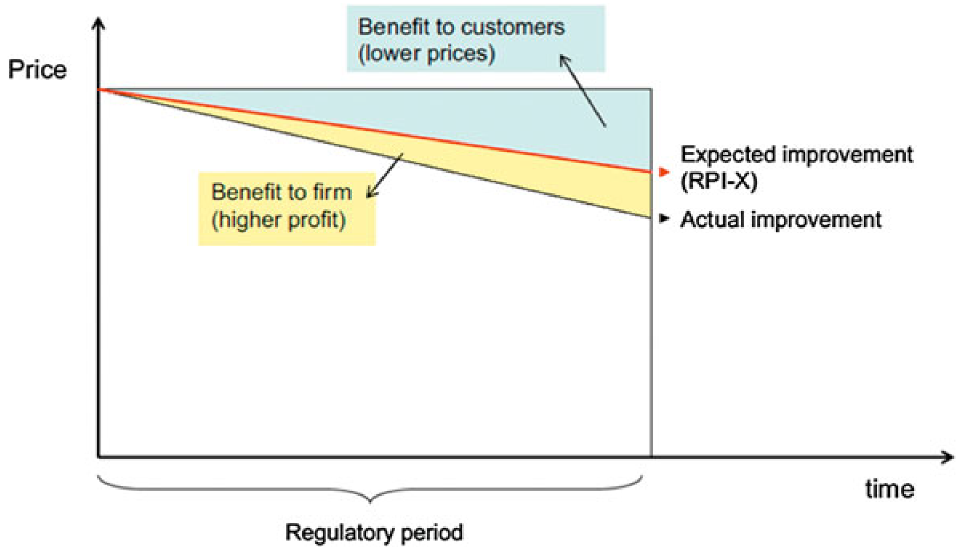


Figure 2.9: Overview of the sliding scale used in incentive regulation schemes; from Gómez (2013)

Incentive regulation is also commonly called RPI-X regulation, based on the formulae used to calculate either prices or revenues under their respective cap system. From Gómez (2013) we find the following formula (Equation 2.1) for incentive regulation under a price cap:

$$\overline{P}_{m,t} = \overline{P}_{m,t-1} \cdot (1 + RPI_t - X) \pm Z \tag{2.1}$$

Here, $\overline{P}_{m,t}$ represents the price that a company is allowed to charge for good m in the year t, and it is based on the price of the previous year, times a factor including the current retail price index (RPI) and an efficiency factor (X). The Z factor is to account for unforeseen circumstances or events.

Similarly, for a revenue cap system, Gómez (2013) presents the following equation (2.2):

$$R_t = R_{t-1} \cdot (1 + RPI_t - X) \pm Z \tag{2.2}$$

Here, R_t represents the maximum allowed revenue in year t, based on the previous year's revenue times a factor including the retail price index (RPI) and efficiency factor (X), and again including a Z factor for unforeseen circumstances.

From these two equations, it can clearly be seen that the system of incentive regulation has some form of assurance towards the firm through the RPI (Allowing the firm compensation for the general economic inflation) and Z factor (Allowing the firm compensation for some unforeseen event, although this Z factor could also benefit the public consumers by being negative), whereas the consumers are the main benefactors of the X factor that eventually lowers the prices. The simplicity of such a system has made incentive regulation very successful in many of the countries where it has been implemented (Littlechild and Glachant, 2013).

One of the drawbacks of the incentive scheme as it is discussed above is the difficulty of determining the correct x-factor for the affected firms. Whereas Littlechild and Glachant (2013) describe that these processes took a few months to a year at the start of the implementation, the increased complexity of distribution networks evolving into full interactive systems has turned these negotiations into multiple year discussions. Over the past few years it has become increasingly clear that new reforms are necessary to cope with these changes. Regulators need new methods to assess the type and amount of necessary investments in new infrastructure and technology. However, they are simultaneously lacking vital knowledge that the firms themselves do have about the same required infrastructural/technological investments and the actual costs that come with these investments.

All in all, it shows that the future of regulation requires some form of open information or collaborative platform to be effective, a point also made by Glachant (2012) in his study on the future of regulation of network firms. Later in this thesis, I will focus in on the regulatory effects on DSO investments, and more thoroughly discuss the views of literature on how regulation needs to be adapted to support the transition investments.

With the general concepts of DSO's and regulation discussed, this chapter will continue with a description of the theoretical frameworks and models used in the thesis analysis.

2.4. Theoretical Framework - Principal Agent Theory

In this thesis, a large portion of the performed analysis is based on inter-actor relations, and how actor goals and relations influence what these specific parties aim to achieve. To this end, a formal theoretical framework was needed to provide a structured approach to the analysis. Here, the theory of principal-agent relationships, and in particular the multiple-principal-agent framework came forward as a sound choice. This section gives a basic overview of the theory of principal-agency problems and the multiple-principal variant.

In terms of basic theory, the idea of using this specific theory came from chapter 3 of the study by Hancher et al. (2008). In this chapter, the authors describe how the regime change in the Dutch infrastructures have led to the emergence of multiple principals and agents. This web of actors, the authors argue, has created an ever-increasing complexity that makes the job of the regulator as principal very difficult.

2.4.1. Principal-agent Theory

Before I describe the specific problem of multiple principals and agents as it is currently viewed in literature, I will first discuss the basics of principal-agent theory. For the specific case of principal-agent models in an institutional or regulatory space, the foundational work by Mitnick (1973) forms a solid base. In this paper, and the following article on agency and behavior in a regulatory environment (Mitnick, 1975), the author describes both the underlying theory of agency and its application to the regulatory realm.

Simply put, the concept of agency exists when one party (the agent) is acting on behalf of another party (the principal), and thus represents the interests of the principal through its actions. These types of relationships exist in almost every public space, ranging from workplace to politics and everything in between (Mitnick, 1973; Waterman and Meier, 1998). Agents are also explained to act on two sets of goals, so-called self-goals and other-goals. Self-goals tie in to basic neo-classical economic thinking of maximizing personal gains, which can be in the form of salary, bonus, profit or some type of self-gain. The other goals are described as goals that, when achieved, benefit another entity, and the pursuit of these goals is often contractually obligated or incentivized (Mitnick, 1973).

Agent behavior

Another key concept described by Mitnick (1973) in this paper is the type of behaviors exhibited by the agents, which he subdivides into contractual and non-contractual behavior. Examples of contractual behavior are:

- *"Acting at discretion"* - In a sense, this type of behavior is due to a certain level of trust from the principal in allowing the agent to act in their stead;
- *"Acting due to authority"* - This type of behavior is exhibited due to the authority of the principal with regards to the agent. Typically, a subdivide is made for different types of authority (In some cases, goals of the agents and principals align, in other cases, reprimand or other consequences make the agent act against their own interests).

Similarly, a whole range on non-contractual behaviors can also be identified:

- *"Coercion"* - The agent acts due to the coercive influence of another entity, but this influence is not contractually obligated;
- *"Altruism"* - In this case, the agent acts in accordance with the self-goal of the principal, without expecting any kind of restitution or reward. One can think of a societal goal as something that might instigate this type of behavior;
- *"Consensual autonomy"* - This type of behavior is classified by the fact that the agent chooses what to do for the other party, which then consents to these acts;
- *"Reciprocity"* - This type of behavior is defined as performing acts that further the other's goal, followed by a similar act from the other party. In a sense, both parties continually "owe" each other and keep acting in the interest of the other party without the need for a contract;
- *"Consensual directed agency"* - This type of behavior is explained as the other party defining the acts that the agents is to perform, upon which the agent consents to performing these acts, in the absence of a formal contract.

The agent behaviors discussed in the above list showcase the possible complexity of a relationship between two of these parties. Even in the formal framework, we can find a multitude of possible factors that determine why an agent does a particular thing. When something like this framework gets translated the a real-world example, the science becomes even more fuzzy due to possibility of a relation between two parties being based on a multitude of these factors. So, an agent could be acting under contractual behavior towards their principal, whilst at the same time being coerced or in some other form of a non-contractual relationship. And this is still not-withstanding the existence of a multitude of these relations with the different parties in the network.

All in all, it shows that the agent can be motivated by a whole range of factors, and that categorizing is not something done easily. During the analysis in this thesis, any categorizations of relationships take into account this complexity, and I will thus refrain from neatly boxing every actor relationship in a particular category. However, I will use the framework to give a detailed description of multiple aspects of a certain relationship, providing some theoretical substance to a discussion based on empirical findings.

Agency problems

The final subject discussed by Mitnick (1973) are the so-called agency problems, which he divides into the principal's problem and the agent's problem. I will give a paraphrased description of both:

"The principal's problem:" For the principal, the main challenge is to motivate the agent to act in the way the principal prefers, towards the goal set by the principal. Mitnick (1973) then goes on to describe different methods principals use to overcome this problem, which can take form in both an explicit exchange of resources or a more implicit supplying of information that instigates the agent to act.

"The agent's problem:" The agent has to choose the best set of actions that work towards the agent's self and other goals. However, the agent might be constrained in some manner through the relation with the principal, which can take a form of the options mentioned in the previous subsection on relationship types and factors.

The above described problem set is of course a vastly idealized and stylized version of reality, as it is sometimes fairly difficult to categorize goals and relations explicitly. However, the regulatory sphere is a fairly solid arena for the theory due to the formalized relation between the regulators and the regulated (Mitnick, 1975, 1982).

Basic principal agent-theory though, is less applicable to the area of research of this thesis due to the complicated relationship between multiple agents and multiple principals. Because Mitnick (1973, 1975) describes a form of the theory that analyzes a single principal and agent, it is necessary to use an expanded form of the theory for this thesis, similar to the expansions discussed by Waterman and Meier (1998).

2.4.2. Principal-Agent Theory in the regulatory arena

Given the origins of Principal-Agent theory in a market setting, several differences arise when the theory is applied in a regulatory setting, or one of public administration. Waterman and Meier (1998) mention that one of the key differences lies in the so-called cost of the agent not acting with the principals goals in mind due to deliberate non-control of the agent. The authors discuss how in an institutional setting, the principal itself is unlikely to bear the cost, which is instead passed to the public. The only moment when the principal itself would bear a significant cost is when this lack of oversight becomes public knowledge. Compared to a market setting, where the cost of not controlling an agent is paid for by the principal, a certain lack of responsibility can emerge for the principal.

Within this area of application, Waterman and Meier (1998) mention two key elements:

- "*Goal Conflict*" - One of the main elements of the theory is the goal conflict between the principal and the agent. This may be in an extreme form of actually opposite goals, or in a milder form where the methods of accomplishing said goal are up for discussion. In the end, goal conflict leads to agents "shirking", as it is called.

- "*Information Asymmetry*" - Information asymmetry has been discussed before in this thesis, but in the context of the principal agent model it means that there is a distinct imbalance of information between the principal and agent, and it allows a certain unresponsiveness from the principal towards the agent.

Furthermore, Mitnick (1992) himself provides some more insights in how agency theory can be used in a more organizational sense. He mentions one important aspect of agency that must be taken into account when using the theory in any way: the fact that fundamentally, agency is relational. The author highlights the fact that this is key in understanding relational variables, by showing that they matter to the other party. Therefore, one should analyse for example the choices available to an agent from the perspective that these choices have meaning for the principal. It should matter (to the principal) what the agent does in order for the theory to produce meaningful results.

Creating a realistic representation of something akin to public administration, or a similar organizational type of analysis, however, requires a critical look at what authors call the "dyadic" relationship of principal agent models. This means that the assumption of a single principal and a single agent needs to be relaxed in order to more closely represent reality (Waterman and Meier, 1998).

Multiple principal problem

One of the first consequences of relaxing the "dyadic" assumption underlying the theory is the emergence of multiple principals. Due to the fact that, in principle, agency exists when one party acts for another (for a more detailed description of how this has influenced agency theory use from a sociological perspective, see Shapiro (2005)). This definition allows for the existence of a long list of possible principals, ranging from interest groups to political or governmental actors, but also groups such as shareholders, general public and similar entities. Returning to the key element of goal conflict mentioned earlier, Waterman and Meier (1998) discuss the fact that goal conflict between the different principals makes the principal-agent relationship even more complex. One would enter a system of where, by successfully performing an action, the agent would accomplish the goal for one principal, whilst undermining another.

Regular, assumption constrained principal agent theory, according to Waterman and Meier (1998), cannot deal with these complexities adequately. They mention the following problems explicitly:

- "*Principal prioritization*" - There is no clear way to determine which principals are to be ignored, and which principals are not. Tying into this, the authors call this a lack of capability to deal with a certain manner of hierarchy within a network of actors.
- "*Watered-down information asymmetry*" - All the different parties in the network have differing levels of information, and some principals may align themselves to further their related knowledge. Therefore, with the existence of multiple principals and agents, there is a more "fuzzy" information asymmetry.

Rather than explicitly solving these problems, Waterman and Meier (1998) have created a more generalized form of the model, where both the level of information and the presence of goal conflict vary. By doing this, a whole range of interaction between principals from different types and agents can be categorically described.

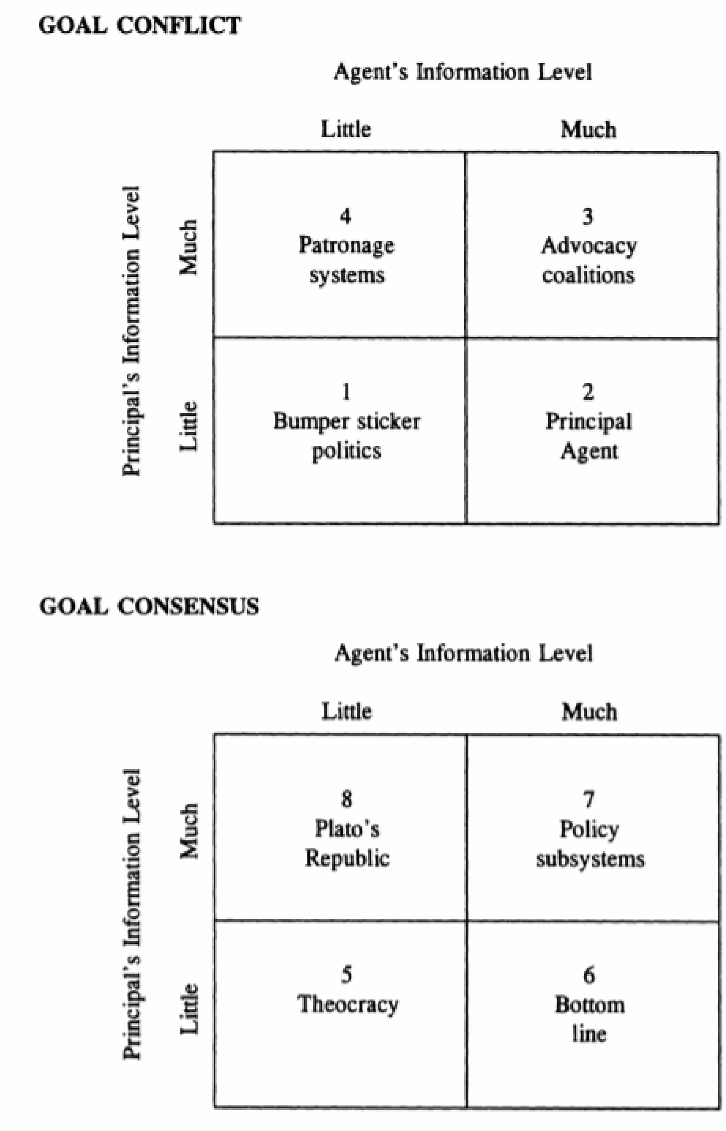


Figure 2.10: Schematic overview of the expansion of principal agent theory, obtained from Waterman and Meier (1998).

A schematic overview of their model can be observed in Figure 2.10, with 8 different situations explained. In their paper, Waterman and Meier (1998) give a detailed description of each situation, which I shall present in summarized form below:

1. In this case, both parties have little knowledge of the issue at hand, but they do have some form of goal conflict. In such a case, discussions on the subject are often based more on ideology than actual knowledge of the problem, and according to Waterman and Meier (1998), the bureaucratic agents are reduced in their implementation power, with active principal involvement;
2. This case is the regular principal-agent case, with a knowledgeable agent and a principal with an information disadvantage. This classical case is also often used when zooming in on the relationship between the regulator and the regulated agent, of which Nolting et al. (2019) provide a good example. In their study, they use this form of agency theory to analyze investment incentives in German grid regulation;
3. In this third case of goal conflict, both the principal and the agent have a good amount of knowledge on the topic, leading to collections of principals and agents on both side of an argument. According to Waterman and Meier (1998), the relationship can be examined using regular principal agent theory in the case of opponents, whilst supporters require a more cooperative model;
4. In this last goal conflict case, the principal is more knowledgeable than the agent, leading to the agents becoming more or less staff of the principal. Whether or not the agents are independent entities at all is questionable in such a case;
5. This fifth case is the first goal consensus case, where both parties have little knowledge on the topic. It leads to so-called implementation of new policies without real scrutiny, with the agents almost blindly following, or protecting, the principal's ideas;
6. In the sixth case, goals are shared between the principal and agent, but the agent has much more knowledge/information. In such a case, the agents are often given a lot of leeway in how they accomplish the shared goal, with the principal delegating the task, so to speak;
7. In the seventh case, both principal and agent have a lot of information, and due to the two parties interacting as peers towards a common goal, some form of mutual trust develops. In such cases, discretion is granted to the agent based on this trust;
8. This final case describes the situation where the goals are aligned, but the principal has a distinct information advantage compared to the agent. Due to the goal consensus, agents simply carry out the principal's policy. Comparing it to the goal conflict version (point 4), the difference is that some measure of resistance might be present in case 4 due to what Waterman and Meier (1998) call rigidity in carrying out policies (doing it by the book, instead of exactly how the principal wants it).

Adding the above framework to the principal-agent theory allows for an expanded analysis regarding the different actors in the network. Going back to Hancher et al. (2008), a whole range of changes to the energy sector in the Netherlands are described, including the change in primary actors and interest groups. The framework discussed in this section will provide some theoretical support for the empirical analysis made in this thesis, the results of which will follow in chapters 4 through 6.

The next section will discuss the theories and tools used in the financial analysis, but we will return to the principal-agent model in the final section of this chapter, where I will provide a theoretical overview of the Dutch system based on the work of Hancher et al. (2008), and link this to the theories used in this thesis.

2.5. Theoretical Framework - CAPM and other financial tools

In this thesis, an analysis of the financial data available is made in order to support the qualitative findings, where the data from annual reports is used to plot the revenues, profits and other interesting variables. Because the research also requires an assessment of the risk that the firms under investigation take, I have opted to use the capital asset pricing model (CAPM) to estimate some risk related variables. The specifics of this estimation, and some other variables, are discussed in this section.

In order to accurately describe the risk profile of the DSO's in the financial analysis, the average project undertaken by the firms needs to be evaluated. However, individual project risks are not explicitly known, nor published, making some kind of proxy tool a requirement for this evaluation. For this reason, I will approximate the relevant firms' risk profile by calculating their asset beta, which represents the market risk of the average project in a firm. There is a caveat though, as the Dutch DSO's are not publicly listed firms, which means that the beta cannot be estimated using historical returns on stock. In order to still arrive at a relevant beta, there are a couple of options:

1. Using an accounting proxy for the stock returns. Literature on accounting or earnings beta make a couple of suggestions of suitable proxy's, such as the firm's change in annual earnings (Damodaran, 2020), or a ratio of change in earnings compared to equity or asset change (Sarmiento-Sabogal and Sadeghi, 2015).

2. Using comparable firms that are traded publicly as a proxy for the private firm. The resulting general beta can then be unlevered and re-levered using the leverage ratio found in the books of the private firm to arrive at the final equity beta.

Both systems have some shortcomings, as the accounting information used for accounting beta's is often manipulated or smoothed for certain accounting purposes (Damodaran, 2020). It makes this type of information less reliable when it comes to the actual value of the beta, but it should not be dismissed if we use it to assess the basic risk profile of the respective firms. The second method, however, is limited by the fact that comparable firms are quite hard to come by in the case of purely regulated DSO's, and that the resulting beta will be the same for all DSO's. For that reason, I am going to use the accounting beta in the upcoming analysis, whilst relying on a report by the company Rebel (Rebel Energy, Water & Climate, 2016) where they do a comparable firm analysis as a sanity check.

The accounting beta can be estimated from the following formula:

$$\beta_E = \frac{COV(\Delta_E, \Delta_M)}{\sigma(\Delta_E)} \tag{2.3}$$

In Equation 2.3, β_E represents the accounting (earnings) beta, Δ_E is the annual change in earnings and Δ_M is the annual change in a representative market index. The annual change parameter can be replaced by a similar proxy, so as a check we could also run the annual change in earnings over assets, or earnings over equity. Given that the Dutch DSO's operate mainly on the Dutch market, the AEX index will be used as a comparative index. It is also important to note that the following definitions for the annual changes:

$$\Delta_{E_t} = \frac{E_{t+1} - E_t}{E_t} \tag{2.4}$$

$$\Delta_{M_t} = \frac{M_{t+1} - M_t}{M_t} \tag{2.5}$$

For the earnings E_t and E_{t+1}, we take the operating profit as reported in the respective firms' annual report in year t and year $t+1$. For the market index, obtaining an accurate but low resolution trend is quite cumbersome. The process to get there requires some degree of smoothing, which will be done by taking a long running average of the daily values of the index. Then, the end of year values are determined by taking the average index value from the smoothed index, with:

$$M_t = \frac{\sum_{t=1}^{n} M_{S_n}}{n} \tag{2.6}$$

Where M_{S_n} is the smoothed value on day n, and n ranging from 6 months prior to t to 6 months after t.

The accounting beta obtained using equation Equation 2.3 requires one last step in order to arrive at a relevant asset beta. This step is necessary due to the use of just historical data to calculate beta, which does not take into account the mean reverting feature of the variable. According to Chang et al.

(2007) accounting variables are a good measure of indicating systematic risk. However, the betas used include a correction towards the mean. Therefore, in this thesis, I will use a similar method of including a mean reversion correction. The application of this correction is seen in Equation 2.7.

$$\beta_A = \alpha + (1 - \alpha) \cdot \beta_E \tag{2.7}$$

Here, α is the correction factor, which is based on historical smoothing, with a higher correction factor leading to a beta that is closer to one. For the purposes of this thesis, a correction factor following the suggested rule-of-thumb (Mirzayev, 2019) of 0.33 is used. Whilst the specific adjustment factor could be obtained using historical statistical analysis, the main purpose of the beta calculation is to give a broad indication of risk. Because I am not interested in the specific number, but more so in the range of beta's, the rule-of-thumb based beta should provide sufficient information to answer the question of the type of asset risk profile one can attribute to the DSO's.

In terms of analysing the resulting beta, beta's below a value of 1 indicate that the respective stock or firm's earnings are less volatile than the market. Low volatility compared to market generally indicates a low risk profile, and typical values for low risk enterprises are in the $0 - 0.8$ range (Berk and DeMarzo, 2017).

Now that all the tools, concepts and frameworks used in this thesis are presented and thoroughly discussed, the next, and last section will combine these theories in a single introductory overview that will be expanded upon in the next chapter.

2.6. Introductory overview of the Dutch System

With all of the theory established in the previous sections, we can create an overview of the Dutch distribution system in terms of actors and relations between these parties. In chapter 3 these relationships will be explored in a more in depth manner, but for now we will try to describe the system as a whole and link this to the theories discussed in this chapter.

The dutch energy utilities have been studied in depth in the study by Hancher et al. (2008), who specifically looked into the effects of regime change on infrastructure investments. I will use their findings to present an overview of the Dutch case, link it to the principal agent theory and the more recent developments and finally provide the structure for the main findings of this thesis.

Mapping the system

Looking at the early years of energy market liberalization, Hancher et al. (2008) have found that the liberalization, unbundling of ownership and the shift in public/private relations have a substantial effect on the investments that are geared towards the long term. This notion of regime-change has made these investments more splintered due to an uncertain investment climate. Part of this uncertainty can be attributed to the regulatory regime employed by the regulating authority of that time (Called DTE (Dienst Toezicht Energie, which in itself was part of the NMa (Nederlandse Mededingingsautoriteit). These organizations have since been replaced by the ACM (Autoriteit Consument & Markt), which is currently the responsible party with regards to the regulatory regime. However, the regulatory scheme itself has not been subjected to substantial changes, as the DSO's in the Netherlands are still regulated using a yardstick competition-based system that contains some quality of supply elements. Therefore, the conclusions made in the WRR report on this system still hold some value today.

Another key message from the study is the abundance of conflicts that have arisen between the agents (in the form of industry firms and the consumers) and the multiple principals (in the form of national and international authorities). The new liberalized market has introduced more actors into the mix that have varying goals and interests. The former vertically integrated utilities have been split up into commercial suppliers that compete in a liberalized market and publicly owned infrastructure firms that are still regulated. In addition, new electricity supply firms have been steadily entering the market, thereby increasing the number of actors and creating an even more varied pool of represented interests (these new firms have also split up their political representation through new trade associations and similar organizations). On the whole, it has created a more competitive and distrustful environment that is still in place to this day. In the next chapter of this thesis, I will delve into the different actor relationships from the DSO perspective in order to show how these parties are currently affecting the DSO's behavior (with a focus on investments). Because these relationships have strong principal-agent characteristics, the theory discussed in this chapter forms an ideal theoretical basis that can be used to evaluate these relationships.

The governance of the electricity sector plays a vital role in this discussion, warranting a deeper investigation. With regards to the involved parties, we observe that DSO's are operating in a framework of energy policy set by multiple ministries and multiple levels of government. Furthermore, they are under the constant supervision of the regulating authority, now the ACM, which has obtained a position of strong authority in the Netherlands. As I will argue in the coming chapters, this dominant position of the regulator is contributing to a wait-and-see approach of the DSO's when it comes to large and risky investments. This is partly caused by a tariff system that is flawed in the sense that it is very difficult to established the correct and *right* tariff rates. As discussed in section 2.3, the rates need to be reflective of the true cost, as setting them too low leaves no room for new investments and setting them too high hurts the consumers through high electricity costs. Because the needed investments caused by the energy transition policies still need to take place within this regulatory framework, I will zoom into the specifics of this system in chapter 4.

A last crucial aspect of this discussion of the Dutch system is the fact that some actors in the network (producers, but also the DSO's themselves) are undertaking new types of activities that are a clear departure from their classical activities. For energy suppliers, it means developing new renewable assets that have characteristics of short development times and are heavily subsidized. For the DSO's, it means experimenting with new transport and storage technologies, implementing smart grid management systems and reinforcing the grid "*ab ante*", without the certainty of grid use that exists with more classical developments such as coal and gas power plants, new neighbourhoods and industrial parks. Due to the fact that these roles and activities are shifting, I will discuss these developments in more detail in chapter 5.

Structuring the findings

Given the system discussed above, the findings of this thesis will follow the following structure. First, I will present the system as a whole, zooming into the specific relationships between actors of interest, and evaluating these relationships using principal agent theory. I will show how the multiple actors and principals have misaligned goals in the context of the energy transition (i.e. not every actor is pushing the DSO to invest in grid reinforcement in the same manner). These varying relationships are creating an investment climate which is still very uncertain and is contributing to the "*risk-averse*" approach to investment of the DSO's (Risk averse in the sense that the DSO's require a certain measure of guaranteed return on investment before actively pursuing these investments).

After presenting the entire system in chapter 3, I will discuss the regulatory relationship between the DSO's and the ACM in particular. The strong position of the ACM and the incentives that are in place in the Dutch regulatory system are one of the main causes of this tentative approach to new investments. Hence, the DSO's are looking at the ACM in terms of regulatory support for new investment activities when sufficient returns are not near-certain. This effect of regulation on financial behavior can also be clearly observed in the financial analysis I performed in this thesis, as I will show in this chapter.

Lastly, after the discussion on regulation and its effects in chapter 4 I will present the final aspect under consideration in this thesis in chapter 5, the new development of renewable assets and the changing roles of the relevant actors. Here, the relationship between the DSO and the energy producer is examined and I show how the new role of small assets is causing the widespread congestion issues mentioned before. Finally, this chapter will also consider some solutions to the problem and focus on one of these solutions in particular, the regional energy strategy.

3

Inter-organizational relationships and their effect on DSO investment behavior

In this chapter, I will discuss the actor network surrounding the Dutch DSO's, and how this influences their investment behavior. I will start with a general introduction of the network, building on the discussion at the end of the previous chapter. After that general introduction to the system we will zoom in on particular actors and the effect they have on DSO behavior. Some of the actors have a particularly interesting relation with the DSO, for example due to being shareholder and stakeholder at the same time. These types of relationship will receive some extra attention in this chapter.

This chapter is also the primary application of the principal-agent framework described in chapter 2. I will discuss the relevant relationships in terms of the concepts mentioned in the theory by Waterman and Meier (1998) and the basic concepts from Mitnick (1973). However, I will only include the goals and relation-classifications where they are either explicit or very strongly implicitly suggested. In other cases, I will discuss the actor relationships in terms of what sources say about the topic, as the theory cannot always accurately describe the nuances of reality.

The goal of this chapter is to build a broad understanding of the actor network and discuss why the topics of regulation and investment uncertainty due to the new roles of actors are of particular importance. To that end, this chapter is used to mainly build the surrounding context and provide the overview in which the next two chapters discuss a particular element.

3.1. The DSO actor network

In terms of the complete actor network, a lot of parties affect the DSO through regulation, network use and oversight. From a system perspective, the DSO is governed through the laws and regulations set by the ministry of economic affairs and climate (EZK), and is affected by the spatial planning laws and documents under the authority of the ministry of internal affairs (BZK). These ministries in turn affect the rules and guidelines that are created by the provincial governments, which in turn flow down to local municipal rules and guidelines. Most of these parties are in a principal-agent relationship with the lower entity, where the lower government acts on the interest of the national governments (Of course, local election do affect the particular political colour of certain lower bodies, but the general direction of the national government is leading).

The regulator is of course a major actor for the DSO in terms effect on investment behavior. Through the regulatory scheme that is enforced by the ACM, the DSO exhibits the kind of economic behavior that is incentivized by the regulatory scheme. The regulator is a prime example of a principal in a principal-agent relationship with the DSO, where the goals of the regulator and the DSO differ in the classical example. This relationship, of course, will be extensively covered in chapter 4, but I will provide some starting points in the next section upon which chapter 4 builds further.

Next, the energy producers are having a major effect on the DSO behavior through their developing of new distributed generation projects and forcing the DSO to invest in its grid. The mismatch of information between these actors will be extensively discussed in chapter 5, but in this chapter I will look more into the specific relationship between these two parties, including a short section on how this relationship has changed over the years and what the effects of this change are.

Lastly, the consumers affect the DSO through their use of the network and the type of consumer behavior. Self-employing small scale renewable generation, demand-response in the network, energy saving behavior and more of these examples all affect how the DSO needs to manage the local grid, and can, in turn, have a profound affect on the investment behavior of the DSO's. These types of actions, in combination with the new projects started by the energy producers are forcing the DSO's to adopt new roles and activities, setting up test-beds for energy storage technologies and smart grid management.

To put all of this in some easy perspective, the overview in Figure 3.1 visualizes the network of actors, with the small P's and A's indicating principals and agents in their respective relationships.

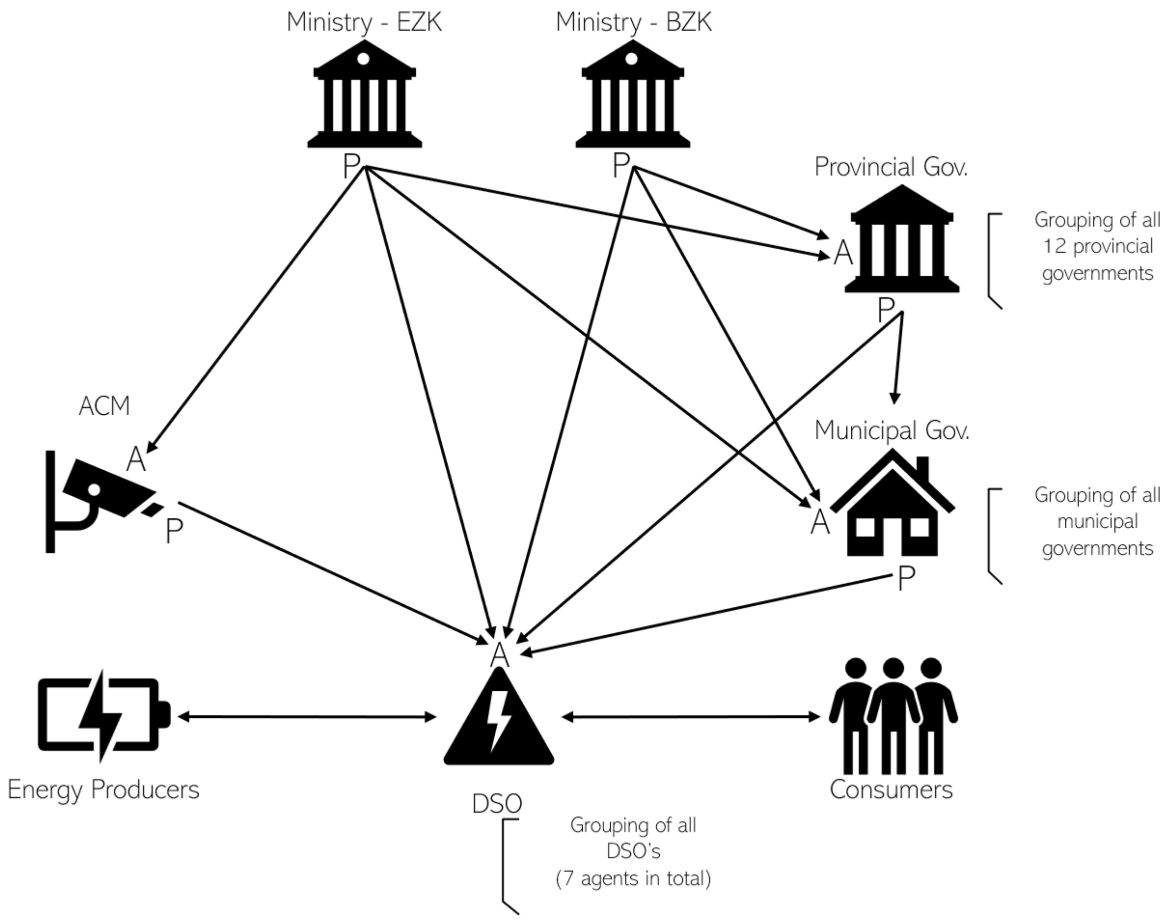


Figure 3.1: Graphical overview of the different parties in a principal-agent relationship within the network.

As can clearly be observed in the above figure, the DSO is in an agent position with respect to the majority of its relationships. Of course, the actual complexity of the network in reality is much higher, but it does show that the DSO represents the interest of a variety of parties. This is something that makes the transition policies so difficult, as they push the DSO in a direction that does not necessarily match what the other principals require of the DSO. More on this will follow in the section discussing the multiple levels of governance, but let us first zoom into the relationship between the DSO and the regulator.

3.2. The DSO and the regulator

The relationship between the DSO and the regulator is, at its core, a classical principal-agent relationship. The specific effect of the Dutch regulatory system will receive more attention in chapter 4, but this section looks at the relationship in terms of actor dominance and goals. The ACM, as the Dutch regulator, is an agent of the ministry of economic affairs (EZK in Figure 3.1), and is responsible for oversight on the operation of the DSO's, and for enforcing the regulatory scheme. Both the DSO and the ACM have particular goals regarding the efficiency of the system and the realization of the climate agreement, in their role as agent of their governing principal:

- "*Efficiency*" - In terms of efficiency, the main goal of the ACM with respect to the DSO is to have efficient grid investments, as this leads to the lowest consumer costs. From the ACM website, we read the following goals with respect to the regulatory regime: Keeping the tariffs at reasonable levels from a society perspective, stimulating grid operators to go about their business in an efficient manner, and making sure that the DSO's get enough income to offer a reliable service and help make the energy provision system more sustainable (ACM, 2020f). With regards to this topic, we can find similar goals for the specific DSO's. For example, Stedin mentions how they are striving to keep the grid as reliable as it is today, and Liander mentions how they work each and every day on reliability and affordability through efficient labour (Liander N.V., 2020c).
- "*Climate & Sustainability*" - With respect to climate and sustainability, the ACM is mostly concerned with two main topics. Firstly, the ACM is concerned with consumer protection regarding sustainability, and has mentioned that they are going to pay extra attention to providing the right information about sustainable services. They wish to make sure that parties are aware what kind of obligations arise from claiming sustainable services (i.e. they are trying to protect consumers from greenwashing). Secondly, the ACM is concerned with making sure that the DSO's are performing their legal obligations in the energy transition, both in terms of keeping the prices low, as well as supporting the energy transition with their infrastructure. Here, they wish to make sure that grid operators do not exploit services that could be operated by commercial market parties (ACM, 2020d). The DSO's mention similar goals, with Stedin mentioning how they are striving to build the energy system of the future by working together with all the relevant parties (Stedin, 2020b).

Of course, the ACM and the DSO operate from a different viewpoint in terms of available information. Therefore, some nuances regarding the information asymmetry can be observed:

- "*System complexity*" - The ACM is mostly concerned with the regulation of the DSO's from a financial viewpoint. Whilst the regulatory system employed does require extensive knowledge on the functioning of the grid, as the network becomes more complex, the ACM is losing more information with respect to the DSO's. Most of this can be attributed to the new ICT that is part of smart-grid infrastructure (one of the forces of the new system as mentioned by Glachant (2012)), but even storage and hydrogen systems can add to this information disadvantage.
- "*Regulatory information*" - The ACM has a large amount of information available regarding practices that fall under regulatory supervision. However, the DSO's often fall under a larger parent company that is specialized in more than just the network operation. Due to this, the DSO's have an information advantage with respect to internal financing, and could, in theory, shuffle around some of the costs to appear less efficient than they actually are. The fact that this type of cross-subsidizing between internal holdings is possible does not mean that it is actually occurring, but the possibility does give the DSO a more powerful information position.

The relationship between the ACM and the DSO's is one following the classic principal-agent model, where the goals between the two parties conflict in theory. Due to being close to a classic example, we can use Mitnick (1973) to make a clearer analysis of the relation. Looking at the possibilities, we see that the DSO's are allowed to act quite independently as long as they meet the efficiency standards. However, the regulatory system is quite absolute regarding not meeting the standards, so we can say that the DSO has some discretionary freedom only in how to accomplish the goals set by the ACM. In that regard, we can say that the ACM is in a very dominant position in the Netherlands, and this is something that is reflected in the discussions on new types of regulation (more on this will follow in chapter 4).

One of the interesting facts of this relationship between the ACM and the DSO is the fact that there is a degree of goal alignment regarding efficiency. Due to the incentive system, both parties are striving for efficiency gains, where the competition from the other DSO's is driving a single DSO to be as efficient as possible. This fact could be one of the reasons why the incentive system works so well in achieving efficiency gains, as an agent that is serving its own personal goals is a motivated agent.

However, this relationship is changing in the energy transition, as the original efficiency goals cannot be strictly kept if a system change is to occur. From this perspective, it is likely that the DSO's and the ACM could return to the more classical version of the principal-agent relationship where the ACM checks investment plans to see whether or not the DSO is over- or underinvesting. In this new reality, the ACM does not necessarily lose its historically dominant position, stressing the fact that one of the avenues for solving the current congestion problems needs to be the critical examination of the current regulatory system.

3.3. The DSO and multiple levels of government

The relation between the DSO and the government parties is another example of a relation that has a critical effect on the investment behavior of the DSO. Given that the ministries create the policy that determines how the entire energy-system will look in the future, layout-wise, make-up wise and actor wise, one could argue that these actors have largest effect the subsequent behavior of the DSO.

Looking at the Dutch perspective and the network presented in Figure 3.1, the three bodies examined in this section are the ministry of economic affairs, the ministry of internal affairs and the provincial governments. Starting with the ministry of economic affairs, we find a couple of interesting facts with regards to its goals:

- Firstly, there is a deep and thorough belief at this organization in the functioning of the market. From the interview with Netbeheer Nederland [Appendix section B.2, p. 101], this market paradigm determines the viewpoints of the organization regarding how its problems need to be solved. Therefore, having a well functioning, market-based energy system is something that is actively pursued by this ministry. This means that if organizations such as the DSO's start to mentioning that leaving this transition to market forces, or that more integration between the market parties and the regulated parties is needed, a conflict arises. It means that the challenges created by the energy transition are being partially created by a drive from the ministry towards this energy market ideal. Of course, in what amount this fact actively contributed to the challenge at hand is hard to say, but it is nonetheless worth mentioning.
- What we do see from the ministry is a very clear and collaboration-based approach to the climate crisis. One only has to view the "pillars" in the climate agreement that great care is being taken to reach solutions that are supported by a wide variety of actors. With regards to the energy grids, we can read that a lot of possible solutions with regards to mismatch between market party project development and infrastructure reinforcement are mentioned and explored (Rijksoverheid, 2019b).

In terms of the relationship between the ministry and the DSO, we see a classical liberal Dutch approach, where there is emphasis and focus on creating the right boundary conditions for the realization of goals through market parties. Here, the ministry clearly gives discretionary power to both the DSO and the market parties and, to a certain regard, trusts in the system to sort itself out. Given that the goal achieving these climate goals in society are quite broadly accepted and shared by the DSO's and the market parties, the amount of goal conflict between the parties is limited on this topic. Therefore, using the framework or Waterman and Meier (1998), this relationship can be classified as the "policy subsytem" version of the principal-agent relationship.

Similar comments regarding goals can be made about the other ministry in the network, the ministry of internal affairs, although I collected no primary source knowledge on similar paradigms within this ministry. However, a more interesting fact to mention is the fact that the different agenda's that are allocated to particular ministries mean that the realization of goals set by the ministry of economic affairs are also very much dependant on policy made at the ministry of internal affairs. A very good example of this is the new "Omgevingswet", and the "Nationale Omgevingsvisie (NOVI)" that is a part of this.

This "Omgevingswet" can be seen as a decentralization law that tries to give more authority to the local governments, with the exception of the areas that are declared to be of national interest, and thus accounted for in the "Nationale Omgevingsvisie". This trend towards less central governance is in start contrast with the call from i.e. Netbeheer Nederland to move back to a system that is centrally orchestrated. However, a working system within this new law set can be accomplished by explicitly accounting for energy generation and grid infrastructure in the NOVI. We can already see some mentioning of this regarding the problems surrounding solar parks in rural areas, for example in the preference order for planning solar PV (Ministerie van Binnenlandse Zaken, 2019, p.61). A focus within the NOVI is to promote clustering (Ministerie van Binnenlandse Zaken, 2019, p.4) of solar PV, and the ministry also mentions efforts to provide the necessary space to create a new national energy system. However, we also see that the ministry places the responsibility of directing these planned systems with the provincial and municipal governments.

Moving towards the provincial level of government, we see another interesting effect on the relationship with the DSO arise. Because the provinces have the capability to more locally direct the initiatives towards the energy transition, they are involved directly in the RES programs and similar initiatives. Given that the DSO's are also at the table for these programs, the DSO's and the provincial governments work together in a direct sense, whilst the DSO is still an agent with regards to the regional grid.

It is also noticeable that the provincial governments perform a lot of own research in the local problems, and taking for example the province of North Holland, we find the following document (Leguijt et al., 2019) detailing the problems and possible solutions:

1. "*Grid reinforcements*" - Increasing the strength of the grid through reinforcement investments is the first solution mentioned in the report. However, the authors do note that there might be spatial planning and regulatory issues (Leguijt et al., 2019, p.81).

2. "*Other technical solutions*" - Other technical solutions mentioned focus on reducing redundancy requirements, ask for lower capacity connections or mention new innovative techniques. However, all of these have some measure of blocking force (through regulations or technological infancy)

3. "*Solving regulatory barriers*" - The document mentions the lack of support for pro-active investments from a regulatory perspective. With this in mind, the authors suggest that some form of loosening the binds is required for the DSO's to have the required manoeuvring space to make the necessary investments.

These general solutions are then specified with regards to the regional energy infrastructure, and show that the provincial governments have the capability to both gather the necessary knowledge whilst still centrally orchestrating a response. To that end, the provinces, under the guise of the RES programs, could take the lead in building the centrally organized response that Netbeheer Nederland is asking for.

3.4. The DSO and its municipal shareholders

The municipalities are a special type of local government in this thesis due to the fact that they are also the shareholders of the different DSO's. This means that there is potential conflict of interest within the municipalities with regards to dividend income increase due to high profits versus higher investments to solve local infrastructure issues, leading to lower profits and lower dividends. This specific problem is mentioned by Kalshoven (2020), where the DSO's are accused of extensive dividend payouts whilst they need to invest the money into the grid.

Looking at the actual numbers, we find that the dividend payouts over the last 8 years have actually remained relatively stable. This can be observed in Figure 3.2.

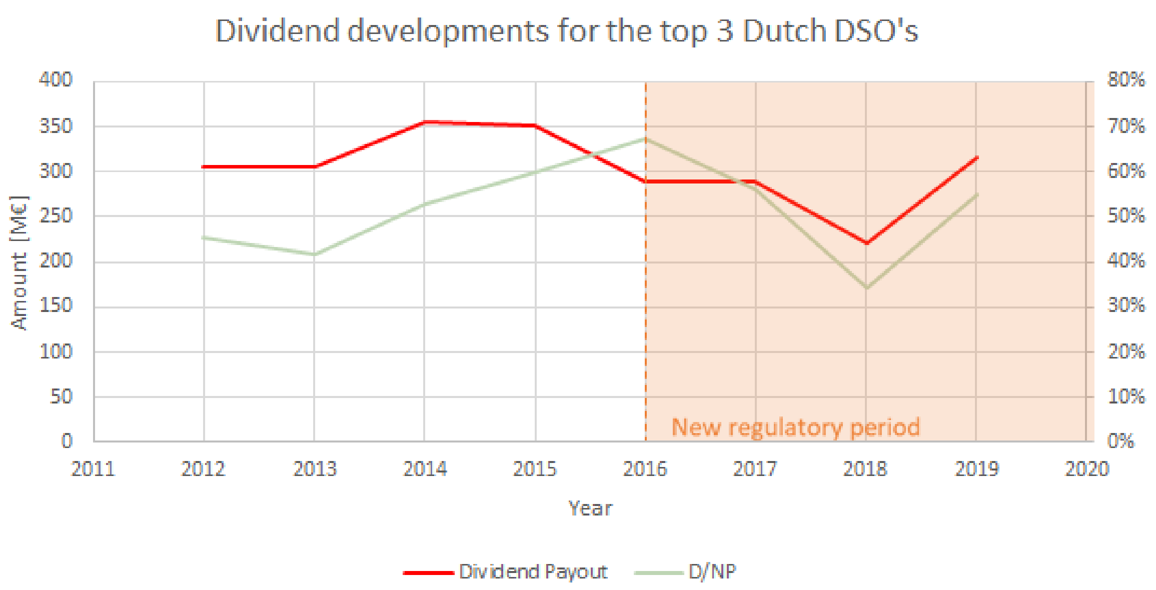


Figure 3.2: Overview of the top 3 DSO (Stedin, Enexis and Liander) divided payouts over the last 8 years. The left axis presents the total dividend payout in million euros, wheres the left axis shows the percentage of dividend/net profit rate.

Clearly, the total dividends fluctuate over the years, but there is no clear upward trend to be observed, whilst the investment trend shown in Figure 4.2 is clearly upward sloping. Therefore, I conclude that the notion that the DSO's are foregoing investments in order to please their shareholders, as suggested by Kalshoven (2020) is rather unfair. Even if we take into account the rest of the DSO's, as can be seen in Table 3.1, there is no clear increase in dividend rates. The smaller DSO's can be said to be slightly more likely to turn over excess profits as dividend, but nowhere is it apparent that the primary goal of the DSO here is to pay dividend to the municipalities.

Table 3.1: Overview of the DNP ratio (Dividends paid over net profits) for all the Dutch DSO's.

Year	Coteq	Enduris	Enexis	Liander	Rendo	Stedin	Westland
2011	-	0%	24%	35%	-	-	162%
2012	-	0%	41%	47%	-	49%	68%
2013	-	42%	52%	28%	-	47%	72%
2014	-	50%	45%	53%	-	61%	68%
2015	0%	59%	57%	65%	-	58%	76%
2016	425%	49%	61%	58%	57%	90%	62%
2017	0%	0%	43%	48%	71%	99%	87%
2018	0%	0%	39%	37%	75%	20%	100%
2019	44%	-	54%	58%	79%	48%	93%

If we consider this problem from a more relationship based viewpoint, we find similar results. For example, when asked to compare between municipal partners that were shareholders and municipal partners that were not, as is the case for parts of the Stedin area of operation, the interviewee mentioned experiencing no difference at all in terms of cooperation [Appendix section B.1, p. 101]. He then goes on to mention that this shareholdership is just the result of historic growth, and that the entire model of the DSO means that in the end, the books of DSO's are balanced by turning over left-over profits as dividend. This is something that can also be clearly observed in the annual reports of the smaller DSO's.

Municipalities are a very heterogeneous group of actors due to size and population differences. Therefore, it is very likely that say, the municipality of Amsterdam or Rotterdam has a much deeper information access than say, a small municipality in the east or north of the country (For an example about the region North Holland, see the interview with Liander [Appendix section B.3, p. 101]). This will, in practice, lead to a different effect on the DSO investment behavior per municipality, due large municipalities such as Amsterdam and Rotterdam being actively involved in local planning initiatives, and thus operating on a similar knowledge level as the DSO, whilst in smaller municipalities these activities are left to the discretion of the DSO.

Clearly, a fundamental information difference occurs here, and it is also interesting to note that most of the congestion problems seem to coincide with areas where the municipalities exhibit more of the small municipality characteristics. This lack of local coordination needs to be tackled through RES or provincial involvement, as it is unlikely that a small municipality suddenly hires a large team to work on local grid infrastructure.

3.5. The DSO and the energy producer

The energy producers are the most important party in the network that is not in a clear principal-agent relationship with the DSO. They are an independent market party, acting as agents for the government and the regulator to supply the energy that is transported on the grid, and they have a profound effect on the investment behavior of the DSO. This is due to their position as renewable generation project developers, that forces DSO investments in part of the grid. From the notes about the new regulatory period from the ACM advisory board meetings (REG2022), we can sense quite some tension between this party and the grid operators, mostly due to the producers calling out the operators on not fulfilling their legal obligation (ACM, 2019a, 2020b). Due to this calling out, they are putting pressure on the ACM to strictly control the DSO's, and this tug-of-war between the producers and the grid operators is creating a rather fuzzy problem, with most parties now questioning where the exact problems lie. Graphically, we can see this in Figure 3.3.

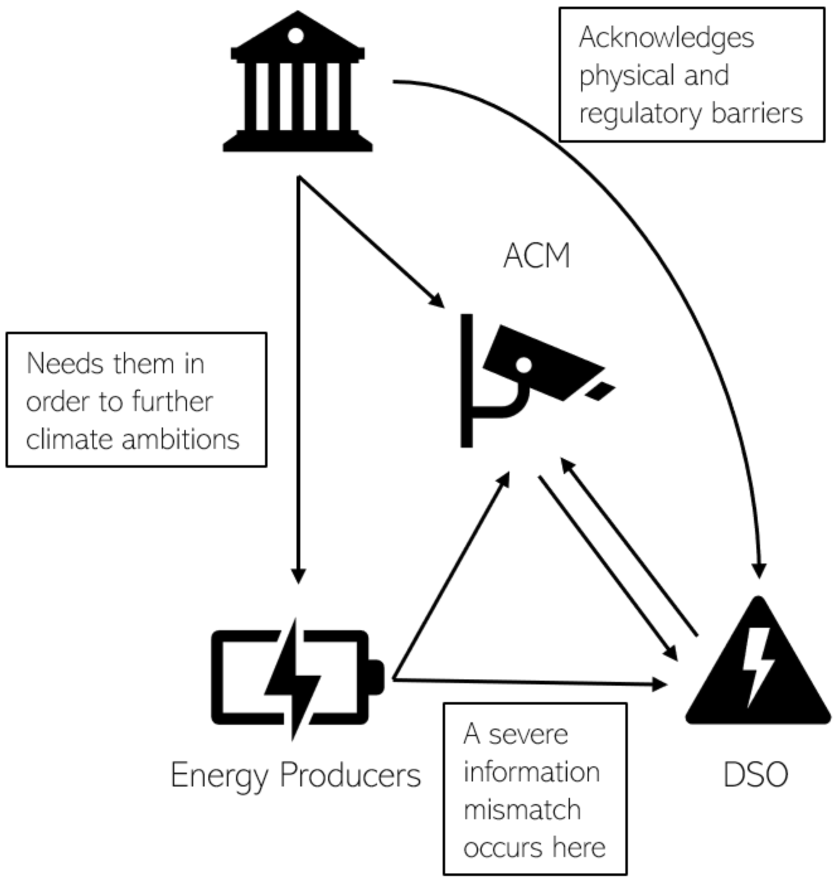


Figure 3.3: Zooming in on the network effect of the energy producers

As can be seen in the figure, from the top government level there is a push to further generation projects in order to satisfy the climate ambitions of the ministry. On the other hand, the ministry also acknowledges that there is both a physical and a regulatory/legal barrier that is preventing the DSO's from effectively doing their job. The ministry is also actively trying to remedy this by changing some of the laws, as discussed in the letter by minister Wiebes, but these processes take time. During this time, the energy producers try to initiate more projects, but they are blocked more and more by the DSO's incapacity to transport their produced energy. Connecting more and more producers only furthers this problem, but it is currently a legal obligation of the DSO's to connect new projects. Because of this, the producers are becoming dissatisfied with the DSO's, mention this to the regulator, who is open for a regulatory discussion, but also states that the DSO's are, by law, required to connect the projects (ACM, 2019b).

Examining the above flow of reactions between parties, it is clear that both the producers and the DSO's do not want to actively hinder the climate ambitions of the government. However, in the current regulatory framework, the information mismatch about new projects, combined with the speed that the energy producers have when initiating (due to short permit periods, see chapter 5 for more details), makes concrete progress very difficult. Therefore, a solution needs to either give the DSO's more manoeuvring room in the regulatory framework, making investments with a higher risk level easier, or the information mismatch about location of projects should be solved. This is also where the RES programs can be a big benefit.

In terms of the relationship between the DSO's and the producers, more coordination between their efforts can also solve the information mismatch. Historically, the DSO and the large producers were part of the same utility firm, and as such were more aware of each other's plans. One could say that in order to solve this mismatch, more inter-firm coordination is required, in a sense moving back towards a more systemic viewpoint. However such coordination is most easily realized by having some level of government orchestration. One of the ideas mentioned about this more systematic approach is mentioned by Ingrid Thijssen (at that time CEO of Alliander, parent company of DSO Liander) in the radio program BNR Energie, who mentions that an approach similar to how the Dutch government tackled the Deltaworks, with an independent commission as supervisor for such a large infrastructural work. Another idea that will play a central role in this thesis is to let the regional energy strategies serve as a tool for this coordination. More on this will follow in chapter 5.

3.6. The DSO and the consumer

The last specific relationship under the loop is the relationship between the DSO and the consumer and its effect on DSO investment behavior. For this particular relationship, it is important to consider that a multitude of consumers exist that have varying influence on the DSO's and their investment behavior. For the purpose of this section, I will discuss how small and large consumers can affect this behavior.

Large consumers, ranging from industrial production sites to data-centers can have a profound effect on DSO investment through the application of new smart-grid technologies. By, for example, being part of demand-response pilots, these type of consumers can reduce the stress on the grid in high congestion areas, making the urgency of investment slightly less critical. These types of technologies can be key in overcoming the large time gap between investments in the grid and their final realization 5 or more years later. Furthermore, a linkage between large consumers of electricity and renewable generation projects can reduce the taxing of the grid. An example would to link a local solar farm to the local factory or data center directly, reducing the stress on the transport capacity of the grid. If consumers and the DSO's can realize these types of initiatives, there is a huge potential gain. Of course, these types of activities change the nature of the DSO's core operations. A distribution system operator is no longer just an operator and maintainer, but an active network manager. It opens up possibilities for new types of departments within the DSO that focus on fulfilling this role as network manager. What is crucial, however, is that these activities will not match the current regulatory system, and a critical reflection of the role the regulations should have in this context is sorely needed.

Smaller consumers have a smaller individual effect on the DSO, but still, on site production and use of energy through home-based solar panels still affect the required transport capacity. And if local neighbourhoods take part in collective initiatives regarding these types of technology, the effect is multiplied. Therefore, smaller consumers can also play a large role in the un-taxing of the grid (another example here is charging electric vehicles and coupling this to a demand response unit in the local grid). Once more, the change of the nature of the work for the DSO's arises, stressing the fact that these developments require serious attention within the surrounding framework of regulation and governance.

3.7. Concluding Remarks

To conclude, this chapter explored the relationships of the DSO with the other actors in the network and tried to present their effect on the investment behavior of the DSO. Some of the actors have a more clear and more profound effect on this behavior than others, but the most important point to take from this chapter is the fact that the goal alignment between the DSO and the multitude of influencing actors (some as a principal, but not all) is causing the DSO's to be caught between parties in a slight "tug-of-interests".

- The most clear effect on the investment behavior of the DSO comes from the multiple inputs from different principals. From economic affairs and the other ministries, there is a core goal of realizing the energy transition, and the DSO's are pushed in this direction as well. So from the ministerial perspective, new investments are necessary, and critical to the success of their agenda. However, there is also a deep-rooted paradigm of believing in market mechanisms, that leaves the execution of the agenda up to the market. Therefore, the governments are trying to create to best possible boundary conditions, but are not actively intervening. From the other direction, the DSO is still getting mainly efficiency incentives from a regulator that is in a very dominant position, that push it to be a risk-averse investor. The conflict between these two forces can be seen as a major cause of the current problems, and it is critical that the mismatch that exists here is solved through either a reduction of the investment risk, making the government agenda achievable under the current system, or by changing the regulatory system to allow more risk. This change in the regulatory system will be discussed in the next chapter, chapter 4, along with a more in-depth exploration of the relationship between the DSO's and the ACM.
- Similarly, the DSO is experiencing different regional effects depending on the specific province, municipality and other actors that exist in these local areas. Large municipalities make the coordination of the grid easier, but also give the DSO less discretionary power.
- The dividend effect from municipal shareholders was also examined. Here, the conclusion is that the shareholdership of the municipalities is not necessarily hindering DSO investment rates, as the dividends are mainly a book closing tool that have not experienced serious increases over the past few years.
- The relationship between the DSO's and the energy producers is deteriorating as a result of the tug-of-interests, whilst both parties would benefit enormously from a more centrally coordinated effort. A large cause of the tension between these two parties arises from an information mismatch that was not present in the historic bundled utility. To that end, it could be a good idea to try to emulate this type of internal information sharing by using a government-coordinated tool to share information. This could be done by using a program such as the RES (This avenue of solutions will be more thoroughly explored in chapter 5).
- The relationship with the consumers is also experiencing change due to the fact that consumers are slowly becoming active network participants. This changes the DSO operations to that of a network manager, but this changing nature of the work needs accommodation within the regulatory system, which is currently not yet the case. More on this topic will follow in chapter 4 and chapter 5.

All in all, the relationships within the actor network have a profound effect on the investment behavior of the DSO through goals being pushed down from principal to agent. Misalignment in these goals in one of the reasons DSO's, in an effort to please most principals, are investing in a tentative or risk-averse manner. Furthermore, the changing nature of the DSO's role in the network is creating a need for a critical evaluation of the regulatory system in the context of these changes. To that end, the next chapter will explore this problem more deeply.

4

Dutch Regulation and its impact on grid investments

In this chapter, a deeper exploration in the effects of regulation on the investment behavior of the Dutch DSO's is presented. Also, the results of te interviews with regards to regulation will be discussed. First, I will present the findings from literature regarding the topic, where we will consider both the observed regulatory effects from empirical analyses, as the literature on how these kind of schemes could be changed in the future to better accommodate transitional investment requirements. Then, in the second section, the specifics of the Dutch regulatory regime will be discussed, including the results of the financial analysis regarding how this system is reflected in the results. Lastly, the research findings from the interviews will be discussed in section 3, followed by some concluding remarks on the topic.

4.1. Regulation & Investment - Findings from literature

The links between DSO's, investment and regulation have been a subject in scientific literature on regulation of network industries for some time. It is especially important to consider that the current DSO's are experiencing a vastly different world that is bound to different rules and systems than the organizations of the past. For that reason, it is quite important to consider how the system has changed, and is still changing when researching possible alternatives to the current regulatory schemes. To that end, this section will start with a description of these phenomena, followed by shorter section detailing effects of current regulation schemes on DSO's all over the world.

4.1.1. Forces of change in a new system - Regulatory impacts

When the DSO and the regulation of the future system needs to be considered, it is critical to make these observations from a broad viewpoint. Glachant (2012) describes these new reality of regulating a general network firm, and mentions the following three forces of change:

1. **New information and communication technology:** The rapid advances in ICT have enabled methods of active measurement of parts of the grid. Large amounts of data that is easily accessible has created new opportunities for revenue increase and cost reduction whilst being less clear it terms of regulatory oversight.

2. **Fluidity of innovation, commercialization and application:** The continuous development and change of new products, ways of implementation and use that arise in the industries that employ active use of innovations leads to a lack of expertise within the administrative bodies. According to Glachant (2012), the fact that these bodies do not actively participate in the creation of these practices is one of the underlying causes for this knowledge gap. It leads to practices that are less easy to evaluate and control, making the job of the regulator more difficult.

3. **Modularity in the production and usage processes:** Due to the step-wise process of innovation and usage processes, Glachant (2012) notes that the required adaptations become more

uncertain. He states that clusters of innovation can impact modules of the network, and that these processes, in turn, disturb regulation. The challenges stemming from this modularity impact all network parties, but also gives rise to new opportunities. For the administrative bodies, this means they have the opportunity to build new roles for themselves. Through the creation of certain public channels, a more even distribution of information can be achieved, making the overall regulation easier in the long run.

All of this shows that the regulatory body in this day and age has to evolve in order to accommodate the system-wide changes induced by the new realities. Hence, the entire regulatory process has to evolve. If one takes the general phenomena described by Glachant and translates them to the case of the electricity distribution grid, we can observe a number of distinct changes that have occurred over the past few years.

First among these are the new options provided by distributed technologies (Perez-Arriaga et al., 2017) such as flexible demand, distributed generation, new storage options and new monitoring and control technologies. The large variety of these new options shows just how complex the task for a regulator can become, as the classical notion of a simple operator that transports power over a grid is no longer applicable. Instead, the distribution system operator has become an active network manager that should not only provide the necessary infrastructure, but also needs to build a strong and robust management system to take full advantage of the advances in smart grid technologies. In a sense, the DSO is becoming an increasingly complex type of firm, and the type of regulation that is needed to control these firms needs to adapt accordingly.

Clearly, the emergence of innovative technologies all along the grid, whether based on new ICT or other types of modular change, are creating an environment where the regulator has to control a system that is moving ever further away from the past system. And if the regulator does not adapt accordingly, the entire system that has been built up can start slipping away as more and more innovation changes occur.

Secondly, the organization of the sector has been undergoing a distinct change over the past two decades through the liberalization and unbundling of the previously vertically integrated monopolies. This has led to the creation of new markets, new regulations and even new companies. As described by Correlje et al. (2012), the increasing number of actors that have entered the network through these events require more complex regulations and institutions. Part of this growth in number of players can be attributed to the rise of modern information communication technology, enabling, i.e. wholesale electricity markets that operate on an international scale.

This system and institutional change creates additional challenges for both the DSO and the regulator. An increasing number of parties requires the services of the DSO on the grid, whether through transport capacity or more ICT-based requests. The DSO, in turn, feels the need to diversify its activities in order to meet these new requests in a satisfactory sense. Thus, the regulator is now dealing with not only a more complex DSO, but also more societal and inter-network interests.

4.1.2. Designing a new regulatory framework

Given the enormous challenge of the system-wide change, how should the regulation adapt in order to provide the incentives needed for a robust and efficient grid? This is one of the key questions asked by authors when considering new types of regulation schemes. Returning to Glachant (2012) once more to get a general idea, the author identifies a set of four themes that play a key role in the design of new regulatory regimes:

1. A refreshed interest in the fixed-cost allocation of the regulated firm, putting up for discussion the way in which these fixed costs are distributed among the various concerning actors. An example of this theme is putting up for discussion whether generators should pay for transport costs during peak load times or at all times, redistributing the total system cost of the network;

2. How property rights are defined and allocated, with a clear emphasis on the fact that new innovations introduce even more interested parties, use-cases and complexity to the system. Glachant (2012) mentions how the regulator still has a key role in allocating the property rights in the system, and defining how access and usage rights are distributed amongst the interested parties is

key. To put this point in some perspective, in the Netherlands there is a so-called "aansluitplicht" (Connection requirement) which says that by law, the DSO should connect any party that wants to use the electricity grid (more on this will follow in chapter 5). Whether this "aansluitplicht" should still exist in a modern regulatory regime is one of the questions that should be asked, and fits with the theme of reallocating property rights;

3. The way in which management of network externalities has changed from a single integrated operator to the concern of many affected parties. The author finds that regulators need to spend extra effort to design and control schemes, citing the example of how current congestion management methods are working well in with short-term goals in mind, but are useless in the long term. Similarly, new attention has to be given to positive externalities that have arisen over the past few years such as interconnections and new types of services. These phenomena have given rise to a more globalized and privatized system, and such a system requires more open operating standards;

4. With regards to the core functionality of the regulator, the promotion of the 'public good', the author describes the possibility of an open forum approach to regulation, where the regulator can, as a neutral party, make a substantial effort in reducing the information asymmetry present in the market. According to Glachant (2012), the regulator must account for the interests of various stakeholders to give these open forums enough consistency to be useful. He mentions soft, incremental regulation as a key component where the regulator actively tries to not violate single other parties through significant and near-instant change.

The themes described by Glachant (2012) are rather broad in scope, and intended to be viewed from the perspective of network industries in general. In a few of the points, I have added some examples that apply explicitly to the electricity grid and the regulation there-off. However, it is still quite interesting to see in what manner these developments have been taken into account when considering new methods of regulation being designed by researchers for the electricity sector. To that end, Perez-Arriaga et al. (2017) describe a framework that can be employed in the restructuring of regulation for the electricity sector. Within this new framework, the authors describe four aspects in particular that are subject to change. These aspects are:

- A more comprehensive and detailed set of prices and tariffs, so that these reflect the actual incremental costs of providing the necessary services;
- Improving regulation with respect to the DSO's with an emphasis on cost reduction, better performance and more long-term innovation and investment;
- A more careful assignment of responsibilities within the electricity system, with a focus on minimizing the potential conflicts of interest that can arise;
- A collection of improvements to the way in which the wholesale market is currently designed. Here, the focus is on better integration of distributed resources, more rewards for flexibility and distortion minimization.

Looking at this set of aspects, it is clear that the authors are looking into new ways of distributing both costs and responsibilities (Point 1 and 2 from Glachant (2012)), but the fact that regulators could create a whole new system based on the open forum approach is not mentioned. Whether this is truly surprising can be questioned, as implementing a system based on open information sharing is a very significant change. If we take the gradual and incremental change mentioned by Glachant (2012) as key to achieving this open forum in the long run, we should not observe a lot of drastic system changes in the literature on future regulation. Looking at a couple of other studies into these schemes, we observe the following:

- **Niesten (2010)** - This study considers the impact of more distributed generation in the distribution grid of the Netherlands, and argues that regulation should stimulate coordinated investments in the network. To do this, the author suggests the use of a connection and a transportation tariff for the generators. In essence, the generator should pay for using the grid, with the DSO being able to change the height of these tariffs and vary them along parts of the network as to stimulate DG growth in certain areas. The job of the regulator is to not let the DSO overprice these transport tariffs, and to keep the overall price caps at a competitive level, as too tight caps can lead to under-investment, and thus to an overly taxed and congested grid in the near future;

- **van der Welle and de Joode (2011)** - This study tries to present a road-map for the Netherlands in terms of regulatory recommendations for the future system. The authors mention a series of key regulatory changes that are, in their opinion, necessary to accommodate the system change. Firstly, their should exist some form of innovation incentives for DSO's, as to stimulate these firms to solve congestion problems with new and innovative methods. Secondly, the regulator should use network simulation tools to effectively assess new investments. Thirdly, the regulator should evaluate its current system of network planning standards, as the current system is not built upon the premise that a lot of future energy will come from sources that vary from day to day. To this end, the standards should use an element of probabilistic reserve requirements instead of a static reserve. Lastly, the regulator should reintroduce use-of-system charges for the generators as to spread the cost of grid reinforcements to not just the consumers, but also the generators.

From the studies mentioned above we can clearly notice a focus on tariff design and a more accurate system of regulation with regards to the true costs. The elements of cooperation mentioned by the authors shows a slight move towards a more open system, but there is no clear or distinct mention of a system-change. It remains to be seen, then, how the open forum of information mentioned by Glachant (2012) is implemented in the future system.

4.1.3. Grid investment under incentive regulation

Before delving into the effects of the current regulatory scheme in the Netherlands, and the discussion on how this system has to change to accommodate the new investments required by the energy transition, let us first consider the effects of incentive regulation on grid investments in general. This topic has already been briefly considered in the introductory chapter of this thesis, so let us revisit a couple of the studies mentioned in that section.

First of these, Cullmann and Nieswand (2016) describe that the investment rate of German DSO's has significantly increased since the implementation of incentive regulation in 2009. The authors do mention that the existence of base years influences the timing of these investments, as there is a strong incentive to strategically invest when this leads to a higher rate base in the following regulatory period. The study of Cullmann and Nieswand (2016) shows that incentive regulation has a strong effect on DSO investment incentives, and that particular attention should be given to how regulation can affect investments under the transition policies of the energy transition.

Given that regulation schemes differ substantially from country to country, the effects of Dutch incentive regulation on investments are of particular interest. Haffner et al. (2010) examine the investment behavior of Dutch DSO's in the period of 2001 to 2008, when incentive regulation was first implemented in the Netherlands. Their area of focus was on the supposed reduction in network quality that occurs when shifting from cost-of-service regulation to incentive regulation. The authors found no evidence of investment cancellation or postponement, and mention that the regulatory system has instead induced a more professional attitude towards investment.

These findings are somewhat surprising when considering some more theoretical viewpoints on the subject. For example, Guthrie (2006) mentions how incentive regulation places the risk of investment more the shareholder side as opposed to the consumer side under cost-of-service regulation. This shift in risk should, according to Guthrie, lead to a lower investment level under incentive regulation, as firms are no longer guaranteed recovery of their costs.

Considering the empirical and theoretical research on this topic, we can conclude that DSO investments are not driven solely by the regulatory regime. In this case, I have to agree with Haffner et al. (2010) that the culture at the Dutch firms (mostly technicians that pride themselves on a quality service) and the specific national make-up of the regulatory scheme considering efficiency and quality incentives do not necessarily lead to under-investment. However, with the recent years showing more and more congestion problems occurring on the Dutch grid, the key question that arises is whether this Dutch scheme is still capable of providing the right incentives for DSO's to invest efficiently. Note

that investing efficiently can of course be taken into two different contexts, i.e. investing efficiently with regards to consumer cost or investing efficiently with regards to a system-change.
It is this second viewpoint which is much harder to accomplish under the current scheme. Recent literature on this particular problem comes to a similar conclusion. For example, Willems and Zwart (2018) argue that it is impossible for a price-cap to both limit the monopoly earnings and incentivize in-time investments. Therefore, they argue that regulators should employ a combined scheme, where both price-caps and output requirements lead to efficient behavior, with enough timely investments through harsher penalization of late investment. Similarly, Borrmann and Brunekreeft (2020) conclude that cost-based regulation is more effective in realizing investment when the primary goal of the regulator is to have sufficient investment. To that end, the authors suggest that regulatory schemes could use a hybrid version of the two systems, using price-based regulation for making operation as efficient as possible, and cost-based regulation for making sure investment is timely and sufficient.

Of course, these specific schemes and ideas are easier to implement on paper, as real world regulatory regimes are vastly more complex than the simplified forms studied by the authors. However, in general, the literature suggests that regulation has a profound effect on investment levels of DSO's, although this effect is not always necessarily negative. Furthermore, the literature brings home the point that regulatory regimes are ever-evolving, and should adapt to their relevant circumstances. This is especially critical in transitional times such as we are experiencing at the moment. In the next section, I will present the specific version of regulation that is employed in the Netherlands.

4.2. Specifics of the Dutch regulatory regime

As mentioned earlier, the DSO's in the Netherlands are all regulated by an authority known as the "Autoriteit Consument & Markt" or ACM. This regulatory body is responsible for regulating a whole range of industries, companies and networks, including the Energy market and grid. The ACM is an independent regulator that has close ties to the Dutch ministry of Economic affairs, given that this ministry is often responsible for the laws and regulations that the ACM tries to enforce.

The ACM is responsible for the regulation of both the transmission system operator (TSO) and the distribution system operators through its regulatory regime. How this regulatory regime is built up between the regulatory periods is decided during set decision intervals. In Figure 4.1 the three decision types and their relevance towards each other can be seen.

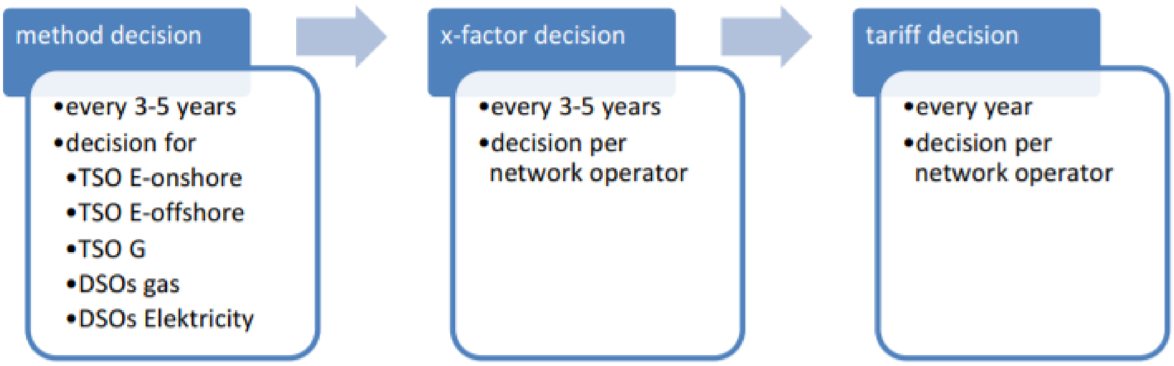


Figure 4.1: Overview of the decision process of the ACM; (ACM, 2017).

The first decision in the diagram, the method decision, sets the methodology employed to determine the allowed revenues for the different regulated parties. This decision is especially important due to the fact that it locks the regulatory system for another 5 years (given a "normal" regulatory period). This decision is currently being discussed in meetings with experts from the DSO's and other interested parties, and will also feature prominently in the next section of this chapter where I discuss the findings from my analysis. Given the fact that these types of decisions are crucial to tackle any regulatory shortcomings, the system employed by the ACM creates a window of opportunity for changing the system, but the lock-in that follows also limits the flexibility of the system. Therefore, it is fair to ask whether it is wise at all to still employ long regulatory periods in this time of transition.

Next, the x-factor decisions contain the actual calculations of the allowed revenues and determine the yearly cut in tariffs (based upon the x-factor). These are the decisions where the efficiency norm is enforced, and they contain the necessary steps to enforce the yardstick competition between the DSO's (i.e. the Dutch DSO's compete against each other in terms of efficiency, and are rewarded when being more efficient than the norm). Lastly, the tariff decisions are used to set the tariffs for all the individual parties involved, based on the x-factor decision and a set of tariff codes (ACM, 2017). These tariff decisions are made on a yearly basis, but the flexibility of these decisions is limited due to the longer period of the method decisions.

Following the decision scheme mentioned above, the Dutch regulatory scheme is based on the typical equations seen in incentive regulation schemes, with the addition of yardstick competition between the DSO's. The base equation used to determine the allowed revenues is discussed in ACM (2017), and looks as follows (see chapter 2 for the general version of this equation):

$$TI_t = \left(1 + \frac{CPI - X + Q}{100}\right) \cdot TI_{t-1} \tag{4.1}$$

Here, TI_t represents the total income in year t, and it is based on the total income of the previous year (TI_{t-1}) multiplied by a factor containing the consumer price index (CPI), an efficiency factor (X) and a quality adjustment factor (Q).

Using the above equation, the development of the annual income is determined, but at the start of the regulatory period (2016 was the most recent year in the Netherlands) the regulator also needs to determine a base efficient income. This base efficient income is calculated in several steps for the DSO's:

1. Calculation of the cost level of first regulatory year (2016 in this case) by taking the average total cost (ATC) of the previous three years;
2. Calculation of the sub-parts of this average total cost, which is made up of operational cost and capital cost. The capital cost can be further split up into depreciation and an allowed return on investments. This allowed return is based on a weighted average cost of capital (WACC) which is then applied to the regulatory asset base (RAB);
3. Calculation of the efficient cost level by taking into account the static efficiency of the DSO's. The ACM (ACM, 2017) describes that they use a system of yardstick competition to obtain these efficiency levels. This system takes the average costs of the DSO as a comparison, so DSO's under-performing will have to improve or take losses in such a system.

All of the above steps are part of an enormous operation that takes into account large data sheets from all the Dutch DSO's. To get an overview of what this process actually entails, box 2.1 contains a summary of some key calculations made for the regulatory period of 2017-2021.

Box 2.1: Summary of key calculations in the Dutch regulatory period of 2017-2021

Firstly, the ACM calculates the average costs (C_a) over the past three years, made up of sub-categories operational cost (C_{0_a}), capital cost (C_{c_a}) and a compensation for new connections (C_{n_a}), all in euros. The numbers for the 2017-2021 period are as follows:

$$C_a = C_{o_a} + C_{c_a} + C_{n_a} \tag{4.2}$$

$$C_a = 9.985 \cdot 10^8 + 8.838 \cdot 10^8 + 1.026 \cdot 10^8 = 1.985 \cdot 10^9$$

Next, the ACM uses these average efficient costs to find an average efficient cost for the last year of the regulatory period, so 2021 in this particular case. However, to obtain such a number, two values have to be estimated. Firstly, the consumer price index is not known for future years. Because of that, the ACM makes a calculated guess using the following system:

$$I_n = \frac{(5-n)}{5} \cdot I_{WACC_{start}} + \frac{n}{5} \cdot I_{WACC_{end}} \quad \text{for} \quad n = 1, 2, 3, 4 \tag{4.3}$$

Continuation of box 2.1
Where I_n is the inflation rate in year n, n is the respective year (Equation 4.3 is used for the middle years of the regulatory period, so 2017 - 2020, with $n = 1$ representing 2017), $I_{WACC_{start}}$ is the inflation in WACC for 2016, and $I_{WACC_{end}}$ is the inflation in WACC for 2021, with both of these numbers set at the start of the regulatory period.
Next, the average of these rates is calculated using Equation 4.4:

$$I_a = \left(\left(\prod_{n=1}^{4}(1+I_n)\right)\cdot(1+I_{WACC_{end}})\right)^{\frac{1}{5}} - 1 \quad (4.4)$$

Then, using the following values, the inflation rate per year is found to be approximately 1.2%

$$I_{WACC_{start}} = 0.77\% \quad \text{and} \quad I_{WACC_{end}} = 1.42\%$$

Secondly, the static efficiency of the DSO's needs to be calculated using the described yard-stick competition. To do this, the ACM takes the efficiency changes from the previous eleven years, and averages them out, arriving at a static efficiency (η_s) level of 0.69%. Now, the efficient cost level for 2021 can be calculated using Equation 4.5:

$$C_{e_{2021}} = C_a \cdot (1-\eta_s)^5 \cdot (1+I_a)^5 + C_{t_n} \quad (4.5)$$

with

$$C_{t_n} = C_{t_o} \cdot (1+I_a)^n \quad \text{for} \quad n = 1, \ldots, 5 \quad (4.6)$$

where $C_{e_{2021}}$ is the efficient cost level for 2021, C_{t_n} is the average estimated transport cost for year n (with 2021 being $n = 5$, and C_{t_o} is the average transport cost in 2016.

Using the calculated efficient cost level and a combined output based on actual production data, the ACM has calculated an expected efficient cost level per unit output of 0.962. This number means that over the course of the regulatory period, the DSO's total output is expected to improve by a factor of approximately 3.8%.

4.2.1. Calculation of the total allowed incomes

With the calculations presented in box 2.1, the ACM then calculates the x-level for all of the Dutch DSO's, which can be found in Table 4.1. Similarly, the relevant Q factors have also been included in the table.

Table 4.1: Overview of the X and Q factors for all the Dutch DSO's

DSO	Coteq	Enduris	Enexis	Liander	Rendo	Stedin	Westland
X-factor	2.21	1.94	2.13	1.9	2.12	1.99	2.25
Q-Factor	0.97	0.38	0.05	0	0.27	-0.13	0.19

The X-factors and Q-factors in the table can then be used to create the allowed income path for all the DSO's over the years within the regulatory period. Using Equation 4.1 and the starting values as supplied by the ACM (ACM, 2016), Table 4.2 can be fully filled in.

Table 4.2: Overview of the allowed income from electricity distribution (TI_t) for the Dutch DSO's in the regulatory period of 2017-2021. (Note that the Q factor has been excluded for from the formula as the ACM handles a Q-compensation separately)

DSO	Coteq	Enduris	Enexis	Liander	Rendo	Stedin	Westland
2016	€12.447.089,-	€69.920.814,-	€697.328.212,-	€859.915.989,-	€8.331.379,-	€538.182.019,-	€32.506.654,-
2017	€12.321.143,-	€61.458.957,-	€690.777.659,-	€853.820.373,-	€8.254.280,-	€533.895.114,-	€32.162.157,-
2018	€12.196.472,-	€61.000.544,-	€684.288.640,-	€847.767.966,-	€8.177.894,-	€529.642.357,-	€31.821.310,-
2019	€12.073.062,-	€60.545.551,-	€677.860.578,-	€841.758.462,-	€8.102.216,-	€525.423.475,-	€31.484.076,-
2020	€11.950.901,-	€60.093.951,-	€671.492.899,-	€835.791.557,-	€8.027.238,-	€521.238.199,-	€31.150.415,-
2021	€11.829.976,-	€59.645.720,-	€665.185.037,-	€829.866.950,-	€7.952.953,-	€517.086.261,-	€30.820.291,-

The numbers in the above table represent the allowed income for the Dutch DSO's as part of their electricity network distribution operations. Because the DSO's are also involved in the operation of gas networks, these numbers differ from total revenues reported in the annual reports. However, the numbers represent the total allowable income that is under the regulatory scheme. Electricity grid investments need to be recuperated through this income, and it becomes clear that these incomes still follow the classic incentive pathway up to 2021. The average transport cost (C_{T_n}) is later added to these x-factor based incomes to arrive at the total allowed income. This total income is defined as follows:

$$TI_F = TI_t + C_{t_n} \quad \text{for} \quad n = 1, ..., 5 \tag{4.7}$$

Using Equation 4.6, the following average transport costs are found for each year in the regulatory period in Table 4.3.

Table 4.3: Overview of the yearly transport costs for all the Dutch DSO's, with the starting costs in 2016 obtained from the x-factor calculation data-set (ACM, 2016)

DSO	Coteq	Enduris	Enexis	Liander	Rendo	Stedin	Westland
2016	€3.686.773	€10.246.056	€179.660.012	€167.595.992	€2.434.756	€113.058.990	€10.529.587
2017	€3.731.014	€10.369.009	€181.815.932	€169.607.144	€2.463.973	€114.415.698	€10.655.942
2018	€3.775.786	€10.493.437	€183.997.723	€171.642.430	€2.493.541	€115.788.686	€10.783.813
2019	€3.821.096	€10.619.358	€186.205.696	€173.702.139	€2.523.463	€117.178.151	€10.913.219
2020	€3.866.949	€10.746.791	€188.440.164	€175.786.565	€2.553.745	€118.584.289	€11.044.178
2021	€3.913.352	€10.875.752	€190.701.446	€177.896.003	€2.584.390	€120.007.300	€11.176.708

Then, finally, the respective cells in Table 4.2 and Table 4.3 are added to arrive at the final total income found in Table 4.4.

Table 4.4: Overview of the yearly final total allowed income for all the Dutch DSO's

DSO	Coteq	Enduris	Enexis	Liander	Rendo	Stedin	Westland
2016	€16.133.862	€72.166.871	€876.988.224	€1.027.511.981	€10.766.135	€651.241.009	€43.036.241
2017	€16.052.158	€71.827.966	€872.593.591	€1.023.427.517	€10.718.253	€648.310.812	€42.818.099
2018	€15.972.259	€71.493.981	€868.286.363	€1.019.410.396	€10.671.435	€645.431.043	€42.605.123
2019	€15.894.158	€71.164.909	€864.066.274	€1.015.460.601	€10.625.679	€642.601.626	€42.397.295
2020	€15.817.850	€70.840.742	€859.933.064	€1.011.578.122	€10.580.983	€639.822.488	€42.194.593
2021	€15.743.329	€70.521.472	€855.886.484	€1.007.762.953	€10.537.343	€637.093.561	€41.996.999

From a technical viewpoint, the Dutch regulatory scheme has some cost-based elements in the form of allowing the DSO an appropriate return on investment through the WACC part of the allowed capital costs. However, this WACC method bases itself on a rather low-risk investment profile, as can be clearly observed in the report by Rebel Energy, Water & Climate (2016) where this WACC is calculated for this regulatory period. This means that the DSO's will can only expect returns on investments that match a low-risk rate of return, and hence, riskier investments are not worth it under this system (if viewed from a purely financial point of view).

If we look at the work by Mulder (2016), we find a qualitative description of the Dutch regulatory system. In his article, the author mentions that the Dutch system of regulation is output-oriented, with a regulator that does not want to overly interfere with the investment decisions of the DSO. It is focused on ensuring that DSO's perform their task efficiently, given that the regulator acknowledges the information gap that exists between the DSO and themselves regarding what constitutes efficient investment. However, some of these aspects of Dutch regulation are currently experiencing change, as will be discussed in the next section on the empirical findings of this thesis.

4.3. Impact on investment behavior - Research Findings

In this last section of this chapter, I will discuss the empirical findings regarding regulation in this thesis. The section will consist of two parts, firstly detailing how the system is currently changing through the presentation of evidence from recent primary sources and how the parties view these developments. In this case, I will also try to frame these developments in terms of the views presented from literature, as to consider which aspects of the new realities are being actively pursued. Then, I will present the relevant results of the financial analysis and the views of the DSO's and other interested parties on the effectiveness of the regulatory regime and how the system can move forward towards 2030. This section will conclude with a concise answer to the research questions 1 and 2.

4.3.1. Recent developments in Dutch regulation

Over the past couple of years, awareness has increased that significant steps need to be made in order to solve the grid congestion problems. To that end, pro-active investing and testing investment plans are firmly on the agenda for the Dutch regulator. In this subsection, I will discuss the findings from the notes of the advisory board meetings regarding the next regulatory period (starting in 2022) and the findings from a recent test by the ACM of the distribution system operator's investment plans.

Regulation of the next regulatory period

A new method decision moment is coming up in 2021 as the current regulatory period is coming to a close. To that end, the ACM is currently meeting with an advisory board of stakeholders (in Dutch: Klankboordgroep) where the future of Dutch regulation is under discussion. One of the key points in the agenda here regards the implementation of measures to stimulate pro-active investment policy from the Dutch DSO's.

In the report of the first advisory board meeting, we can read comments of most of the affected parties regarding pro-active investment policies at the Dutch DSO's (ACM, 2019a). In this meeting, the ACM concludes that the regulatory regime is not one of the main contributors to the problem of underinvestment, and that the main source delay can be found in coordination between the DSO's and the project developers. They do, however, admit that some elements of the regulation do not give incentives to keep enough transport capacity available.

In this same report, we can read that according to the trade association of the Dutch grid operators, Netbeheer Nederland, the problem needs to be solved in a four-fanged approach, utilizing not just the regulation, but also the regional energy strategies (RES programs), the systematic checks of investment plans and the adaptation of laws. With regards to regulation, the organization states that it is key to obtain a clearer picture of the type of incentive that the regulation really gives, as to understand how it should be adapted to give the right incentive.

In the next couple of pages of the document, the various advisors at the table mention the problems surrounding the regulation and the respective incentives, and conclude that it is very unclear at the moment what the specific problem is. More research is needed to identify where it is going wrong, and how this should be fixed.

In general, this first advisory board meeting shows that there is awareness of the problem that exists with regulation, but the lack of concrete solutions show that the parties are slightly sunk into their own way of thinking. Looking at the interviews done for this thesis, this point is supported by one of the interviewees regarding what occurs at the table in these meetings [Appendix section B.2, p. 101], where there is too little time to really think about systematic change in the system. The meeting exists to tweak the current system, and any solutions will most likely have to fit into the current system due to time constraints. In a sense, there could have been a much larger fundamental research project regarding a new system, but instead, the regulator opts to use what it has in a slightly new, or tweaked, way.

Some time can be found between the meetings of the advisory board until the topic is discussed again after the initial discussion during the first few meetings. In the 12th meeting, there is a presentation by Netbeheer Nederland regarding pro-active investment, which leads to new reactions from the affected parties (ACM, 2020c).

Most of all, the parties at the table discuss how the DSO's are currently investing and how this does not support the growth of renewable projects where these are planned by their developers. One of the parties mentions how DSO's are only investing when plans have been signed, almost waiting for a guarantee before setting their own investments into action.

One interesting part in the discussion regards the yardstick competition driving the efficiency of the DSO's. Here, Netbeheer Nederland mentions that this yardstick competition is a major reason for the risk-aversiveness of the DSO's, but that the fact that all DSO's have to make huge investments is almost masking the problem. However, taking this mask as a sign that there is no problem at all is a dangerous path to take according to the trade association.

All in all, in this board meeting there is a very clear divide between the actors on whether or not regulation really needs a change. Some parties representing the generators mention that connecting new projects is simply the lawful requirement that DSO's have to fulfill. Whilst this is true in general, and a view shared by the ACM (ACM, 2019b), the meeting shows that one of the points that is not being driven home is the fact that the regulatory scheme makes DSO's very risk-averse investors (as supported by empirical evidence in this study, [Appendix section B.2, p. 101]). The question that could be asked here, is whether the system needs to allow for less efficiency to counter this risk-averse behavior.

The topic is also under discussion during the last meeting from which notes have already been made public (ACM, 2020b), where the following remarks regarding pro-active investing are interesting to note.

Firstly, there is a clear emphasis once more on the lawful requirement of DSO's to connect parties that want to have a connection, and the regulator mentions that whether or not they can utilize their authority to penalize the DSO's depends on whether the shortages can be attributed to regulation or not. If policy in general is causing the shortages, the ACM can be more strict with the DSO's to enforce connections.

However, the meeting also shows that the actors still have no clear sight on which specific elements of the regulation are causing the DSO's to under-invest. The DSO trade association mentions that one of the key points is the avoidance of random investment that lacks solid support. What the DSO's need under the current system is more security with regards to where investments need to be made, and infrastructure reinforcement realized. In the end, the parties note that the Dutch DSO are receiving investment incentives from the score of possible clients that request a connection, but that this does not mean that the regulation is currently giving the correct incentives. However, the uncertainty of what is wrong in specific terms leads to the yardstick competition element being removed from the discussion.

All in all, this last meeting confirms what the interviews have told me, which is that the parties are currently trying to tweak the current system, and are lacking solid evidence to try and realize a completely new, or hybrid regulatory system. The actors mention that the uncertainty problem can be solved through solid RES programs, and that will also help in this specific discussion. The next chapter of this thesis will continue with this topic. In the end, it seems that the DSO's and the regulator are not putting through a structural change in the regulation, but are relying on other solutions. One of these solutions is the investment-plan audit by the regulator that has started in 2020.

Investment-plan audits

Since 2020, the ACM is auditing the investment plans of the Dutch DSO's every two years. With this scheme, the ACM hopes to gain more insight into where problems are going to arise, and which DSO's need to be pushed to do more than they are currently planning to do. These investment plans have been discussed in the recent report on these audits (ACM, 2020e), the results of which are the following:

Firstly, none of the investments identified in the plans have been classified as unnecessary. That means that all of the investments are needed to solve the grid capacity problems plaguing the Dutch electricity grid.

Secondly, the ACM identifies problems with the investment realization for the DSO's Liander, Enexis and Enduris, and mentions that the capacity issues will continue to grow under the current plans and demand scenarios. This indicates, to the ACM, that more, or faster investment is required. The DSO's themselves mention that the capacity issues that are arising as a result of these plans are mostly stemming from investment uncertainty, and will have to be solved by tackling this uncertainty problem.

Due to the problems with the investment plans identified by the ACM, the regulator has stated that the DSO investment plans need to be improved for the next round through the addition of more detailed scenarios, that take into account more changing variables and possible developments. Furthermore, the ACM has stated that the investments require more argumentation of necessity through detailed cost-benefit analyses, and wishes to see both of these elements in the next version of the investment plans.

4.3.2. Relevant results of the financial analyses

Taking into account all that has been said by the DSO's, the ACM, and the scientific literature regarding investment in the grid under regulation, if we take a look at the actual numbers, we see the following picture in Figure 4.2.

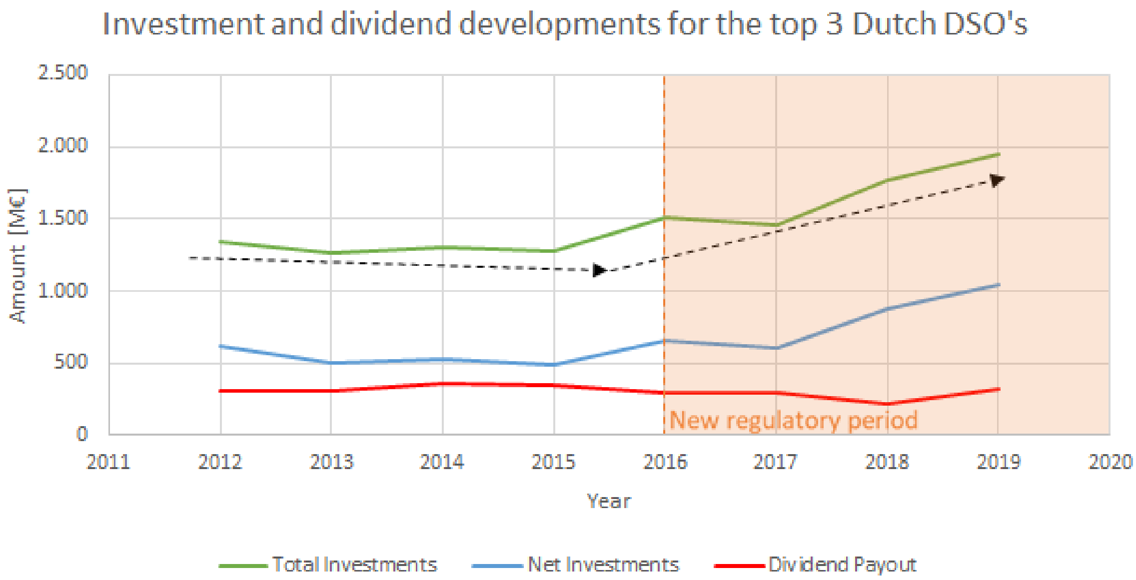


Figure 4.2: Overview of the investments and dividends as reported by the top 3 Dutch DSO's: Enexis, Liander and Stedin. An indication for trend and the start of the new regulatory period is included in the figure.

As can clearly be observed in the figure, both the total investments and the net investments made by the top 3 DSO's in the Netherlands have experienced a substantial increase. The graph also shows that this increase is not seen in the dividend payouts, meaning that most of the new profits seem to have been put towards new investment, contrary to some claims in the media (Kalshoven, 2020). These increases have been occurring since the start of the current regulatory period, which is interesting when considering the findings from Cullmann and Nieswand (2016) that DSO's tend to invest more in years where the rate base is determined. Even though my sample size is too small for stating that their finding is confirmed, higher investments in the base year do seem to occur in the Netherlands as well.

Of course, the base year of 2016, and especially the years thereafter have seen much more attention placed on the DSO's with regards to investment and its link to the congestion problems. So this occurrence of high base year investments can have multiple causes.

From a qualitative viewpoint, however, it is interesting to see that investments have increased substantially. Given the enormity of the energy transition challenge, these investments are only expected to become higher and higher, which in itself shows that there is a clear break of trend. Hence, critically assessing whether or not the regulatory system can still cope with these type of changes is very important if the policy goals of the climate agreement are to be met.

Next, if we consider the development of the operating profit, the plot seen in Figure 4.3 appears. Hence, the new regulatory period still works in taking some of the efficiency gains from the DSO's, and the DSO are still making their grid more efficient, as evident from the increasing operating profits within a regulatory period.

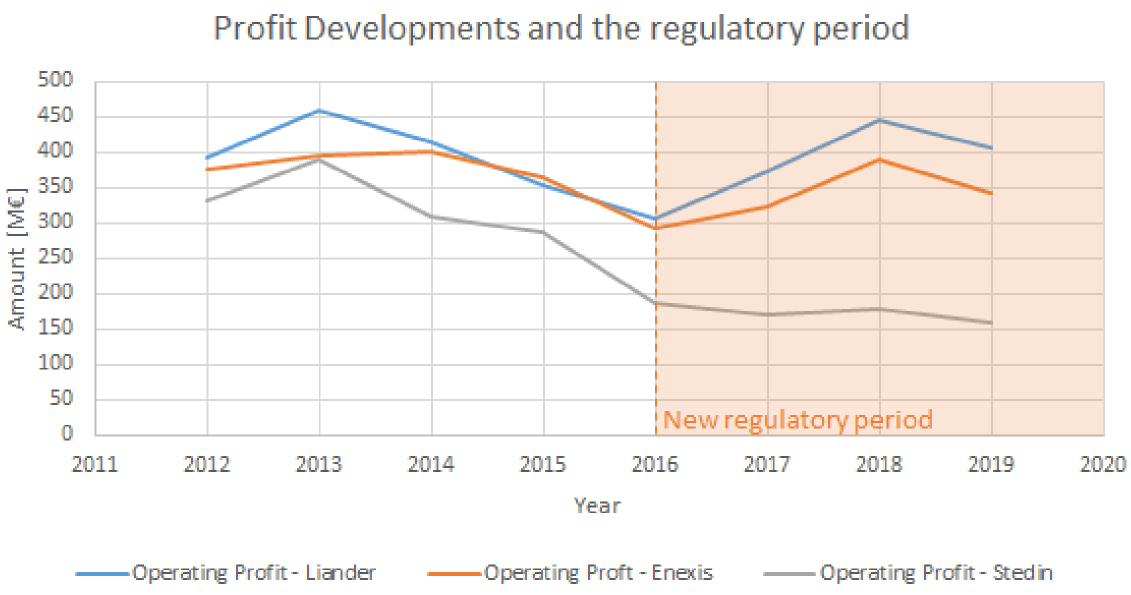


Figure 4.3: Overview of the operating profit for the firms Enexis, Liander and Stedin, with an indication of the new regulatory period start.

One of the key takeaways from these findings is the fact that both the ACM and the DSO's are still very good at using the system that is in place to their advantage. Both elements that make incentive regulation very effective in realizing a cheap, but high quality grid (allowing DSO's to gain more profits for higher efficiency, and passing these gains to consumers after a regulatory period) are still very much functioning well almost 20 years after the implementation of incentive regulation. This theme will return in the next section, where I present the empirical findings from the interviews regarding regulation.

Lastly, the analysis of the beta's tells us some valuable things about the type of risk that the DSO's are taking. As discussed in chapter 2, firm asset beta's can be helpful in determining whether a firm typically invests in high or low risk projects. The firm asset beta's along with the accounting beta's found for the Dutch DSO's can be seen in Table 4.5.

Table 4.5: Overview of the betas calculated for all the Dutch DSO's. The full calculations can be found in Appendix A.

Variable	Coteq	Enduris	Enexis	Liander	Rendo	Stedin	Westland
Earnings Beta	0,4278	0,1792	0,0791	0,1110	0,1565	0,0350	0,1216
Asset Beta	0,6185	0,4528	0,3861	0,4073	0,4377	0,3567	0,4144

Except the firm Coteq Netbeheer B.V., all Dutch DSO's have a very low earnings beta, and consequently, an asset beta in the 0.3 to 0.5 range. Because the total data-set for coteq is only five years, one year of non-typical results can lead to this observed difference.

Comparing these numbers to some ranges found in literature can help in drawing the correct conclusions from these numbers. I only consider ranges due to the source of these beta's being annual reports, meaning the specific value is not really telling us anything. Firstly, Berk and DeMarzo (2017) provide a range of typical asset beta's for utilities. Their numbers range from 0.2 up to 0.4, showing that the numbers obtained from the quantitative analysis do match up. Given that Berk and DeMarzo (2017) used the American utilities for their beta range, a slight difference is to be expected, along with the fact that their beta's are given for publicly traded firms.

Secondly, Rebel Energy, Water & Climate (2016) has made an estimate of the asset beta for the Dutch DSO's using a comparable firm analysis. Using a set of publicly traded utilities, the following mean and median asset beta's were obtained in the rebel report:

- Mean asset beta: 0,35
- Median asset beta: 0,42

If we take the beta's from the analysis in this thesis, we find the following mean and median asset beta's:

- Mean asset beta: 0,44
- Median asset beta: 0,41

Clearly, the median asset beta is very similar, and the mean is in the same expected range. As stated in chapter 2, low asset beta's ($0 < \beta << 1$) indicate that the market risk of the average project in a firm is low (Berk and DeMarzo, 2017). Given the low asset beta's for all the Dutch DSO's in the analysis, it is safe to say that on average, Dutch DSO's invest in low risk assets or projects. This is of course, a rather expected result given the efficiency focus of the Dutch regulations. Any high-risk project could lead to unforeseen costs, penalizing the DSO quite harshly.

These findings show that the WACC used by the ACM to determine a reasonable return are following the typical pattern that is to be expected from a utility-based firm. However, whether this approach is still justifiable in a period of energy transition is hard to say, given that the investments that need to be made are likely to be riskier. Riskier investments mean that the DSO's will not make the investments as early, and will likely try to reduce the risk by waiting and gathering more information, until the risk level falls within these acceptable bounds again. Of course, these speculations cannot be supported by hard evidence, but it does show how the system has to capability to force the DSO's to take a wait-and-see approach.

4.3.3. Empirical findings in the interviews

One of the first themes that returned in all interviews performed for this thesis was that there is a notion that the regulatory system that is in place in the Netherlands is very effective, and that the results that have been accomplished over the past 20 years are nothing to scoff at. For example, in the interview with Stedin, it becomes clear that the effects of the current regulatory system were known well in advance, and that the discussion about DSO's not performing their legal obligations ignores the fact that this system was "ordered" by Dutch politics during the liberalisation [Appendix section B.1, p. 101]. The representative from Stedin then goes on top explain that being efficient, and remaining efficient, is not something that we should just throw away in an attempt to solve the problems. He mentions that a large factor here is the investment uncertainty, and that under the current scheme, the DSO's simply require more certainty to invest.

If we look at a similar theme in the interview with Liander, we find that according to them, one of the key results of the current system is that new investments by DSO's simply need very strong support. A new substation, for example, needs some very concrete government plans or clients lined up in order to go ahead. However, they also mention that this does not mean that the investments are not planned in time. There simply is a very large requirement to make efficient investments, and not doing so would result in unnecessary costs for the Dutch society. Therefore, the premise of the system is not wrong, but it does lead to a low-risk investment strategy [Appendix section B.3, p. 101]

This fact is once more supported by Netbeheer Nederland, who go a little more in depth with regards to this topic. They state that under the current system of regulation, the electricity grid of the Netherlands is one of the best in the world in terms of relative quality (i.e. very few outages whilst maintaining a very low price). But that same system is causing the DSO's to only make investments when they help this system of efficiency [Appendix section B.2, p. 101]. Therefore, only investments that can be earned back, guaranteed, are typically made. This in turn has made the DSO's a completely risk averse actor. Sometimes, for example, when a zoned industrial area needed to be connected, the DSO's took a little more risk when the clients were not lined up, but in general only projects with clear and set-in-stone characteristics received upfront investments. And it is this risk-aversiveness that is now one of the main causes of the troubles we are experiencing [Appendix section B.2, p. 101]

When considering the question of how the system should be adapted in order to work in the context of the energy transition, the parties that were interviewed gave a mixed response. The divide between the DSO parties that focus on grid activities and the trade association that can afford more time to think about regulation becomes clear here.

According to Stedin, there need not be a purely regulation based solution to the problem. The main problem can be found in uncertainty of investment, and solving that should receive the most attention. At most, the regulation is currently constricting the DSO's a little too much, and a slight loosening of regulatory costs could help. However, the main problem can be solved by focusing in on spatial planning and offering more certainty with investing. Keeping the regulatory system simple is the preferable option, solving the problem through other channels [Appendix section B.1, p. 101].

Liander confirms these statements in the sense that they too believe that the solution is not necessarily found in changing the regulation too drastically. It should not chucked-out, as the principles of efficient investments are good. You could lose the flexibility if the regulator needs to pre-approve all investments, so they are not in favor of that either. In a sense, they mention that solving the uncertainty problem is key is solving the congestion problems [Appendix section B.3, p. 101].

According to Netbeheer Nederland, the solution of the regulatory problem lies in the re-coupling of the system. The regulation for the DSO needs to be based on a system view, not just on the smaller part that is an efficient grid. In a sense, they argue that this aspect of the liberalisation and unbundling has caused two integral parties that are immensely inter-connected to consider themselves separate, and now that the entire system needs to change, this is causing new problems. This same problem also arises when one thinks of future solution to the energy transition. One can question which party is responsible for storage on the grid, for changing excess electricity into hydrogen and releasing the stored energy when needed. Here, the core of the problem is that these type of questions cannot be solved by simply leaving them to the market, as they are integral to the grid. So in order to arrive at the goals set by the climate agreement, these problems need to be tackled from a system perspective, and regulation is one of them [Appendix section B.2, p. 101].

4.4. Concluding Remarks

In the Netherlands, the regulatory regime is having a substantial effect on the investment behavior of the Dutch DSO's. Through the strict regulation of the tariffs and the allowable income, DSO's are pushed to be as efficient as possible, and this push has remained in place for the last 20 years. Solving the current problems requires some critical evaluation of the system, but the proposed solution directions vary among the different parties at the table. With regards to the two main research questions under investigation in this chapter, we can say the following:

- In terms of the effect of regulation on DSO's, literature has shown that incentive regulation makes DSO's less likely to over-invest, even though this does not mean that there is systematic under-investment. However, the yardstick competition has made the DSO's very risk averse, which is a conclusion that is supported by both the financial analysis in terms of asset returns and beta's and the empirical findings from the interviews. There is awareness among the actors that the current system is affecting investment behavior, but there is also a clear preference to solve the problems within the bounds of the current system. And this means that there will still be a large incentive for DSO's to invest very efficiently in the coming years of the energy transition. Whether this caution is what the problem needs at the moment is a fair question, but not one that will be solved in the near future.

- In terms of what changes are needed to be able to better tackle the problems introduced by the energy transition, we find a clear answer in literature that an element of cost-based regulation can be very useful. This is not something that is actively considered in the Dutch system at the moment. The affected parties themselves do not see new forms of complex regulation as a serious option, and instead wish to focus on solving challenges that fit within the current system, such as investment uncertainty. However, adopting a more system-based approach could seriously help the discussion, and this could also bring the element of cost-based regulation to the table again. Here, it is key to note that this regards adding a few cost-based elements to the system where applicable, as to not lose the efficiency incentives that serve their purpose well. One thing in particular that interests me in this discussion is the fact that letting the operators of renewable generation pay for putting energy onto the grid is not mentioned in any of the discussions, whilst being a fairly solid idea to give the DSO's some new avenues of cost recuperation.

This chapter has shown that within the current regulatory regime, the DSO is forced to adopt a careful, low-risk approach to new investments. Given the preference of a lot of the actors at the discussion table for the next round of regulation to keep to majority of the system intact, solutions outside of the regulatory system are needed as well. One of the solutions in this regard is the testing of investment plans by the regulating authority. Whilst this measure reduces the collaborative nature of the relationship the DSO's currently enjoy with the ACM (to a certain regard, but there is certainly room for more explicit conflict, see the REG2022 discussions section for some clear examples), it can create a push for the DSO's to more actively pursue new investments that help solve the grid congestion problems. However, whether this solution works can only be said after having been implemented for some time.

Therefore, the next avenue of solutions to consider is the reduction of the uncertainty mentioned by a lot of the DSO's. To that end, the next chapter will discuss the cause of this uncertainty and mention how the RES program can serve as a possible solution. In this regard, the changing roles for the energy producers and DSO's will also play a central role.

5
Distributed generation development and pro-active investing

In this chapter I will discuss the process of distributed generation development as it occurs in the Netherlands and how these processes have affected the energy producers and the DSO's. In the first section, the process of going from an idea on paper (for a new renewable asset) towards a realized project is presented, along with the similar procedures as they occur for reinforcements or similar expansions of the electricity grids. Because of the difference in these procedures and the short development cycles for distributed generation, a lot of congestion is occurring in the rural areas of the Netherlands. The first section will also present the current status of the congestion problem, from where the chapter will move towards a discussion of the findings regarding planning speed of projects and possible solutions.

In the final section of this chapter I will provide a detailed description of the RES, given that this tool has the potential to be a prime tool in reducing the uncertainty that is currently delaying a lot of investments. In this last section, I will discuss the content of the RES program and discuss how effective can be as a tool the solve the current congestion problems. To this end, I will show how the RES can serve both the energy producer and the DSO in their new roles within the energy system.

5.1. Development of new distributed generation projects

New projects for distributed generation in the Netherlands have to go through a process of financing, getting the appropriate licenses and then building their asset. One of the key reasons for the current congestion problems mentioned in the letter by minister Wiebes (Wiebes, 2019) is the fact that the speed of this process is currently much higher than the respective speed of planning new grid infrastructure. In this first section, I will lay out the details of this process and show where it has caused congestion in the Netherlands by assessing the area of each DSO separately.

5.1.1. Subsidies, licenses and realization

In terms of financing new projects, a key aspect is the SDE+ subsidy that developers can get for realizing new renewable energy generation projects. As mentioned by Wiebes in his call to attention of the congestion problems, a key change that has been occurring regarding this subsidy is that new projects have to preemptively check with their respective DSO's to see whether there is enough transport capacity in their realization area to complete the project.

Under the old SDE+ subsidy program, the Dutch government made a very large budget available to project developers of renewable energy. The specific rules for the old subsidy are not overly strict (Rijksdienst voor Ondernemend Nederland, 2020c):

1. Strong argumentation and support for the project is a first hard requirement. It is up to the developer to deliver a strong project plan that convinces the government that the project is realistic;

2. The documentation needs to include a feasibility study;

3. Relevant licenses must already be awarded to the project developer. These licenses can concern spatial planning, ground water use etc.;

4. A full subsidy request form.

Under this system, a lot of the subsidies went to solar farm development projects from 2017 onward as the competitive price of these projects experienced a steep decline. Hence, more of these projects could be realized for less subsidy, making them a more attractive choice. In addition, the decline off biomass that can also be observed in Figure 5.1 has also been a cause of this shift.

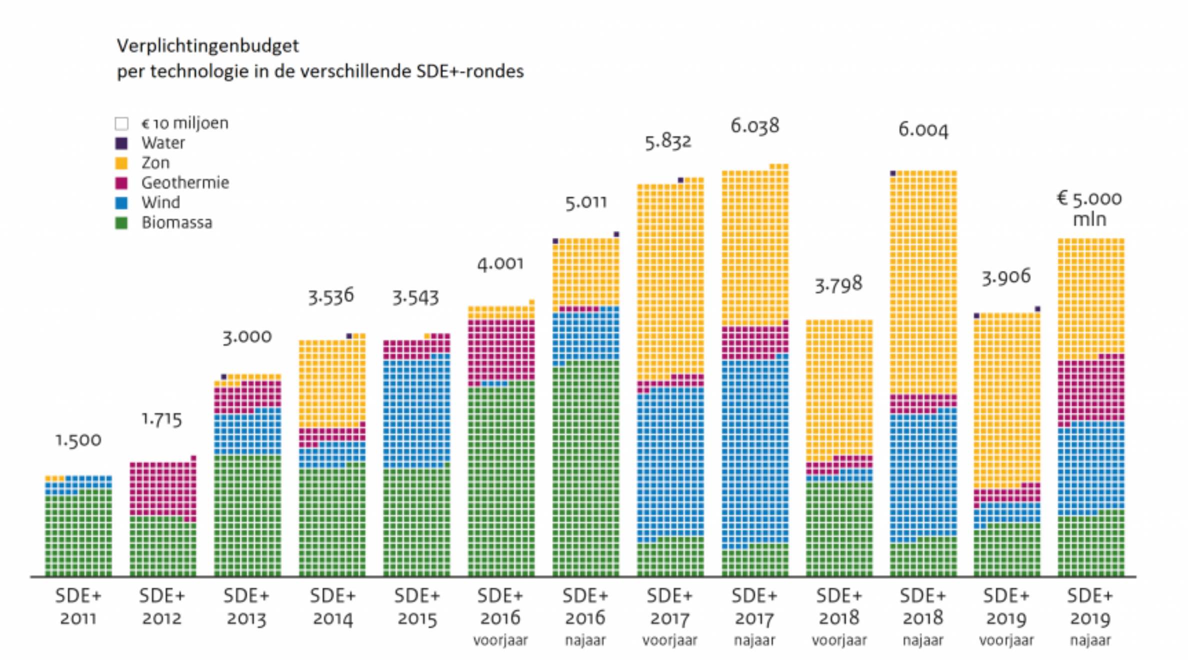


Figure 5.1: Overview of the SDE+ subsidy awards towards multiple technologies. The blocks show that the amount of subsidy has been increasing steadily over the past few years. Also, solar technology has experienced a clear and drastic increase in funding since 2017. Obtained from: Rijksdienst voor Ondernemend Nederland (2020b)

In terms of licensing, the difference between the options shown in the figure above are numerous. But effectively, the procedure for wind and biomass is much more intensive then the similar procedures for solar energy production. Large scale solar fields require an “omgevings-vergunning”, which is only awarded if such a field fits into the zoning plans of the municipality where the project is to be realized. Most of these municipalities have separate maps of areas where these types of farms are likely to be approved, but in general, as long as the project fits the zoning plan, the required license can be obtained without to much hassle. This entire process has an upfront check, followed by a legal period of approval that can take up to 26 weeks. This means that a solar field can be approved within half a year if everything goes smoothly (Zonnestroom Nederland, 2020).

Contrary to solar energy production, wind parks of 20 windmills or more require a “Milieueffectrapportage” (MER) before the licensing procedure can even start. Parks smaller than 20 still require a check whether an MER is necessary, and even if this MER is not required, the “omgevings-vergunning” that is requested has an added environmental effects test requirement. All of these cases mean that a lot of research is needed before even asking for a license, as the MER is subject to a lot of national and European laws and regulation. Then, a more extensive licensing procedure is started, followed by possible additional licenses for water-use and environmental protection exceptions. From the “Rijksdienst voor Ondernemend Nederland” (RVO, Federal Service for entrepreneurial Netherlands) we find that these procedures take at least two years, with the most excessive cases requiring almost 9 years of research and licensing (Rijksdienst voor Ondernemend Nederland, 2020a).

Lastly, realization speeds for solar farms are also higher than the realization speeds for wind parks due to the ease of construction. All of this leaves an image of solar parks that can pop-up within a year or two-year horizon (construction within approximately a year), whilst wind parks are realized within a four year minimum horizon (construction within two years). To combat the effect on the grid, all projects now require a DSO approval with regards to transport capacity (Rijksdienst voor Ondernemend Nederland, 2020c), but it is easy to see that solar fields have to capability to utterly surprise the DSO's with regards to the speed from which they go from idea to realized project.

5.1.2. Grid congestion due to distributed generation

The above procedures have been one of the causes of the widespread congestion in the Netherlands occurring over the past few years. Starting with DSO Liander, Figure 5.2 shows the available transport capacity of this DSO.

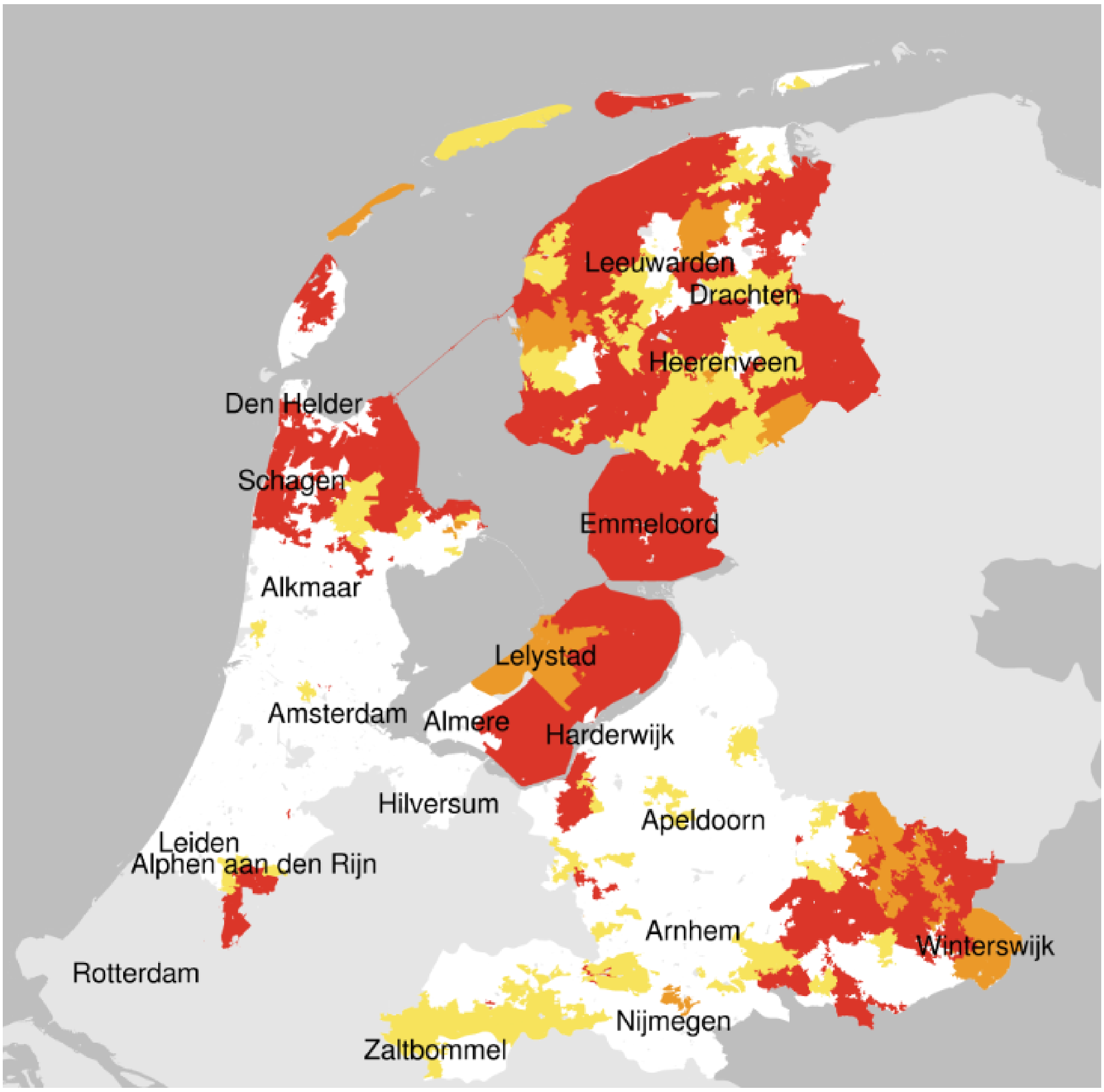


Figure 5.2: Overview of the areas of congestion of DSO Liander with regards to the production of electricity. Areas in red are fully congested, with no capacity available, areas in orange are heavily congested with limited available capacity, areas in yellow are slightly congested and areas in white are not congested. The larger grey area falls outside Liander's area of responsibility, see Figure 2.4; (Liander N.V., 2020a).

In Figure 5.2, we notice a few interesting facts regarding the congestion in the Liander area of opertaion. Firstly, we see that the provinces of Friesland and Flevoland are heavily congested, whereas only parts of North Holland and Gelderland are congested. This regionalization of congestion problems follows the notion that urban environments have heavier grids. The provinces of Friesland and Flevoland are relatively (by Dutch standards) rural areas with far lower grid capacity (During the interview with Liander it was mentioned that the region around Amsterdam has more capacity than the entire province of Friesland [Appendix section B.3, p. 101]) It is also quite alarming that a large part of this DSO's area of responsibility is currently fully congested, meaning that any new renewable energy generation projects that are planned in this region will experience serious delays until the congestion is resolved. Given the that the availability of space in the Netherlands is limited in the urban region of the Randstad, congestion problems in the rural provinces are a serious issue with regards to a majority of small renewable projects (Wiebes, 2019).

Next, in Figure 5.3 the congested areas for DSO Stedin can be observed. Some of the area of responsibility for this DSO are close to being congested (East Utrecht province and some parts of the more rural South Holland municipalities. However, none of these areas are currently fully congested, so small renewable generation projects can still proceed mostly as planned. Given the fact that most of Stedin's area of responsibility is within the urban Randstad region, grid capacity is much higher on average, and it is thus not a big surprise that there is no current congestion within their grid yet. However, in the interview with Stedin it was mentioned that they are expecting issues in the coming years, and are hence already experimenting with congestion management and other mitigation options[Appendix section B.1, p. 101].

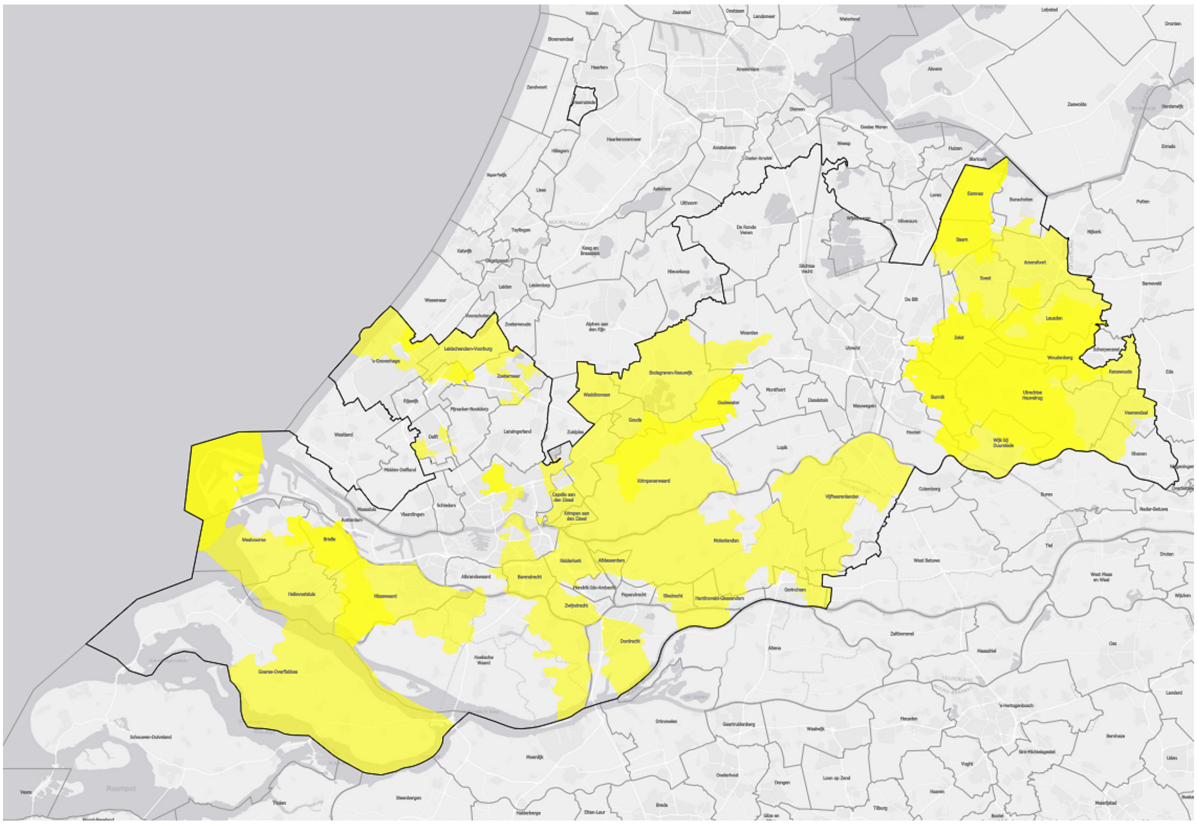


Figure 5.3: Overview of the areas of congestion of DSO Stedin, with regards to the production of electricity. The same color scheme as figure 1.2 applies, meaning that no areas of full congestion are present, with only slightly congested zones occurring in the darker yellow colored areas; (Stedin, 2020a).

Similarly, the capacity available in the province of Zeeland, under the administration of DSO Enduris can be seen in Figure 5.4. Zeeland is a province that contains a few urban regions around the Middelburg and Vlissingen region, which is coloured pink and white, respectively. Some areas around the Vlissingen Harbour region still have a high available capacity, but most of the pink coloured areas with low capacity consist of mostly farmland. Once more, grid congestion seems to be most prevalent in rural regions with lower grid capacity, but ample physical space for new renewable projects.

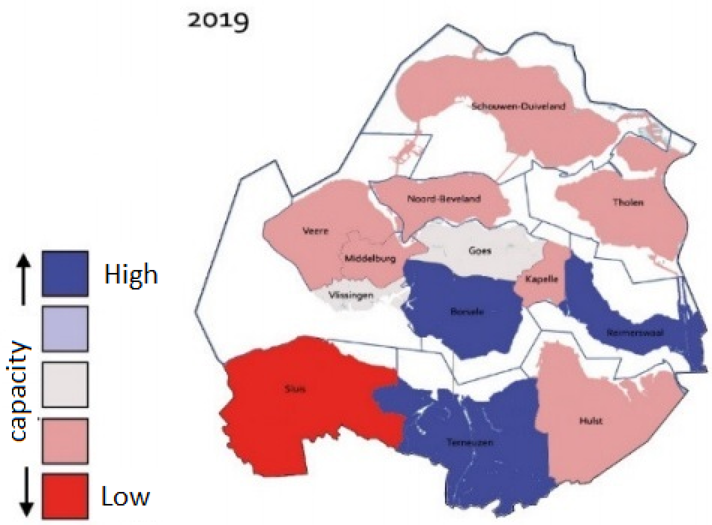
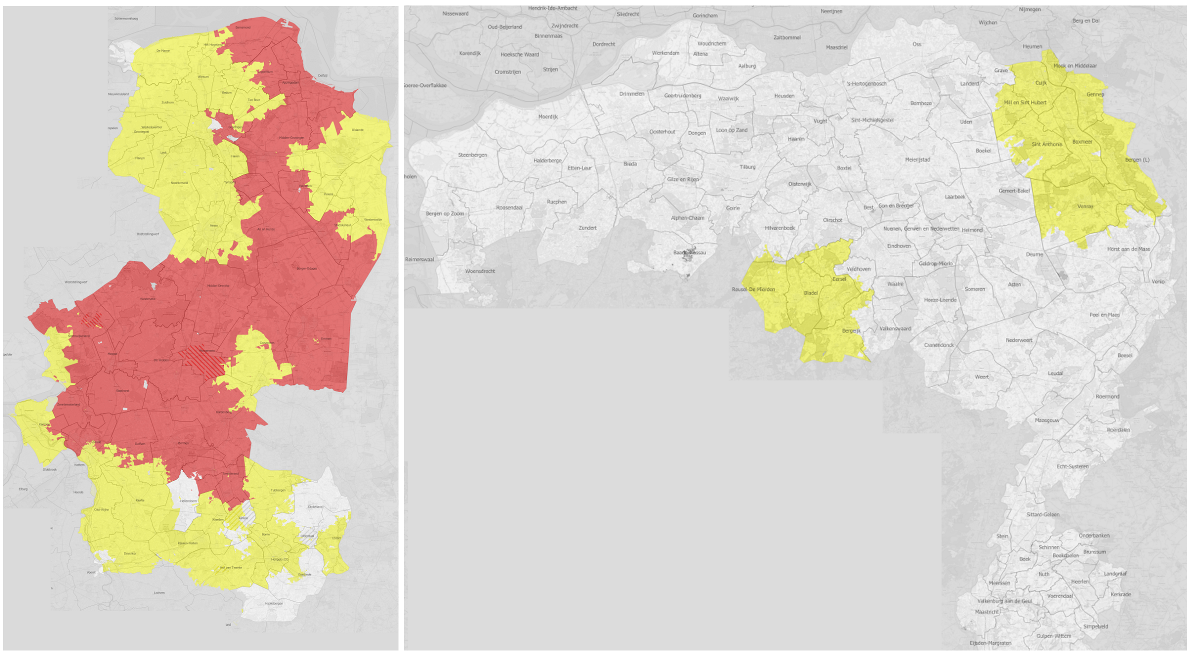


Figure 5.4: Overview of the available capacity in the province of Zeeland; (van Gastel and de Jonge Baas, 2019)

Lastly, the DSO Enexis is responsible for large parts of the more rural east of the Netherlands. As can be seen in Figure 5.5, grid congestion is prevalent in the provinces of Groningen, Drenthe and Overijssel, but not really a problem in the provinces of Noord Brabant and Limburg. In terms of urban versus rural types of land, Brabant contains multiple large cities (Tilburg, Breda, Eindhoven and Den Bosch), which can explain the low grid congestion due to a higher regional transport capacity. Limburg, although less urban than the randstad area, does contain a large industrial site in the form of Chemelot which has a massive power requirement. In addition, the slightly more hilly terrain makes Limburg a less logical target for new wind and solar generation projects.



(a) Enexis - northern provinvces (b) Enexis - southern provinces

Figure 5.5: Overview of the areas of congestion of DSO Enexis, with regards to the production of electricity. Once more, red areas are fully congested, yellow areas somewhat congested and grey areas not congested. The map of the Enexis northern provinces also contains the data for two smaller DSO's, Coteq Netbeheer B.V. and N.V. Rendo; (Enexis Netbeheer B.V., 2020).

Within Figure 5.5a, the DSO's Rendo and Coteq are also included, with Coteq active in the lower right part of the map, in the "Achterhoek" area near the city of Enschede. The congestion in this area is not as prevalent as the more northern province, but it is still experiencing a low available transport capacity. Rendo is active in the dashed red area in the middle of the figure, and is experiencing almost full congestion.

The last Dutch DSO to be covered is Westland Infra Netbeheer B.V., who do not have a readily available map to show their capacity. However, we will assume that the small part of the grid under their administration is similarly congested compared to their neighbouring DSO, Stedin, given the proximity to the Stedin part of the grid.

All in all, the congestion maps show that the distribution grid in the Netherlands is taxed to capacity in large areas of the ”rural” east and north, with some room for expansion left in the southern provinces. It is also clear that the different DSO’s have a varying degree of congestion amongst them that can be partially explained by the type of area (urban or rural) they service.

5.2. Investing with limited information - problems and possible solutions

With the previous section having shown how renewable projects are typically developed and where the congestion problems have arisen as a result of this, now it is time to approach the problem from the DSO side. In this section, I will show how typical DSO infrastructure is planned and realized, and discuss how the DSO’s look at the problems caused by the rapid development of solar fields. Then, I will discuss some possible solutions that focus on reducing the investment uncertainty for the DSO’s, as mentioned by them in the interviews or found in other sources.

5.2.1. Developing new grid infrastructure

New grid infrastructure takes a long time to develop from a planned expansion to a realized asset. An example that serves to illustrate this point is the development of a new substation. According to standard procedures, these types of assets take five to eight years to realize (Wiebes, 2019). Because these types of assets effect the living environment of a lot of people, the procedures in the Netherlands regarding these projects are carefully orchestrated and take a relatively long time.

Furthermore, planning where these types of assets need to be placed is a process that is a collaboration between the DSO’s and the local governments. From the interview with Liander, we know that the substation in the Haarlemmermeer has been delayed for years due to the inability to reach consensus on where this asset needed to be placed [Appendix section B.3, p. 101]. Sometimes, the politics of these bodies regarding upcoming elections affect the planological decision making capability, and this hinders effective deployment of new assets.

Lastly, if we look at the investment plans handed in to the ACM (ACM, 2020a), we can see that a lot of the investments that are currently planned do show this time horizon of 2025 and beyond. Therefore, if we compare the development time of grid infrastructure to the development time of renewable assets, the mismatch between solar assets and grid infrastructure becomes all too clear, whilst this problem did not exist when most of the SDE+ went to wind and biomass due to their similar development times. This conclusion is also supported by the interview with Liander, where this specific aspect of the development time mismatch was explicitly mentioned [Appendix section B.3, p. 101].

5.2.2. Lack of national or regional planning

Another problem regarding the planning of new distributed generation assets that has been explicitly mentioned by all the interviewed parties is the lack national or regional planological documents that can help the DSO’s to invest earlier. Stedin, for example, mentions that one of the key characteristics of the current problems is that a lot of the developments are subject to spatial planning decisions. They mention the fact that in a country as the Netherlands, where almost every part of the country has been zoned in some way, changing these zones to include very clear guidelines on where solar fields and new grid infrastructure should be placed is necessary [Appendix section B.1, p. 101].

In the interview with Liander, this specific problem was extensively covered. First and foremost, they mention that they require very extensive plans to exist in order for them to be able to argue why a 20 to 30 million euro investment in a new substation is needed. These investment decisions are not made lightly, and thus they require solid support [Appendix section B.3, p. 101].

One of the most important steps that need to be made is the creation of a clear strategy on where solar fields are going to be developed, and this strategy needs to be centrally organized in order to achieve a system-wide perspective. Liander mentions how the congestion problems are not really caused by onshore wind farms due to the long planning procedures and the existence of clear planological documents [Appendix section B.3, p. 101].

Mr. Jurjus from Netbeheer Nederland discusses this topic in much detail as well, starting with the fact that for the transition to succeed, the most important the government can do is creating a clear strategy that includes information about the spatial planning of renewable assets. He calls this a “vlekkenkaart” (spot map), en mentions that such a thing would give the DSO’s enough confidence to start making preemptive investments. Because under such a document, the only thing that would realistically lead to these assets appearing outside the designated areas, or not appearing at all, is if we collectively lose our trust in sustainability politics. And such a thing is unlikely to happen [Appendix section B.2, p. 101].

5.2.3. Solving the uncertainty

According to the interviewed parties, and after the consultation of other sources (Wiebes, 2019; van der Linden, 2019), the most obvious solutions lie in the creation of centrally planned documents where the locations of renewable assets are determined. Some of the possibilities include a new ”vlekkenkaart” as suggested by Netbeheer Nederland, but this could also be solved in some of the existing documents. For example, linking energy production to the NOVI (Nationale Omgevingsvisie) program (Ministerie van Binnenlandse Zaken, 2019), and specifically organizing a national strategy regarding solar energy in these type of documents could be a good step.

The other option is to seriously consider how the more regional approach of the RES can help in determining these national or regional spatial plans. Given that this topic is the current course of action, and was also extensively covered in the interviews, the next section will detail the RES programs in particular.

Figure 5.6: National program regional energy strategies: Overview of all the different regions that are creating their own strategic plans (Rijksoverheid, 2019a)

5.3. The Regional Energy Strategy (RES) - A useful tool?

The national program regional energy strategies is one of the outcomes of the Dutch Climate Agreement of 2019. The program is a collection of research and decisions on how renewable energy will be implemented in the Netherlands in the different regions. This section will provide an overview of the RES programs and their current status.

5.3.1. The RES: Basic principles

In the Dutch Climate Agreement, a subdivision of the Netherlands into smaller regions that could apply specific solutions to their particular problems was agreed (Rijksoverheid, 2019b). The division of the country into these RES regions can be observed in Figure 5.6.

As can be seen in the figure, some of the regions are the same or similar to the Dutch provinces, whereas some other regions are clearly different. According to the Stedin interviewee [Appendix section B.1, p. 101], these regions have grown this way historically, which makes sense when evaluating them from a functional perspective. Some of the regions have a more common theme than, say, a provincial level, which is probably why a concept like this was chosen.

Within a regional energy strategy program, multiple parties come together to create a suitable energy strategy for their particular region. Parties involved are municipalities, provinces, national government, the “waterschappen” (a Dutch local government organisation regarding water management), grid operators, energy producers and other local entities. The idea of these programs is to obtain a highly varied degree of input, as to create plans that can count on the highest degree of support. In their own words, a RES is a combination of three things (Rijksoverheid, 2020):

1. First and foremost, the RES is an instrument that is used to make choices about regional renewable energy generation, the heat transition in buildings and local environments and the regional energy storage and transport infrastructure;
2. Secondly, the RES is a tool that empowers collaboration between all the relevant regional parties, with an emphasis on preparing this collaboration for more concrete projects that will emerge in the future;
3. Lastly, the RES is also a product containing the actual implementation strategy for a RES region to achieve the goals stipulated in the climate agreements.

In terms of added value, the Dutch government believes that the RES programs serve a purpose of creating a broadly supported plan for regional energy implementation, providing region-specific solutions that would not be picked under a more nationally oriented program. Furthermore, they state that the programs offer an ideal platform to combine knowledge about energy-related topics from multiple sources, such as local governments, infrastructure managers and other stakeholders.

5.3.2. Process of creating a RES

Because the RES is a complicated instrument and document, the creation of these strategies takes a lot of time and effort. A lot of the rules about the process have been captured in a separate document called the “*Handreiking Regionale Energiestrategieën*” (Rijksoverheid, 2018). A lot of the information in the document regards the technical content of the RES, but from a process-oriented view, the timeline and actor involvement are most interesting.

Officially, the program started back in 2018 with the formation of the regions shown in Figure 5.6, followed by the start of the actual creation of the RES documents. The signing of the climate agreement was a major milestone in this process, as from that moment onward, the RES regions would have one year until they were required to present the first official version of the RES, or RES 1.0. Then, implementation starts and the document is reviewed and rewritten into a version 2.0 after a maximum of 24 months.

Of course, this process also requires the collaboration of ranges of stakeholder, and the documents require approval from multiple governing bodies, including provincial governments, municipal governments and waterschap boards. Due to the prevalence of the Corona-virus in the Netherlands in 2020, this process of collaboration was slowed down significantly for several months, so some delays in the program are expected.

5.3.3. Current RES status and link to electricity grid

As of the writing of this thesis, the RES regions are at different points in their development cycle. Some of the regions are further ahead than others, but the deadline of handing the concept-version of the RES is nearing (September 2020). In a reaction to the concept-RES programs that are already available, the dutch association for renewable energy made a few comments regarding the electricity grid and the RES programs (NVDE, 2020). In their analysis of the programs they note that the plans in all the regions create new bottlenecks in the grid, but these can all be solved by new investments in transformer stations. Some of the regions have enough capacity to accommodate the plans, but in order to realise the 35 TWh goal of the climate agreement, the emphasize the need for quick and thorough investments. Another point they make is that the national government needs to accommodate these required changes to land in their policy on land use (A new dutch law on land use is coming soon, the "*Omgevingswet*".

The concept-RES programs illustrate the need and importance of collaboration between project initiators and the grid operators. Some of the regions have presented a so-called net-impact analysis, which is not congruent to trends observed by the distribution system operators in the market. This mismatch needs to be solved if the plans in the RES document are to be fully realised sometime in the future.

5.3.4. Interview viewpoints on the RES

In this final subsection I will discuss the RES viewpoints as they came up during the interviews. The RES program was extensively discussed as a possible solution to the current congestion problems, and the different parties had quite varying views on the topic.

Starting with Netbeheer Nederland, the RES is, in their opinion, a vital tool of the energy transition and one of the key elements of solving the current congestion problems. Given that distributed generation is something that is planned locally, a system of local plans that is nationally coordinated has the capability to really affect the current planning problems. The fact that these plans are created from a regional perspective is also very good for the popular support of the energy transition. However, in order for the RES to succeed, a couple of steps need to be made. Firstly, there is a chance that the program could contain regions that plan assets in locations where the negative effects mostly occur in other regions. These type of political and governmental issues need to be solved by orchestrating the plans from a higher governmental level. The national government needs to pre-approve certain regions for certain assets, or the areas of high congestion need to fall under national supervision. This would, in essence, create the "vlekkenkaart" that is needed for the transition to succeed [Appendix section B.2, p. 101].

From the viewpoint of Liander, the RES is very important in providing the necessary information, and to that end, they try to provide as much information about the grid layout to the responsible committee. One of the main goals here is to try to get a RES that keeps the infrastructure layout in mind when planning new assets, and to have the assets that are to be realized first be placed in regions where the grid can accommodate these assets. Therefore the RES has the capability to be a vital planning tool [Appendix section B.3, p. 101].

However, the Stedin representative mentions that for the particular region that he is involved in, the RES is currently simply a local governmental document that is not setting any hard rules or zones, and is mostly serving the awareness of the problem in its current state. This early phase of the project means that it currently cannot be used in planning new investments. So in essence, there is no hard link between the RES and project investments at the moment, only an informal link, and this hard link needs to exist for the documents to become effective planning tools [Appendix section B.1, p. 101].

5.4. Concluding remarks

In general, this chapter has shown how the development of distributed generation occurs in the Netherlands and how this has caused, partly, the current congestion problems. The main questions that were covered in this chapter can be answered as follows:

- In terms of the effect of investment uncertainty, we know from the previous chapter that DSO's are very risk averse investors, and require a lot of certainty in order to make the large investments in, i.e. a new substation. Therefore, not having this certainty will cause the DSO's to wait with their investment until said certainty has arrived, which could be in the form of a formal subsidy request for a new solar field. However, this chapter has also shown that the short procedures to develop such a project are currently outpacing the development cycle of new grid infrastructure, leading to the current congestion problems in the rural parts of the Netherlands. Solving this problem requires a linkage of uncertain solar projects to regions where there is enough transport capacity available, or it requires documentation about spatial planning that can solve as a source of more investment certainty for the DSO's.

- The RES is one of the possible solutions to this uncertainty problem, as it has the capability to become a national map of where distributed generation is going to be developed. Most of the parties working the RES recognize the potential of the programs, but in their current state they are not yet effective. In order for the RES to succeed, it requires some form of national orchestration, as to make the most effective choices from a system-based perspective.

Finally, considering the development of new projects, as well as the new role for the DSO as an active grid manager, the RES can serve as a platform from where this role can be most effectively realized. Both the DSO's and the energy producers have the capability to voice concerns over plans made in the RES, and through collaboration, the program can bring these two parties closer together again, working towards the system-based perspective mentioned earlier in this thesis. In a sense, that is the crucial point to be taken from this chapter, that the RES program can serve a vital mediating role that is necessary to solve the current congestion problems.

6

Conclusion and Thesis reflection

With all of the piece-wise topics covered in chapters 4 through 6, this chapter will provide a general overview of all the findings and the answer to the particular research questions. Then, the main research question and research hypotheses will receive answers and support. The limitations and recommendations for future research will be included in the next chapter.

6.1. Summarized findings

This research used both quantitative financial analysis and empirical findings from interviews to gain insight into the investment behavior of the Dutch DSO's. For the research, annual reports were examined and a database of revenues, profits, investments and similar indicators was created, culminating in a couple of figures that show the historical investment patterns for all the DSO's, which can be found in Appendix A. For the interviews, an unstructured approach was used given the exploratory nature of this research. The interviews were conducted with two of the big three DSO's in the Netherlands and the trade association for DSO's, Netbeheer Nederland. For more insight, numerous other sources such as meeting notes, officially published documents and research reports were used to build the conclusions of this research.

The role of actor relationships

This thesis started with an in-depth examination of the actor network. Here the main findings were the following, answering the first research question on the effects of the actor network on DSO investment behavior:

- The investment behavior of the DSO's is most affected by the different inputs coming from different principal actors. The ministries have a very clear climate agenda that the DSO's are expected to support, but they still have to comply with the regulation set by the ACM. Here, the dominance of the ACM in the Dutch case can be clearly observed, and any solution coming from the regulatory sphere will need support from this organization. The Dutch regulation is giving mainly efficiency incentives, whilst the climate agenda from the government is giving investment incentives. This mismatch can be seen as a major cause of the current problems, and can be solved by either changing the regulatory system to support the government agenda more (through the allowance of more investment risk, and thus, less efficiency), or by decreasing the investment risk, making supporting the government agenda possible under the current system.
- With regards to the other actors, the DSO experiences regional effects based on the type of municipalities, as the amount of discretionary power depends on how capable in terms of resources the local governments are. With respect to the energy producers, these parties have a profound effect on the investment behavior of the DSO, and coordinating distributed generation investments with DSO infrastructure investments is sorely needed to solve the information imbalance that currently exists. Lastly, the consumers influence the DSO through their application of new technologies such as demand response and their implementation of behind-the-meter power generation to lighten the load on the grid.

These findings then led into the further investigation of both the regulatory regime in chapter 4 and the energy producers and new asset development cycle in chapter 5.

Regulation and investment behavior

The next section of this research focused on the effect of the Dutch regulatory regime on the investment behavior of the DSO's. Here, some key findings regard the risk-aversiveness of the DSO's as a result of the regulation and the apparent uncertainty that exists among the affected parties on how the internal regulatory problems can be solved:

- The regulatory regime has a profound impact on the level of risk that is taken by DSO's for new investments. Literature that was examined in this thesis shows that the added effect of incentive regulation, next to decreasing the likelihood of over-investing, is a push for DSO's to be extremely risk averse. This finding was confirmed in the interviews, showing that under the Dutch system, DSO's simply will not make investments if they are not sure these assets can be earned back within a reasonable timeframe. One of the factors that comes into play here is the use of the weighted-average cost of capital (WACC) to allow the DSO's a fair return on investment. This WACC is coupled to a very low asset beta, meaning that this risk-aversiveness is inherent to the system employed.
- The actors currently discussing the new regulatory system are aware that there is a clear effect on the investment behavior coming from the regulation, but there is also a certain pride in the well-functioning of the system. Therefore, there seems to be a preference to solve the current problems within the bounds of the current system. Without any systemic changes, this means that for the next regulatory period, the strong efficiency incentive and the resulting risk-aversiveness or tentative investment behavior will remain in place. It is questionable whether this approach is going to be able to solve the current problems due to the fact that incentive regulation was never designed to tackle system-level change. However, given that the actors are unlikely to completely overhaul the system, the solution is currently being sought in the reduction of investment risk.
- Another part of this research zoomed in on how the regulation can change in order to better fit the challenges of the energy transition. Here, the literature provided a clear answer that some element of cost-based regulation is key. This cost-based regulation would need be added onto the existing system as to not lose the valuable efficiency incentives, and according to Netbeheer Nederland, need not be permanent at all. They could be seen as a temporary solution in times of change, to be dismantled once a system-wide change is well supported. However, this is currently not on the table in the regulatory discussions, and there appears to be a preference among the actors to keep the system simple, and related to what they already know.

The effect of this system was shown in the figures coming from the financial analysis, where a clear link between the regulatory periods and the level of profits and investments could be observed. However, the actual investments have already been increasing over the past few years, both in the total and the net investments. This result is quite apparent in Figure 4.2.

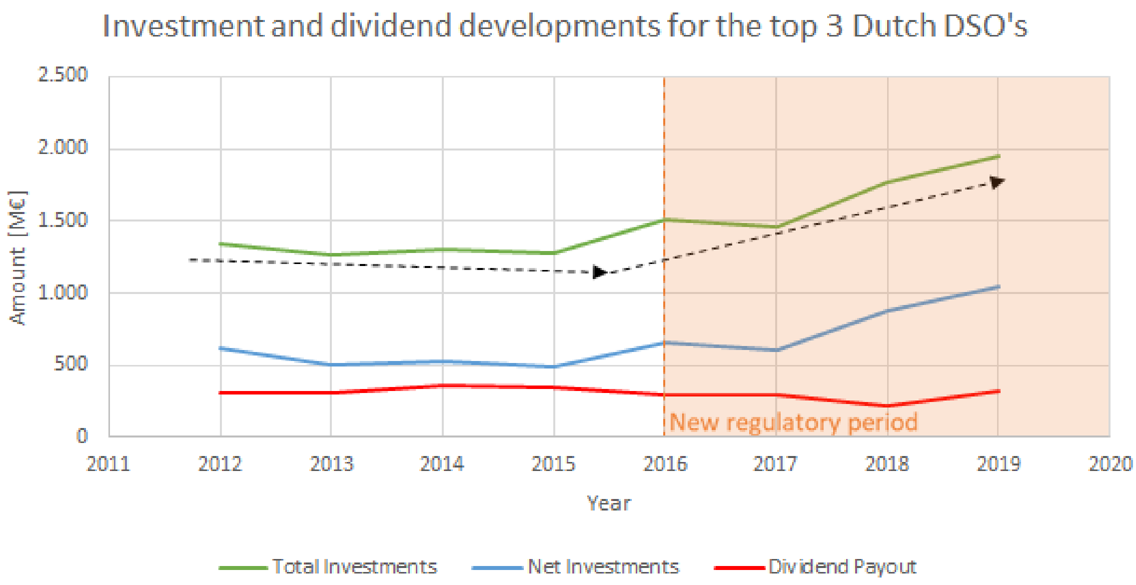


Figure 4.2: Investment trend results of the financial analysis. (repeated from page 51)

From this figure, a couple of conclusions regarding the second research question on the historical investment behavior of the DSO's can be drawn:

- Investments made by the Dutch DSO's have already started a substantial increase, which began somewhere around the start of the new regulatory period. The most likely cause of this increase is the increased awareness of investment need and the prevalence of more and more congestion on the grid since the new regulatory period. Since a couple of years, governmental bodies, regulators, and other parties have become acutely aware of the capacity problem, which has already led to some ministerial promises regarding new instruments, tools and laws to support the solutions. This support might have caused the DSO's to make slightly riskier investments, due to the increased security offered by the government.
- Dividend payments by the DSO's are used mainly as a tool to close the books, according to one of the interviewees. It is observable, however, that smaller DSO's have a relatively higher dividend payout rate than the big 3, Alliander, Enexis and Stedin. Given that investments have increased and dividend rates have mostly stayed constant, there is no clear reason to suspect some kind pressure from shareholders to keep paying dividend. Furthermore, during the interviews it was mentioned that this shareholdership by the municipalities is something that has grown historically, and that no significant difference was experienced in the collaboration with shareholder municipalities versus non-shareholder municipalities.

Investment uncertainty - Problems and solutions

The last section of this research has presented the development of renewable generation in the Netherlands and how this process has contributed to the current congestion problems. Then, the possible solutions to the uncertainty that arises from this process were thoroughly discussed, with the following points as main findings:

- The interviews have shown that the DSO's are not making the 20-30 million investments in new substations unless there is a very certain use-case. These type of investments need to be strongly supported by a business case in order for the DSO the justify the investment to both the shareholders and the regulator. However, the short procedures that exist for solar fields and the explosive rise in solar subsidies seen in Figure 5.1 clearly shows how the DSO's have been surprised by the current problems regarding grid capacity. In order to solve these problems, new renewable projects need to be planned in areas where there is enough transport capacity available, and where possible, the development cycle of grid infrastructure needs to be sped up in order to more closely match the development cycle of solar assets. Previous experiences with wind parks that have a longer development cycle have shown the DSO's as a capable investor if given enough information, in time.

- A much discussed solution track is the creation of more centrally coordinated guidelines on where renewable generation is going to be developed in the future. These types of documents would give the DSO the certainty needed to invest preemptively under the current regulatory system. These types of documents and decisions decrease the investment risk, and make said investments justifiable to shareholders and the regulator.
- One of the main candidates for such a solution is the RES program. The current status of the RES is still rather preliminary, due to the process of creating them being delayed (partly due to the impact of the COVID-19 pandemic). In this preliminary form, the RES programs have limited value in creating concrete information sharing, but they do work as a good platform for sharing awareness about the problems surrounding the electricity grid capacity. Therefore, the current influence of the RES is still limited.
- In order to obtain the effect that is hoped for by multiple parties, the RES program needs to provide solid, concrete information. In order to become this effective instrument, the RES requires active participation from the DSO's, concrete plans that provide information security, and a manner of sanity checks by energy producers (due to them not being involved actively in creating the documents). All of this requires central orchestration to make decisions from a system-based perspective.

All in all, this section has shown that solutions outside of the regulatory sphere can work, but that they require careful management of all the relevant parties. In the end, the purpose of the programs as the RES needs to be to facilitate a more open information platform, reducing the information misalignment and providing the necessary security that the DSO's need to make large investments well in advance.

6.2. Answers to the main research question

The main research question of this thesis was phrased as follows:

"How do the factors of regulatory regime, investment uncertainty and actor-network affect the investment behavior of Dutch distribution system operators in a period of energy transition?"

The findings presented in the above sections present a coherent story where the regulation has made the Dutch DSO a very risk-averse actor, that does put value on the regulatory system as it currently exists. Therefore, the relevant parties are trying to solve the current congestion problems within the bounds of the system, and thus need to rely on reducing the investment risk. This ties in to the second factor, the investment uncertainty. In its current state this uncertainty is the primary cause of the current problems, and solving this requires a coupling of grid investments and generation investments. Also, some form of central orchestration is required in order to work from a system-based perspective, as the energy transition is asking for a system-wide adaptation. This system-perspective is being partially blocked by the paradigm that exists within the governmental actors about the well-functioning of market mechanisms. Therefore, the government is trying to create the correct boundary conditions to solve the problems without direct intervention. As the actor analysis has shown, all the parties in the actor network influence DSO investments through their goals, make-up and relation with the DSO. In the current situation, all of these factors are creating what can be called a perfect storm of factors hindering DSO investment, and solving the crisis requires piece-wise solutions for all these aspects.

6.3. Research Limitations & Recommendations

In these final two sections of this thesis I will critically reflect on the research that I have presented in this document. I will discuss the limitations of the research and make some suggestion for future research directions. Then, I will provide a more personal reflection on the thesis process, and discuss where and how certain decisions were made and what I learnt from the experience.

At the start of this thesis I already mentioned a couple of limitations from the outset. Whilst these limitations (Resources in the form of time and budget) still apply, in this section I will focus more on the research-based limitations of scope, methodology and execution. All of the limitations discussed are lead-ups to suggestions for future research.

Scope

Firstly the scope of this research is limited to the Netherlands, which makes the results found rather specific to my country of analysis. Regulatory frameworks, Market conditions and actor types and responsibilities all vary from country to country. For example, in Germany, the regulation is a more direct form of incentive regulation without the yardstick competition used in the Netherlands, and there are over a hundred DSO's in Germany. In that sense, applying the findings of this thesis to another country requires a careful check of the conditions in that country. One has to ask the questions of how subsidies are organized, how does the regulatory framework look, how many DSO's are there and what kind of discretionary power are they allowed to have. All of these factors can change the results, which makes the applicability of my findings limited to the Dutch case.

Secondly, the scope of this research is limited in terms of time-frame. Regulation, investment and the energy transition in general are ever evolving over time, making the findings of this thesis only applicable to the current situation. Maybe the next regulatory period introduces changes to the system that fundamentally alter the investment behavior of the DSO's. In such a case, the findings of this thesis require an extensive review.

In terms of recommendations, performing similar studies across multiple countries could help form an idea in how these factors play into each other in different circumstances. To that end, doing a couple of extra case studies can help generalize the findings from this study, both in terms of geographical factors as well as time-frame. It would be very interesting to see how slightly different regulatory schemes affect investment behavior, with for example the British system being hailed as a good step forward. Whether this is so, and how these factors interplay could form a very interesting angle for another study.

Methodology

Because this thesis is considering the combined effect of factors in play in the situation currently experienced in the Netherlands, the aspects under investigation (regulation, investment uncertainty and actor network effects) were all examined in a brief and global manner. By focusing on one of these topics, a lot more information can still be obtained on the specific influence of the separate elements. This limitation is also a strength of this thesis, as I try to consider the wider picture, and link this more to a realistic representation of what is happening.

Another limitation in terms of methodology can be found in the use of annual reports as sources for the financial analysis. These types of sources are subject to accounting standards and allowed methods of representing finances, meaning that is hard to draw concrete conclusion from the data. To that end, I have used the information from these sources in a more supporting role, drawing the main conclusions from the interviews and the other primary sources that were referenced.

Here, the obvious recommendation is the further the research into the separate factors, in order to gain more in-depth knowledge about the specific effects. To that end, a study that delves deeply into the Dutch regulatory system and how it could change can help parties such as the ACM to develop new and more effective regulation. This study has shown that there is a clear effect coming from the regulation in terms of risk-aversiveness, but how this effect is created in detail is not yet known. This could be an interesting angle for another study.

Execution

In terms of execution of the research, there is more information to be found in this topic by considering more data sources, and doing more interviews with for example a more varied list of actors. In that sense, this thesis gives a good general overview of the effects of the regulatory framework, the investment uncertainty and the other actor effects, but a more in-depth study with all the relevant parties could expand this premise with more factors and peculiarities that make the current

Furthermore, the factors under scrutiny in this research were supported with claims from interviews or excerpts from other primary sources. Whereas these findings are empirically supported through this method, the expanded interviews, additional sources and other data sources can help in the further validation of this research. From a qualitative viewpoint, the findings of this research are interesting, but to really start using the findings in practice I believe that a study that gathers more hard evidence is needed. In that sense, this study is really only a first step in this process.

With regards to this last topic, where the study can be narrowed, it can also be made even more broad and exploratory, opening up with the question of the main factors influencing investment behavior of the DSO's in the Netherlands. I believe that this study deeply covers the two most important ones in the form of regulation and investment uncertainty, but the actor network effects can be expanded upon. Here, a future study can help in the building of a large research body regarding the investment effects on Dutch DSO's.

6.4. Critical Reflection on the Thesis process

Looking back at the thesis process, a couple of facts come to mind as interesting to note in this final reflection.

Firstly, the research progress was slow at the start due to the complexity of the system under examination. In that regards, I believe that I underestimated how complex regulation of an organization such as a DSO really is. From a theoretical perspective, the principles guiding regulation are more easily understood, but the actual application of this theory leads to a very complex system. Luckily, most of the required elements of this system could be found publicly at the website of the ACM, but I nonetheless noticed that it is very easy to go to deep within this system.

To tackle this, I had to ask myself the question of whether or not delving deeper into the regulatory system was going to help the conclusion of the research. Whilst in the end, the answer might have been a tentative yes, this would have required such a large amount a getting used to notational standards of the ACM, specifics of the formulae used, and collection and reading of hundreds of data sheets. I determined that that kind of work is not suited to a relatively short Master's thesis, and thus, I opted to keep my analysis of the regulatory system a little simpler. In this regard, I followed the example of a couple of authors whose papers I have read and included in the reference list of this thesis (Haffner et al., 2010; Mulder, 2016; Gómez, 2013). In the end, I believe to have arrived at an analysis that is in depth enough to make some interesting conclusions, but was manageable within the timeframe of this thesis.

Secondly, the start of this thesis included some troubles concerning the application of the theoretical framework. I initially had the idea to create a so-called ideal DSO in order to simulate how ideal investment behavior would look like, and then compare the real-world data to these findings. However, I quickly found out that the system I was attempting to model was so much more complex than I initially thought that it is virtually impossible to make an "ideal" DSO. Every distribution system has its own layout, and particular aspects that you have to take into consideration. To that end, in order to accurately model a DSO, one needs to use a method of simulation of the electricity network under their supervision. Then, you could introduce some renewable generation to such a model and see how the grid reacts. Such a tool could help with preemptive investments, but even then, you would still need to pick the locations of the generation based on qualitative findings.

I believe that using such a method, one would run into the exact problem that the DSO themselves are running into: That this type of information is not available when you need it, and that it only becomes apparent that a project is being planned when you are already to late to adjust you grid investments accordingly. To that end, I believe that the current direction of my thesis helps more with this particular problem, highlighting how these projects are popping up so quickly and doing some suggestion on how this could be avoided in the future.

To end on a more personal note, the writing process of this thesis was not without its bumps in the road, and the first version that I wrote was very much oriented towards the actual activities that I performed for the research topic. In that sense, I found it hard to let go of this methodological and chronological structure that I had created in my mind. In the end, I believe that in its current form this thesis gives a good picture of the situation by following the findings of the research instead of focusing on the execution of the research. It has become more a report of the findings and less of a research technical report. This is not something that I have done before in my academic years at the TU Delft, and thus it was not an easy process, but a very valuable one nonetheless.

Looking back at the entire writing process, I would have to do it all again I would try to set out in a more structured approach and write the first versions of the document a bit earlier in the process. The feedback rounds contained some very valuable tips that I could have applied earlier if these preliminary versions were finished at an earlier stage. However, I believe that the process of writing this thesis has taught me a lot about how to tackle these types of projects in the future, but it has also shown me that I would not like to continue my career in a pure research fashion. I enjoyed the interactive parts of this thesis most of all, talking with my interviewees about the problems and relaying these findings to something usable. That is something that I wish to keep doing, so in that sense this thesis has served as a valuable, personal lesson.

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A

Complete financial analysis and Data Sheets

In this chapter the Dutch DSO's will be analysed by using the published annual reports. The specific methodology for this analysis can be found in the previous chapter, and the results will be discussed in the next chapter.

A.1. Determination of index values

Using the method described in chapter 2, the relevant index (AEX) has been subjected to couple of smoothing operations. First, the daily value of the index has been obtained from Investing.com (2020), with data taken from the 1st of June 2010 up until the 1st of June 2020. The value used in the graph is the reported daily value, which is itself the daily average value. This data was used to create the graph seen in Figure A.1

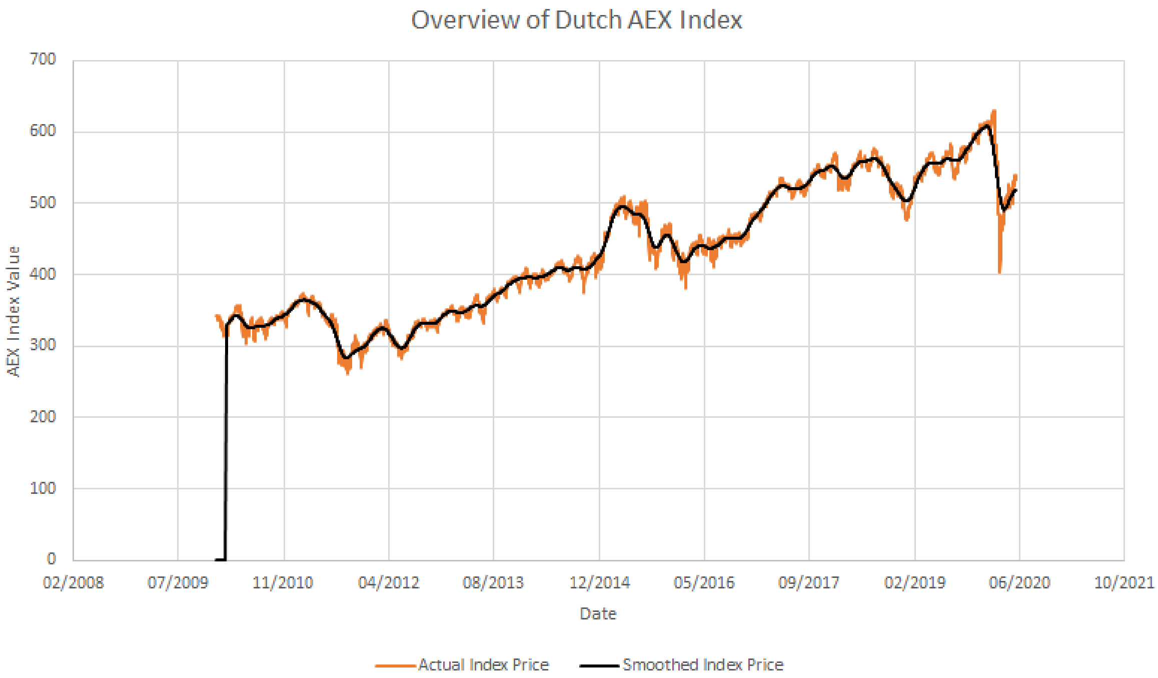

Figure A.1: Development of the AEX index value (in orange) and the smoothed version after two rolling average operations (black).

The smoothed version of the index has been created by performing two rolling average operations on the imported data values. In the first smoothing operation the average is taken from the 12 days prior and the 12 days after, creating a 25 day rolling average. For the second smoothing operation, this rolling average was increased to a 45 day rolling average as the resulting smoothness from the first operation was deemed insufficient.

Next, a trend-line operation was performed using the definition described in Equation 2.6. Once more, the reason for the creation of this trend-line is to obtain a measure that can be effectively used to compare against the variation in earnings. Given that the annual reports are reported once per year, a similar yearly value for the index is required. The results of the trend-line operation can be seen in Figure A.2.

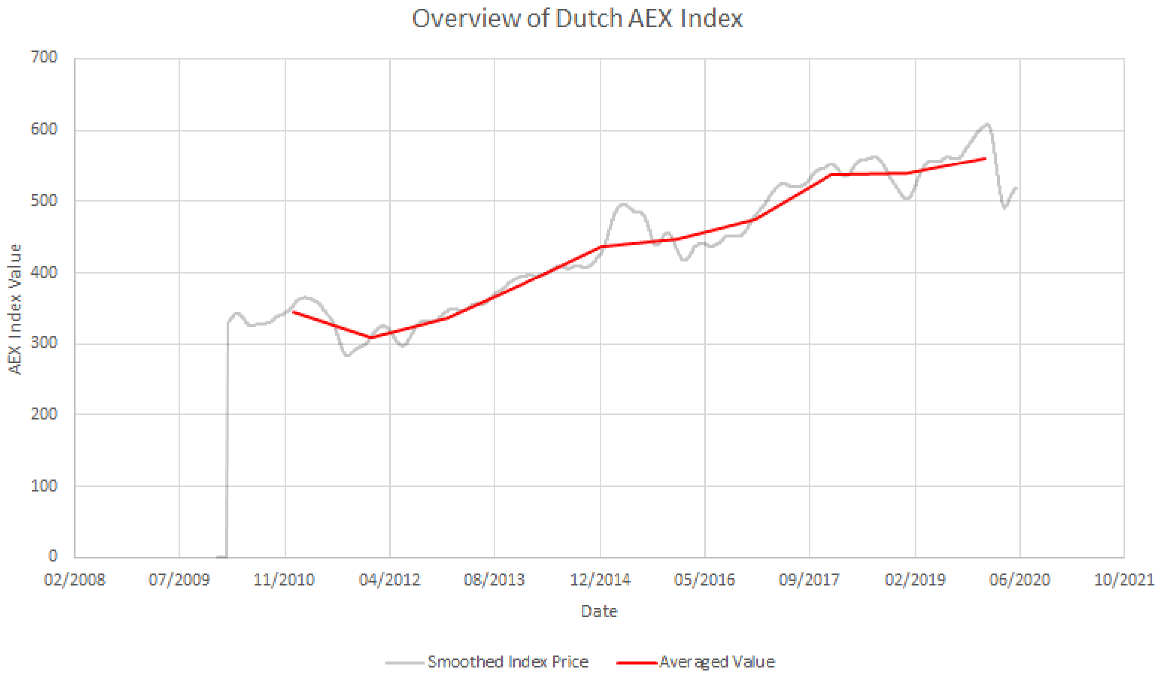

Figure A.2: Presentation of the trend-line (in red) that was created for the calculation of accounting beta's.

The red trend-line shown in Figure A.2 gives the following values for the market index in the relevant years:

Table A.1: Overview of the AEX value according to the trend-line for each year in the analysis. Values are taken for the 1st of January.

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
AEX Value	344,89	308,68	335,99	385,13	437,02	448,12	473,83	538,29	539,90	560,31

With the values presented in Table A.1, the beta's for the DSO can be calculated in their corresponding section of this chapter. With these steps that are common to all DSO's finalized, the next section will go over every firm on a firm by firm basis.

A.2. Firm-by-firm Analysis

Using the structure defined in chapter 2, this section will go over interesting accounting variables for all of the Dutch DSO's.

A.2.1. Coteq Netbeheer B.V.

For the firm Coteq Netbeheer B.V., annual reports can be found from 2016 up to 2019. For this analysis, the reports listed in Table A.2 were used.

Table A.2: List of annual reports used for the Coteq Netbeheer B.V. analysis

Year	Title	Reference
2016	Jaarverslag Cogas Infra en Beheer B.V. 2016	
2017	Jaarverslag Coteq Netbeheer B.V. 2017	
2018	Jaarverslag Coteq Netbeheer B.V. 2018	
2019	Jaarverslag Coteq Netbeheer B.V. 2019	

As can be seen in the table, a name change occurred in 2016, when *"Cogas Infra en Beheer"* became *"Coteq Netbeheer"*. However, the numbers mentioned in the annual reports still match, so the change is not fundamental from a financial perspective. Attempts to find earlier annual reports did not yield any results, leaving the data-set on the smaller side. For the sake of completeness, the analysis has still been included in this thesis, but the explanatory value of the data is limited due to the small sample.

Revenue

The development of Coteq's revenue can be found in Figure A.3. Both total revenue and gross revenue have been shown to give an indication of the total transport costs for the firm.

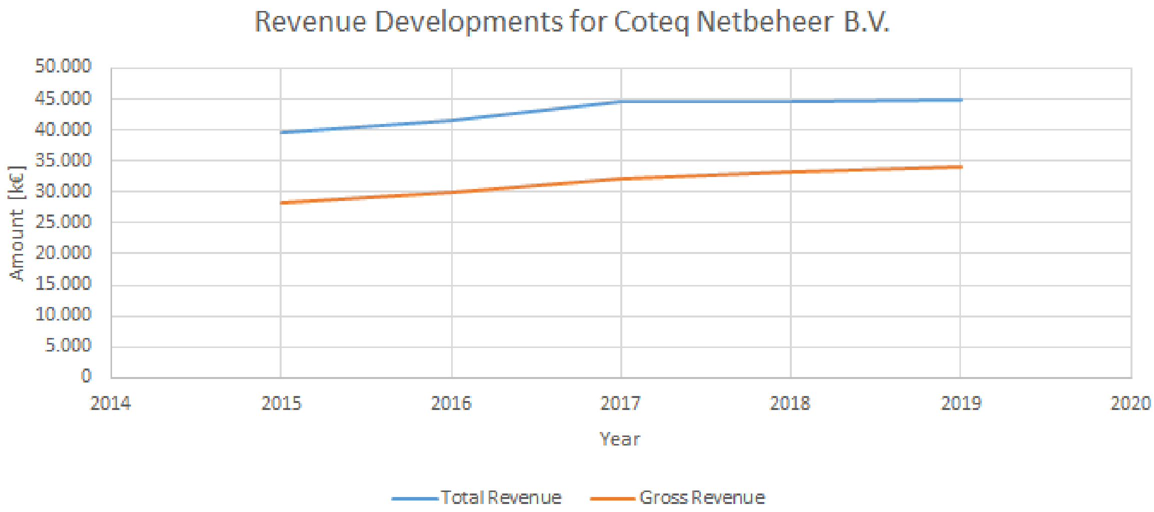

Figure A.3: Overview of the revenue development for the firm Coteq Netbeheer B.V.

As can be seen inFigure A.3, the annual revenues for Coteq have been experiencing a small increase over the past few years. Due to the lack of earlier data, not much can be said about the earlier regulatory period.

Accounting variables of interest

A complete overview of all the figure made for Coteq Netbeheer B.V. can be found in Appendix A. The most interesting results are presented and discussed below.

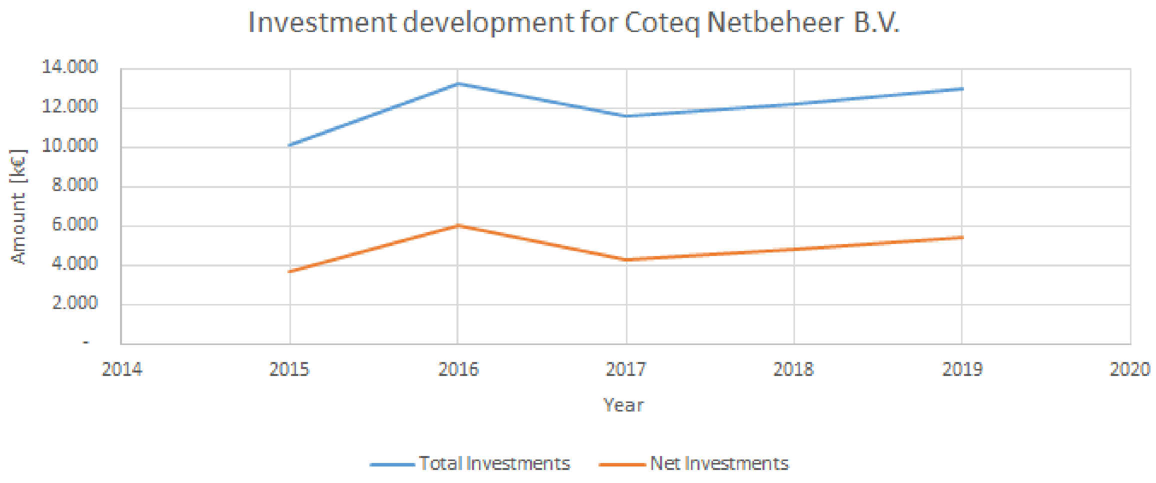

Figure A.4: Overview of the annual investments made by the firm Coteq Netbeheer B.V.

In Figure A.4, the annual investments made by Coteq can be observed. Firstly, the sharp increase and consequent decrease in investments in the year 2016 and 2017 are notable. Secondly, the relative difference between total and net investments appears to be rather constant due to a stable depreciation amount.

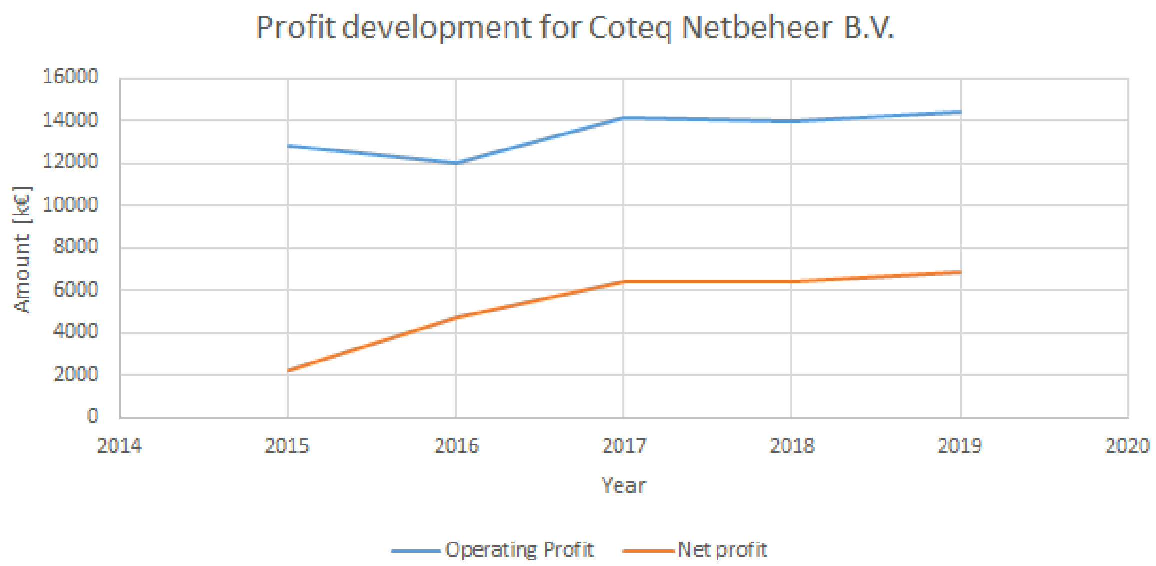

Figure A.5: Overview of the annual profits made by the firm Coteq Netbeheer B.V.

From Figure A.5, a clear increase in net profits can be observed, whereas the difference between operating profit and net profit has decreased. This is due to either a change in taxes or due to a difference in accounting measures. For the firm Coteq, there is a large item called *“vrijval overlopend actief”*, which is causing this change. This item is to indicate a flow of assets to the coming book year.

Lastly, where dividend is considered for Coteq, an interesting devlopment can be observed. Coteq does not hand out a steady dividend, but does occasionally hand out very large dividends. In the year 2016, the dividend payout was 20 M€, leading to a dividend over net profit ratio of 425 %. A further 3 M€ dividends were paid in 2019, with a D/NP rate of 44%. Combined, the total dividend payout over the last few years was 23 M€, whereas the total net profit over this period was 26.675 M€.

Accounting Beta

For the accounting beta of Coteq, we will use the operating profit as yearly earnings. To complete Equation 2.3, we first need to find the variance of the change in earnings, followed by the covariance of the change in earnings with respect to the change of the market index. Using Excel's *VAR.S* and *COVARIANTIE.S* functions, the values for these variables are found. Then, using Equation 2.7, the value for the asset beta is found. All results are presented below:

$$
\begin{aligned}
\sigma(\Delta_E) &= 0,0108 \\
COV(\Delta_E, \Delta_M) &= 0,0046 \\
\beta_E &= 0,4278 \\
\beta_A &= 0,6185
\end{aligned}
$$

A.2.2. Enduris B.V.

For the firm Enduris B.V., annual reports can be found from 2012 up to 2018. For this analysis, the reports listed in Table A.3 were used.

Table A.3: List of annual reports used for the Enduris B.V. analysis

Year	Title	Reference
2011	Jaarrapport 2011 - DELTA Netwerkbedrijf B.V.	
2012	Jaarrapport 2012 - DELTA Netwerkbedrijf B.V.	
2013	Jaarbericht 2013 - DELTA Netwerkbedrijf B.V.	
2014	Jaarbericht DELTA Netwerkbedrijf 2014	
2015	Jaarbericht 2015 - Enduris B.V.	
2016	Jaarbericht 2016 - Enduris B.V.	
2017	Jaarbericht 2017 - Enduris B.V.	
2018	Jaarrekening 2018 - Enduris B.V.	

As can be observed in the above table, a name change from DELTA Netwerkbedrijf B.V. to Enduris B.V. took place, but there is no difference in accounting information due to this change. However, Enduris was taken over by the Stedin Groep in 2017, meaning that the annual reporting stopped in 2018 for Enduris as a lone entity. Because the Stedin reports do not discuss Enduris as a seperate segment, the information for the year 2019 was not available. For that reason, this analysis goes until 2018.

Revenue

An overview of the revenue development for Enduris B.V. can be seen in Figure A.6.

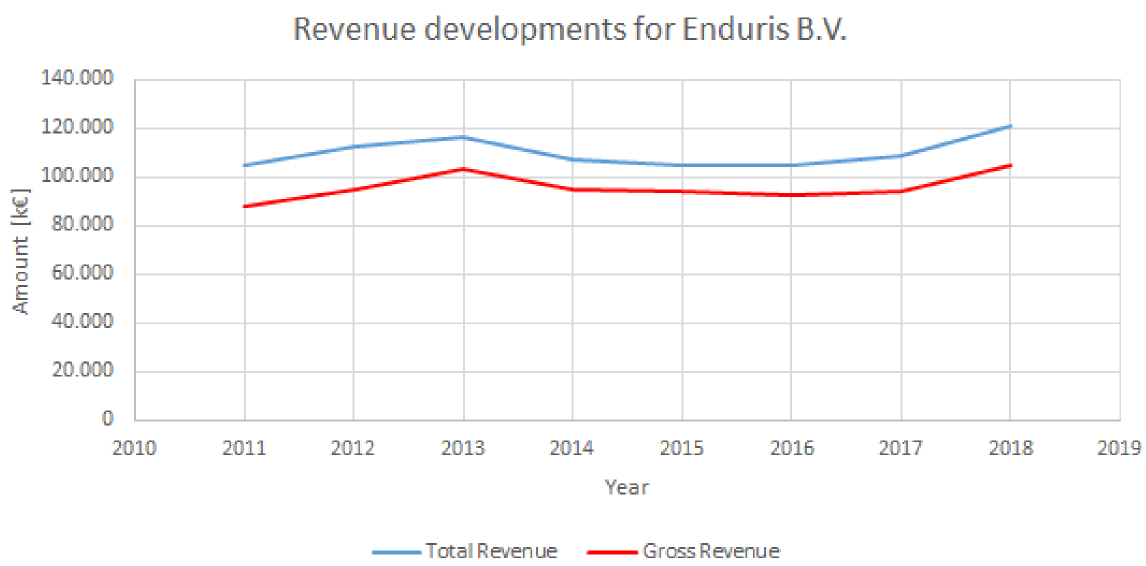

Figure A.6: Overview of the revenue development for the firm Enduris B.V.

As can be clearly observed in the above figure, the revenue for Enduris has remained at a stable level over the past 8 years, hovering round the 90 M€ mark.

Accounting variables of interest

A complete overview of all the figures made for Enduris B.V. can be found in Appendix A. The most interesting results are presented below.

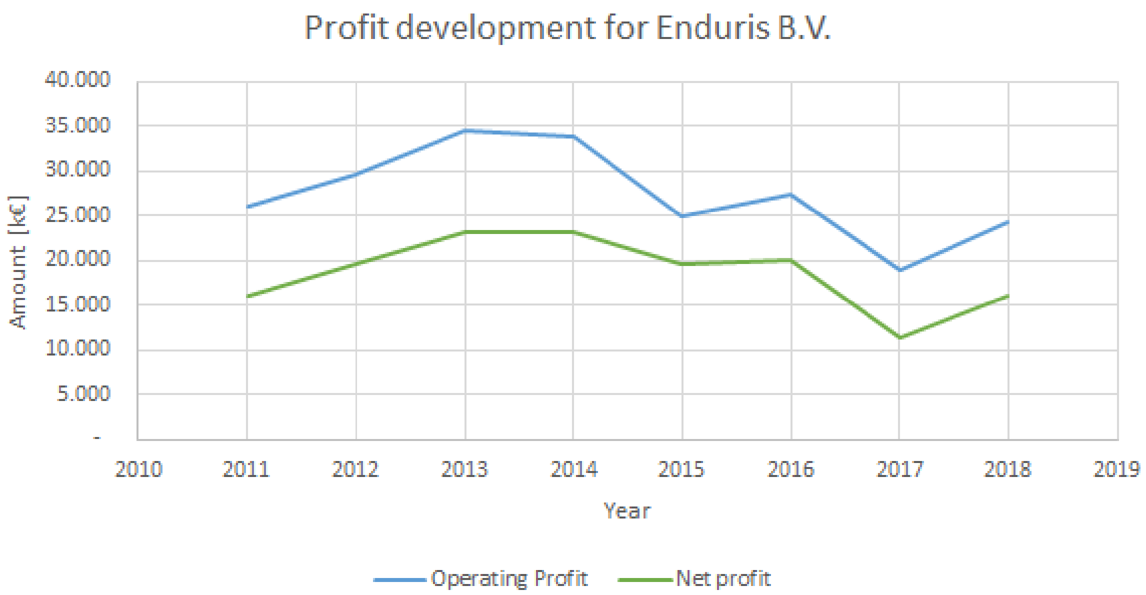

Figure A.7: Overview of the profit development for the firm Enduris B.V.

In Figure A.7 the profit development for the firm Enduris B.V. can be seen. Clearly, both operating profits and net profits have decreased in the past few years when comparing it to profit levels of the early 2010's. The specific difference between operating and net profit also seems to have decreased, meaning that either taxes have changed or some additional amount of cash was deducted from the operating profit in the earlier years of the overview. The start of the new regulatory period was in 2016, but there is no clear link to the lower profits as is the case for some of the other firms.

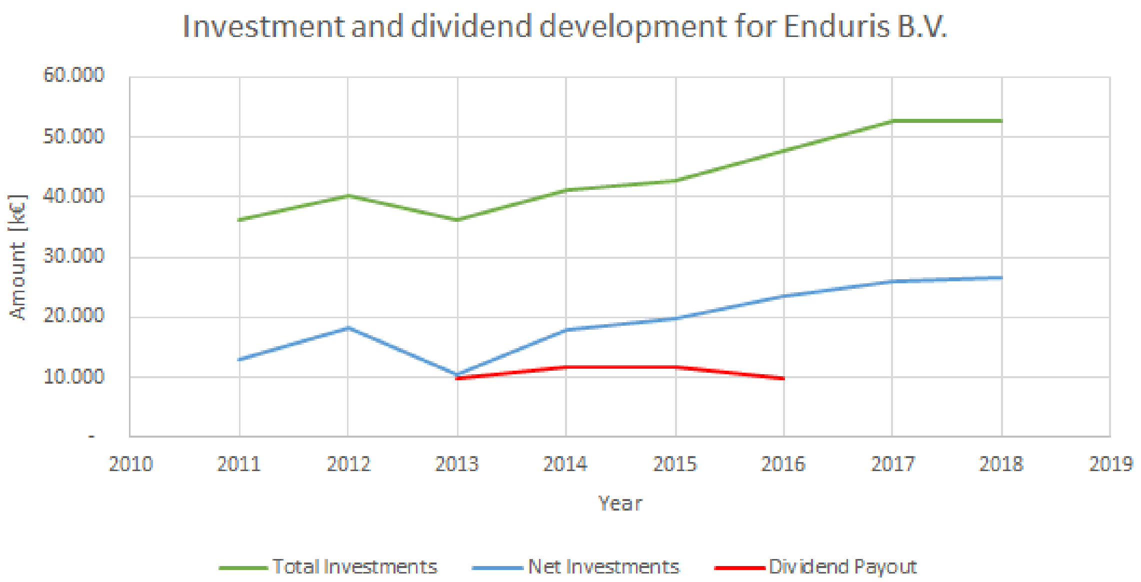

Figure A.8: Overview of investments and dividend payouts for the firm Enduris B.V.

In terms of the investments made by Enduris B.V., a clear increase in both total and net investments can be seen in Figure A.8. It is also interesting to note that Enduris did not pay any dividends since the start of the new regulatory period.

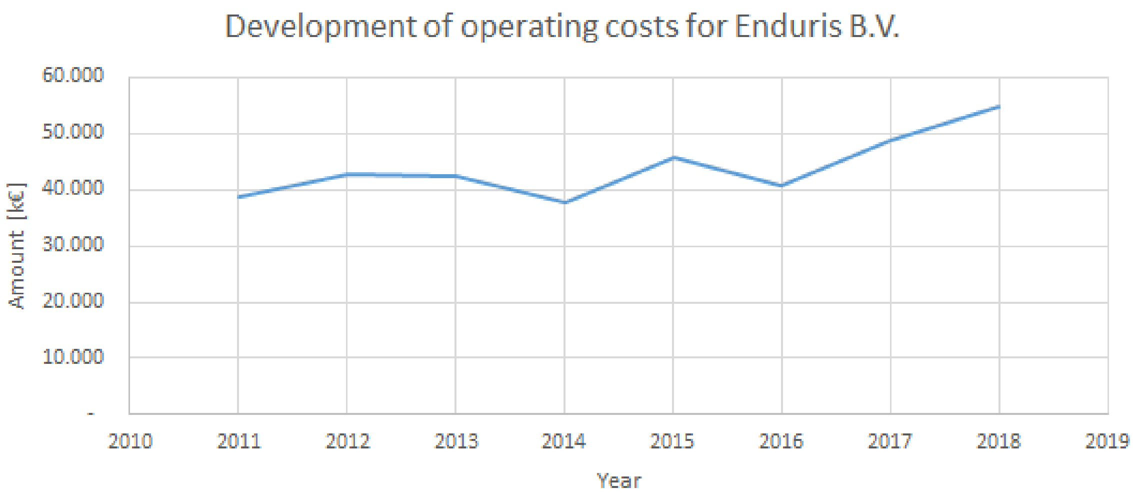

Figure A.9: Overview of operating cost development for the firm Enduris B.V.

In Figure A.9 the development of operational costs can be seen. Given the clear increase observed here, the clear increase in investments and stable revenues, the decrease of profits as observed in Figure A.7 is easily explained. The question that arises from these observations is why the operating costs have increased. To answer this question, a look at the last income statement shows that costs of third party services in particular have increased.

Accounting Beta

For the asset beta, the same method of calculating the variance of the change in earnings and the covariance of the change in earnings compared to the market changes was used. Then, using Equation 2.7 once more, the value for the asset beta was found. All results are presented below:

$$\sigma(\Delta_E) = 0,0304$$
$$COV(\Delta_E, \Delta_M) = 0,0054$$
$$\beta_E = 0,1792$$
$$\beta_A = 0,4528$$

A.2.3. Enexis Netbeheer B.V.

For the firm Enexis Netbeheer B.V., annual reports can be found from 2009 up to 2019. For the purpose of this analysis, the following reports were used:

Table A.4: List of annual reports used for the Enexis Netbeheer B.V. analysis

Year	Title	Reference
2011	Jaarrekening 2011 - Enexis B.V.	
2012	Jaarrekening 2012 - Enexis B.V.	
2013	Jaarrekening 2013 - Enexis B.V.	
2014	Jaarrekening 2014 - Enexis B.V.	
2015	Jaarrekening 2015 - Enexis B.V.	
2016	Jaarrekening 2016 - Enexis B.V.	
2017	Jaarrekening 2017 - Enexis B.V.	
2018	Jaarrekening 2018 - Enexis Netbeheer B.V.	
2019	Jaarrekening 2019 - Enexis Netbeheer B.V.	

All of the reports in Table A.4 are consistent with respect to firm or holding mutations, so no excessive data discontinuities should be present. The reason for using the Dutch reports is due to availability of the reports for the specific segment (In the English version, only the complete holding reports are available, whilst we are interested in just the DSO part of the holding).

Revenue

The development of Enexis' revenue can be found in Figure A.10. Both total revenue and gross revenue have been shown to give an indication of the total transport costs for the firm.

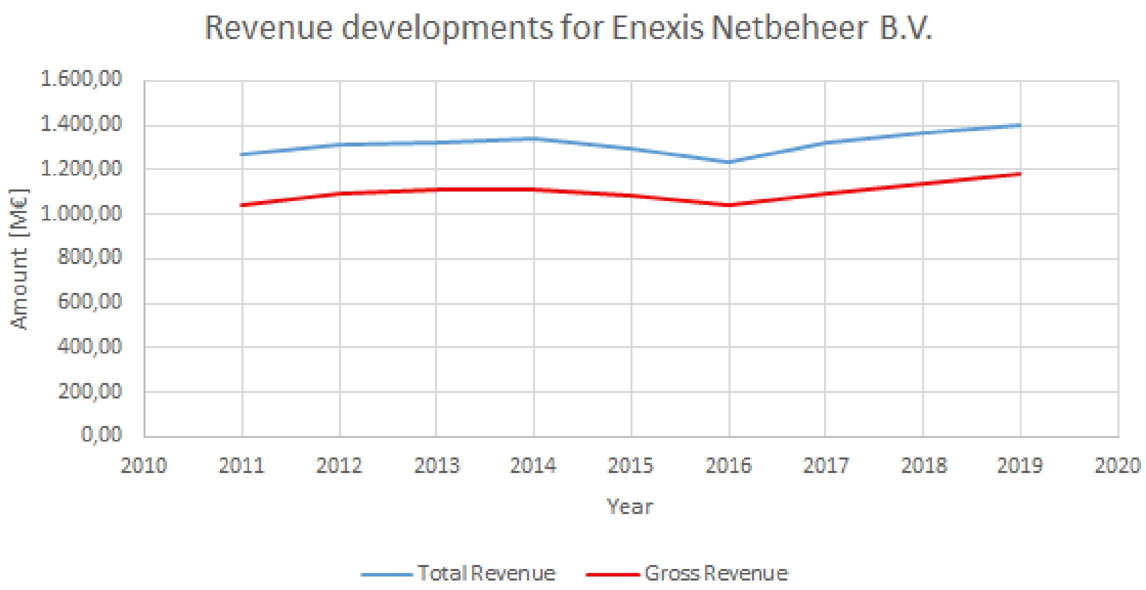

Figure A.10: Overview of the revenue development for the firm Enexis Netbeheer B.V.

As can be seen in the above figure, the revenue for Enexis Netbeheer B.V. has been increasing steadily over the past few years. One clear observation that can be made is that the revenue drops significantly in the year 2016, which coincides with the start of the new regulatory period.

Accounting variables of interest

A complete overview of all the figures made for Enexis Netbeheer B.V. can be found in Appendix A. The most interesting results are presented below.

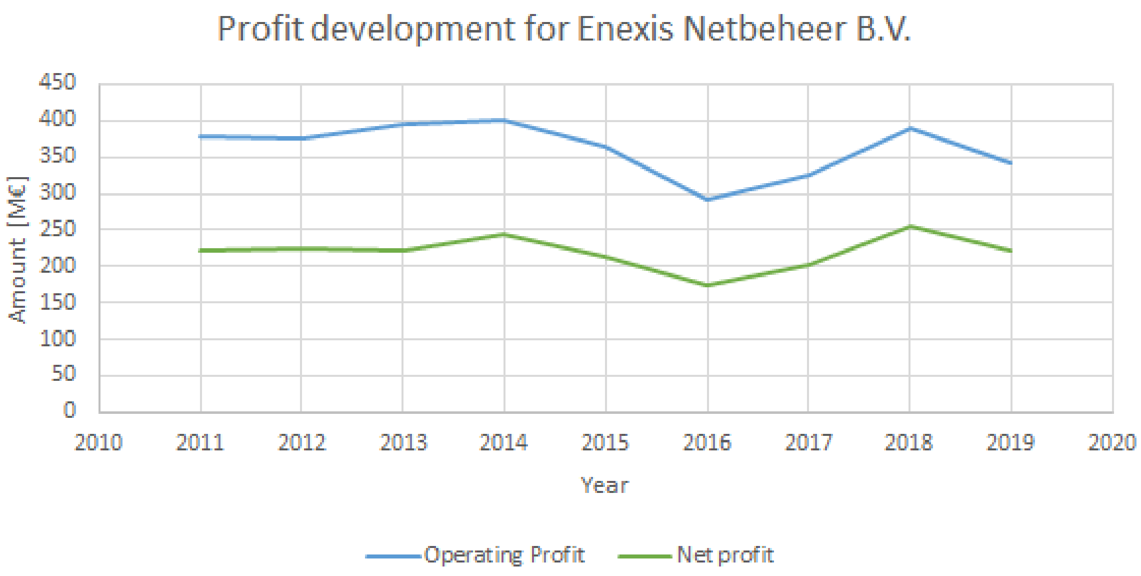

Figure A.11: Overview of the profit development for Enexis Netbeheer B.V.

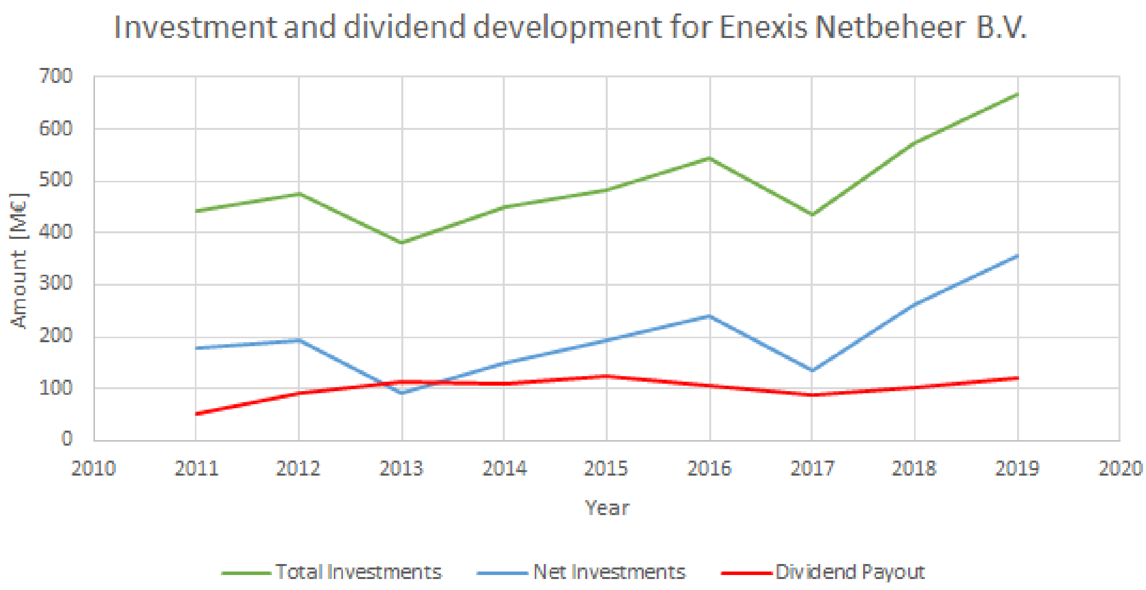

Figure A.12: Overview of the investments and dividend payouts by Enexis Netbeheer B.V.

In Figure A.11, the development of profit is presented. Two observations can be made from this figure. Firstly, the level of profit is rather stable, but the difference between operating profit and net profit has become smaller. This means that the firm either has more financial obligations, or the tax system has changed. Secondly, a clear dip in profit can be observed around the start of the new regulatory period in 2016.

Next, in Figure A.12, the investments and dividend payouts can be observed, with another two key observations that can be made. Firstly, the overall investments made are clearly increasing, although the new regulatory period seems to have affected this investment rate (with a lag of 1 year). Secondly, the dividend payout is relatively stable from the year 2012 onward, hovering close to 100 million euros every year.

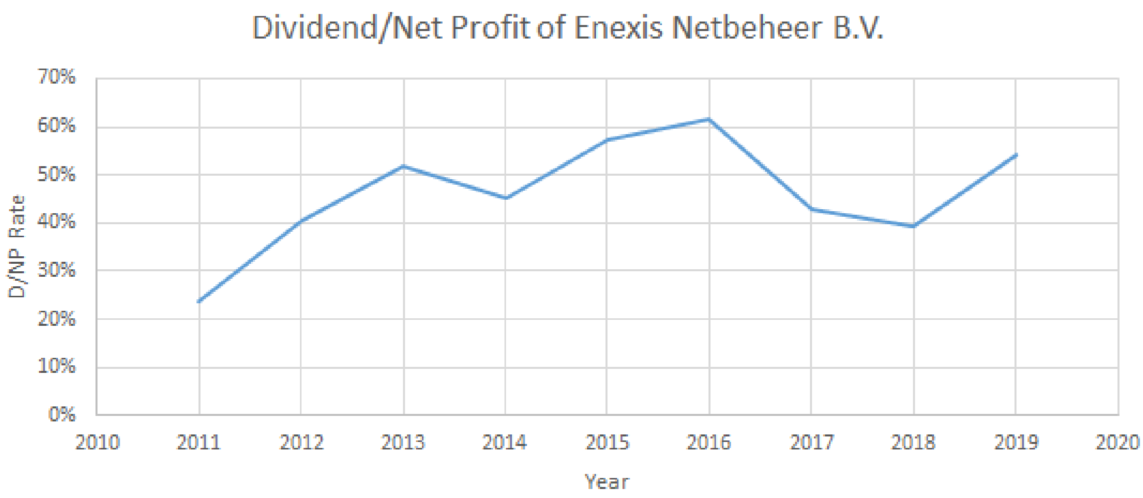

Figure A.13: Dividend payouts over Net profit (D/NP Rate) for Enexis Netbeheer B.V.

In Figure A.13, the ratio of dividends paid with respect to net profit can be seen. Clearly, this ratio experienced a serious increase in 2012, after which it has stayed between 40% and 60%.

Accounting Beta

Given that the asset beta is the unlevered beta (Damodaran, 2020), we will use the operating profit as yearly earnings. To complete Equation 2.3, we first need to find the variance of the change in earnings, followed by the covariance of the change in earnings with respect to the change of the market index. Using Excel's *VAR.S* and *COVARIANTIE.S* functions, the values for these variables are found. Then, using Equation 2.7, the value for the asset beta is found. All results are presented below:

$$\sigma(\Delta_E) = 0,0171$$
$$COV(\Delta_E, \Delta_M) = 0,0014$$
$$\beta_E = 0,0791$$
$$\beta_A = 0,3861$$

A.2.4. Liander N.V.

For the firm Liander N.V., annual reports can be found from 2009 up to 2019. For this analysis, the reports listed in Table A.5 were used.

Table A.5: List of annual reports used for the Liander N.V. analysis

Year	Title	Reference
2011	Samen slim met energie - Jaarverslag 2011	
2012	jaarverslag 2012 - De verbinding naar morgen	
2013	Energie voor een duurzame samenleving - Jaarverslag 2013	
2014	Energie geef je door - Jaarverslag 2014	
2015	Zonder energie staat alles stil - Jaarverslag 2015	
2016	Samen omschakelen - Jaarverslag 2016	
2017	Jaarverslag 2017 - Samen omschakelen krijgt vorm	
2018	Jaarverslag 2018 - Samen verder	
2019	Jaarverslag 2019 - Samen werken aan transitie	

As can be seen in the above table, the firm Liander N.V. has a rather complete overview of the accounting data for the past decade. No clear variations in accounting standards were observed, leading to a seamingly continuous data-set. Given that the annual reports were made for the holding company Alliander, the segmented information was used to find the specific values for the DSO part Liander.

Revenue

The development of Liander's revenue can be found in Figure A.14. Both total revenue and gross revenue have been shown to give an indication of the total transport costs for the firm.

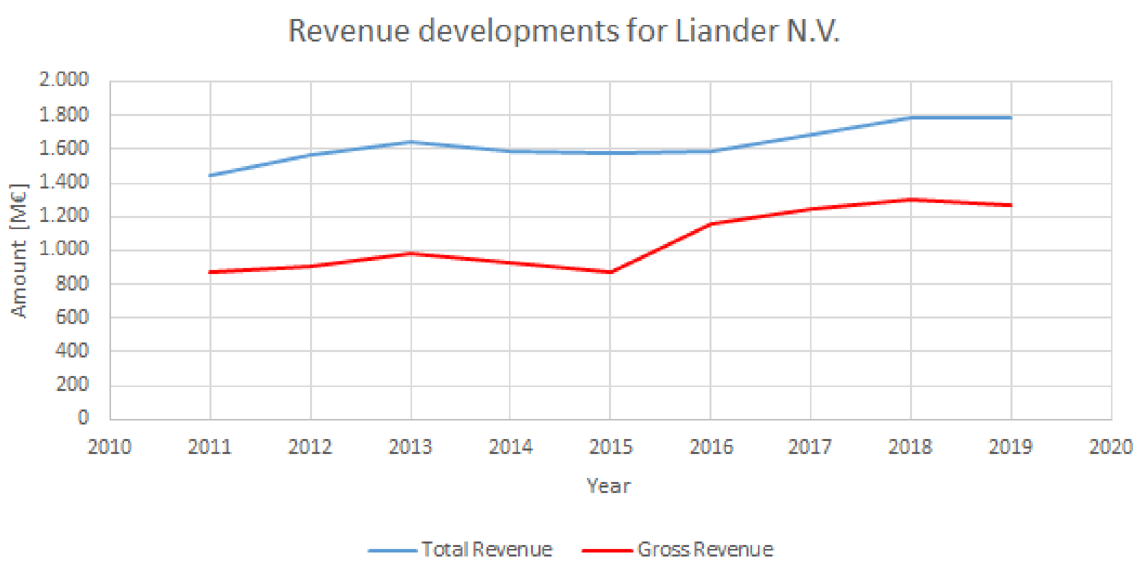

Figure A.14: Overview of the revenue development for the firm Liander N.V.

Clearly, the revenues for Liander N.V. have steadily increased over the past few years, following a similar trend as the revenue developments for Enexis Netbeheer B.V. followed.

Accounting variables of interest

A complete overview of all the figures made for Liander N.V. can be found in Appendix A. The most interesting results are presented below.

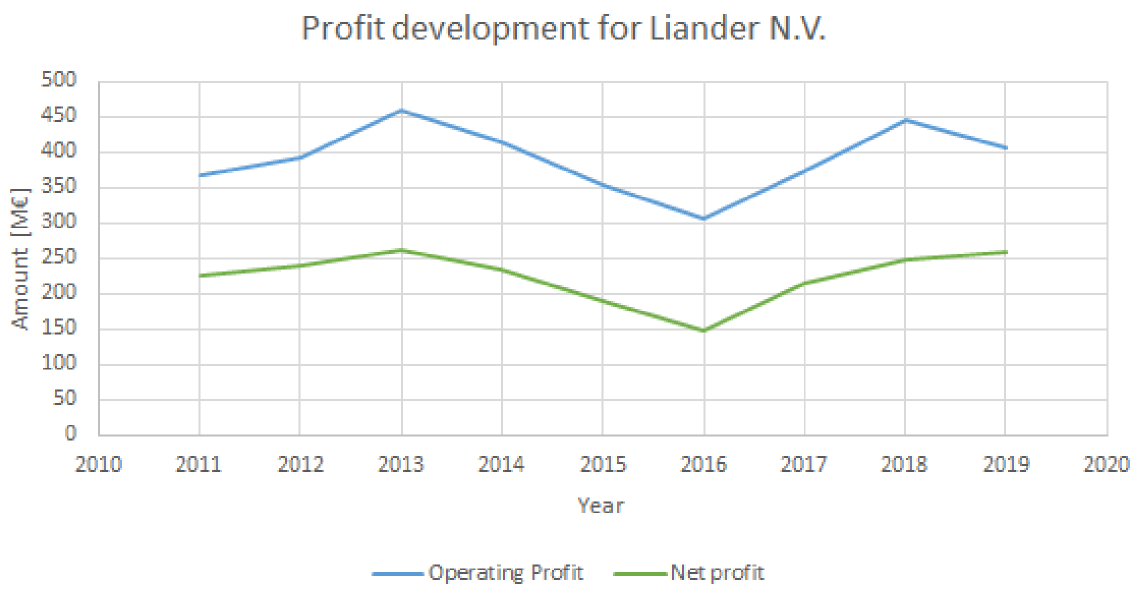

Figure A.15: Overview of the profit development for Liander N.V.

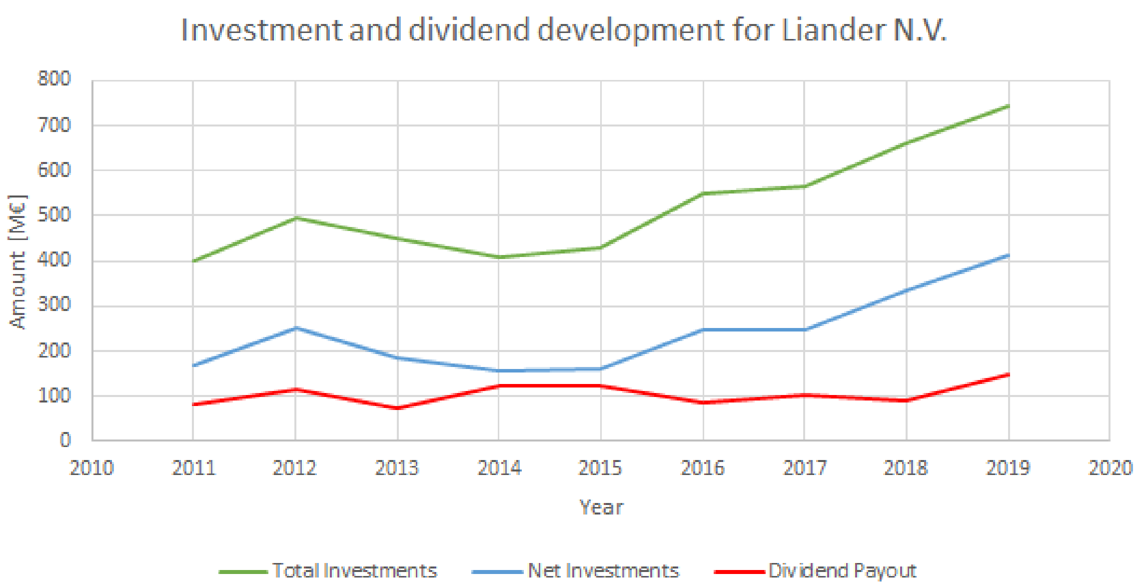

Figure A.16: Overview of the investments and dividend payouts by Liander N.V.

In Figure A.15, the profit trends for Liander N.V. can be observed. A clear dip is present around the start of the new regulatory period in 2016, but over the years the profit levels have recovered to the early 2010's levels. The difference between operating and net profit has remained relatively stable.

In terms of the investments and dividends observed in Figure A.16, a very clear increase in investments is observed. This change seemingly start around the start of the new regulatory period in 2016, and has kept increasing over the years. The level of dividend payout however, has remained stable, suggesting that Liander is investing more of its revenues.

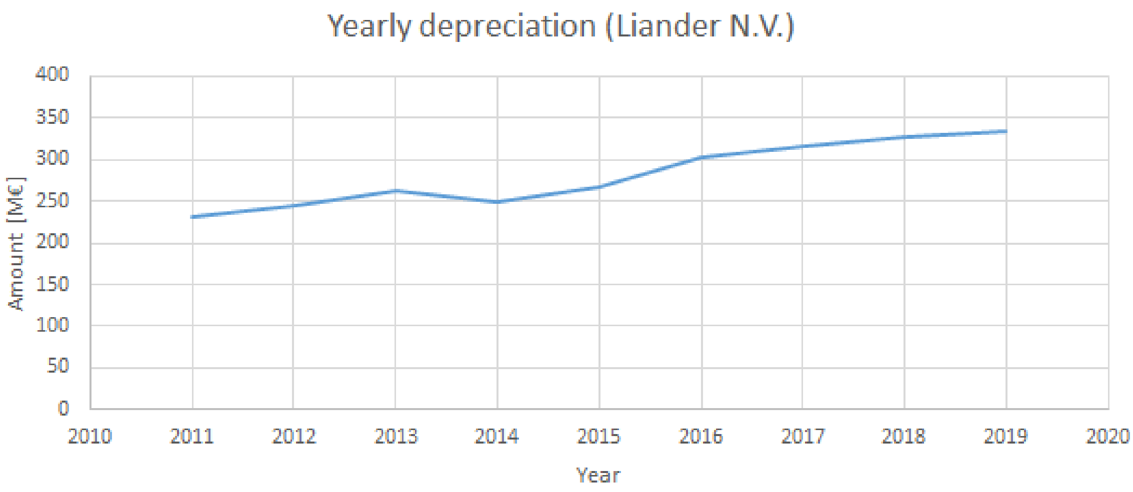

Figure A.17: Overview of the annual depreciation by Liander N.V.

However, a large part of the increase in total investments is compensated by the substantial increase in annual depreciation rate as observed in Figure A.17. This increase is in the order of 100 M€ over the past eight years, which is around a 50% increase.

Accounting Beta

For the earnings beta and asset beta the same methodology as described for the earlier firm analyses was used. Once more the change in operating profit was compared to market changes, leading to the following results:

$$\sigma(\Delta_E) = 0,0239$$
$$COV(\Delta_E, \Delta_M) = 0,0026$$
$$\beta_E = 0,1110$$
$$\beta_A = 0,4073$$

A.2.5. N.V. Rendo

For the firm N.V. Rendo, annual reports can be found from 2017 up to 2019. For this analysis, the reports listed in Table A.6 were used.

Table A.6: List of annual reports used for the N.V. Rendo analysis

Year	Title	Reference
2017	JAARVERSLAG 2017 N.V. RENDO HOLDING	
2018	JAARVERSLAG 2018 N.V. RENDO HOLDING	
2019	JAARVERSLAG 2019 N.V. RENDO HOLDING	

As can be seen in the above table, the amount of data that can be used for the Rendo analysis is limited. The three reports provide four years worth of accounting data, so the current regulatory period is still covered. However, nothing can be said about the change in certain values compared to an earlier period. In terms of data continuity, no clear changes were detected, so the set should be usable.

Revenue

The development of Rendo's revenue can be found in Figure A.18. Both total revenue and gross revenue have been shown to give an indication of the total transport costs for the firm.

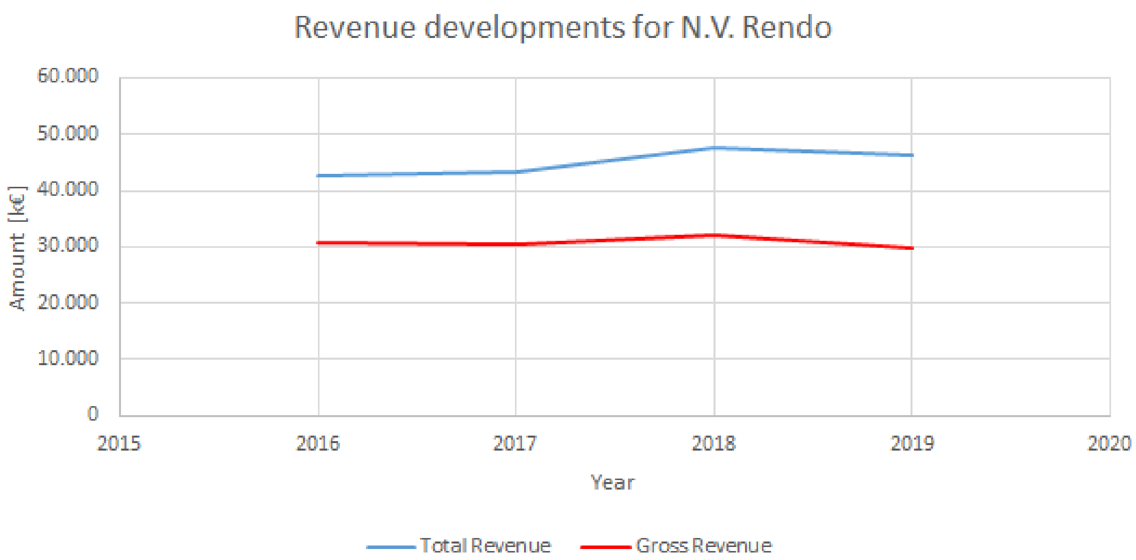

Figure A.18: Overview of the revenue development for the firm N.V. Rendo

As can be observed above, the revenue levels are relatively stable for N.V. Rendo, with no clear deviations. The difference between total revenue and gross revenue does seem to get larger, meaning that the cost of sales or supplies has gone up for this particular firm.

Accounting variables of interest

A complete overview of all the figures made for N.V. Rendo can be found in Appendix A. The most interesting results are presented below.

In Figure A.19, a clear decrease in profits can be observed, whereas the investments in Figure A.20 have increased. Note the relatively high dividend level for this firm, which has remained constant over the past four years.

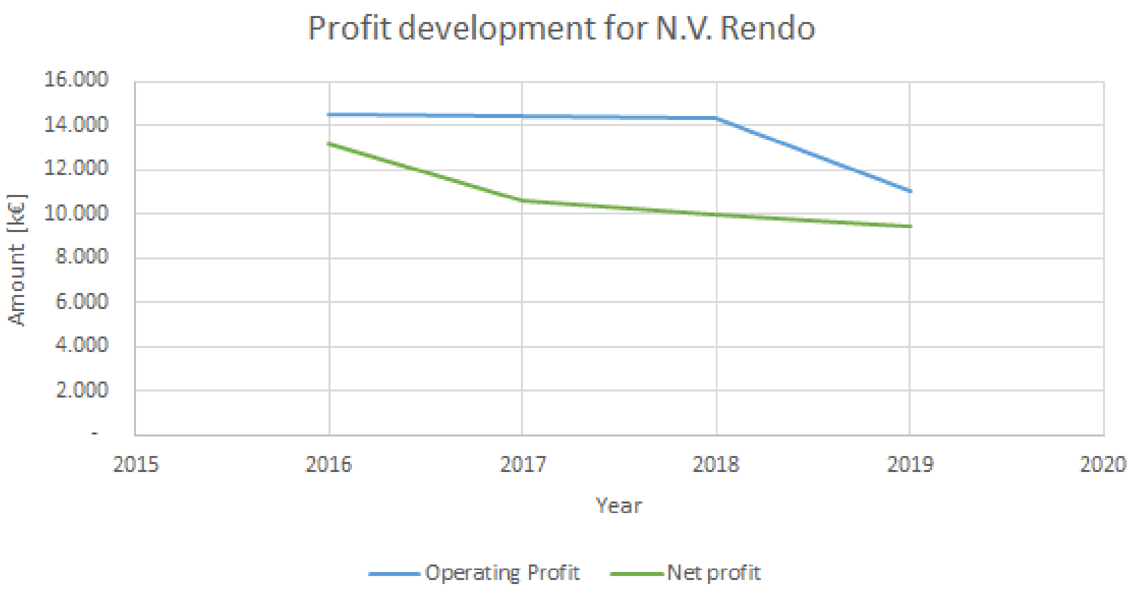

Figure A.19: Overview of the profit development for the firm N.V. Rendo

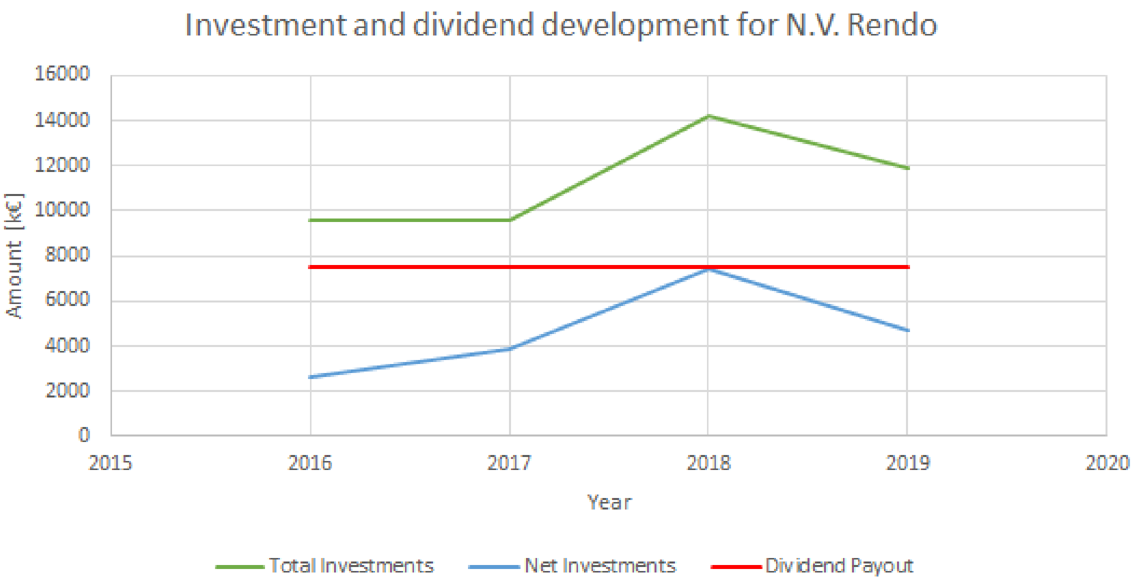

Figure A.20: Overview of the investments and dividend payouts for the firm N.V. Rendo

Accounting Beta

For the earnings beta and asset beta the same methodology as described for the earlier firm analyses was used. Once more the change in operating profit was compared to market changes, leading to the following results:

$$\sigma(\Delta_E) = 0,0163$$
$$COV(\Delta_E, \Delta_M) = 0,0025$$
$$\beta_E = 0,1565$$
$$\beta_A = 0,4377$$

A.2.6. Stedin

For the firm Stedin, annual reports can be found from 2013 up to 2019. For this analysis, the reports listed in Table A.7 were used.

Table A.7: List of annual reports used for the Stedin analysis

Year	Title	Reference
2013	Samen voor duurzaam - Jaarverslag 2013 Eneco Holding N.V.	
2014	Eneco, oog voor de toekomst - Jaarverslag 2014 Eneco Holding N.V.	
2015	Eneco, verbinding en innovatie - Jaarverslag 2015 Eneco Holding N.V.	
2016	Eneco, De toekomst tegemoet - Jaarverslag 2016 Eneco Holding N.V.	
2017	Energie door samenwerking - Jaarverslag Stedin Groep | 2017	
2018	Onze leefwereld - Jaarverslag 2018 Stedin Groep	
2019	Samen schakelen - Jaarverslag 2019 Stedin Groep	

As can be seen in the above table, Stedin used to be part of the Eneco Holding before its unbundling in 2017. Because of this reason, the segmented Stedin information found the Eneco reports was used for the years 2013 until 2017, whereas the segmented Stedin information found in the Stedin Groep reports was used in the last two years. Accounting values for 2017 (which overlap) did not match completely, but the order of magnitude was similar, and the total difference was not enough reason to discard one of the sets. It is, however, noted that discontinuities in the data can occur due to this accounting change.

Revenue

The development of Stedin's revenue can be found in Figure A.21. Both total revenue and gross revenue have been shown to give an indication of the total transport costs for the firm.

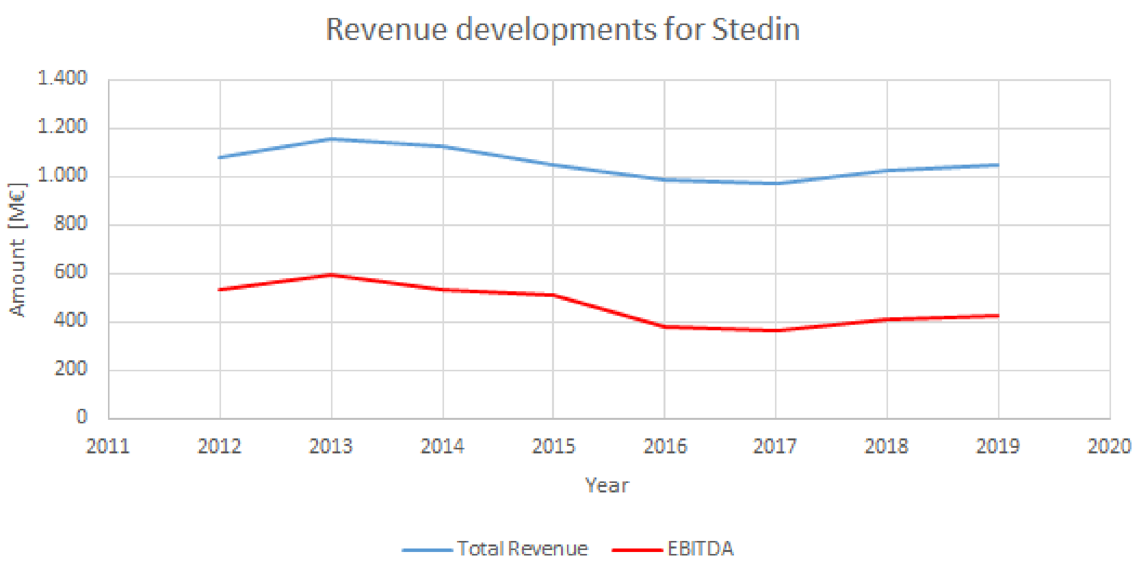

Figure A.21: Overview of the revenue development for the firm Stedin

Clearly, the revenues for Stedin have decreased slightly over the past few years. Also note that the red line in the above figure represents the earnings before taxes, depreciation and amortization, given that the actual gross revenue could not be found in the segmented information. It is also interesting to see that revenues started increasing again in the new regulatory period.

Accounting variables of interest

A complete overview of all the figures made for Stedin can be found in Appendix A. The most interesting results are presented below.

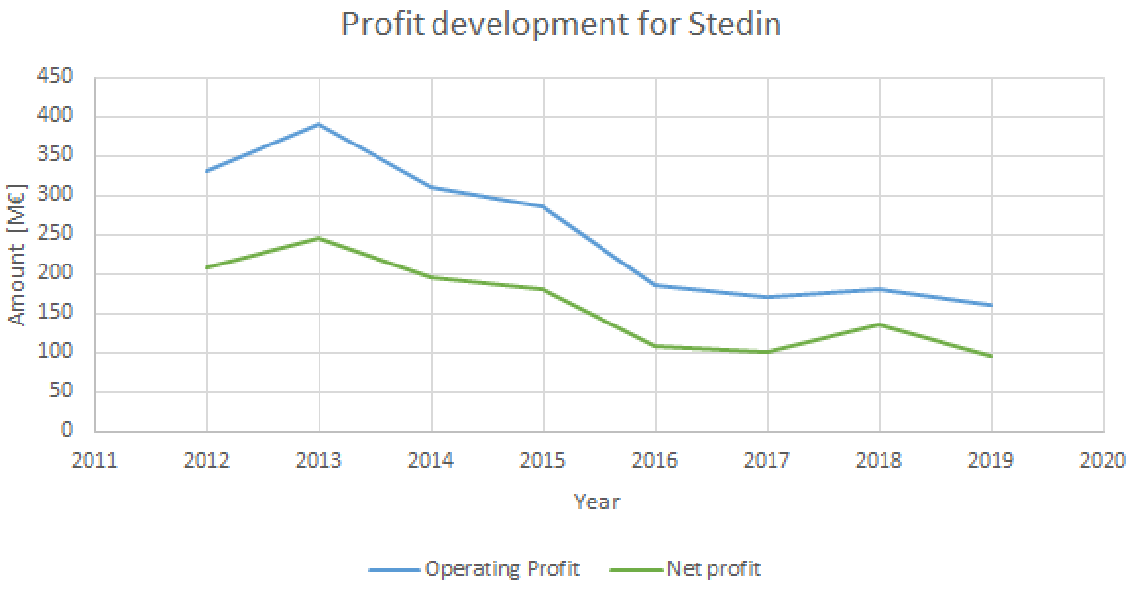

Figure A.22: Overview of the profit development for the firm Stedin

As can be seen in Figure A.22, the profit levels of Stedin have decreases dramatically over the past few years. No clear discontinuity is seen during the 2017-2018 switch, although the bump that is there might be partially explained by accounting changes. However, the overall trend in profits is clear. The reason for this decrease can be found in the following figures.

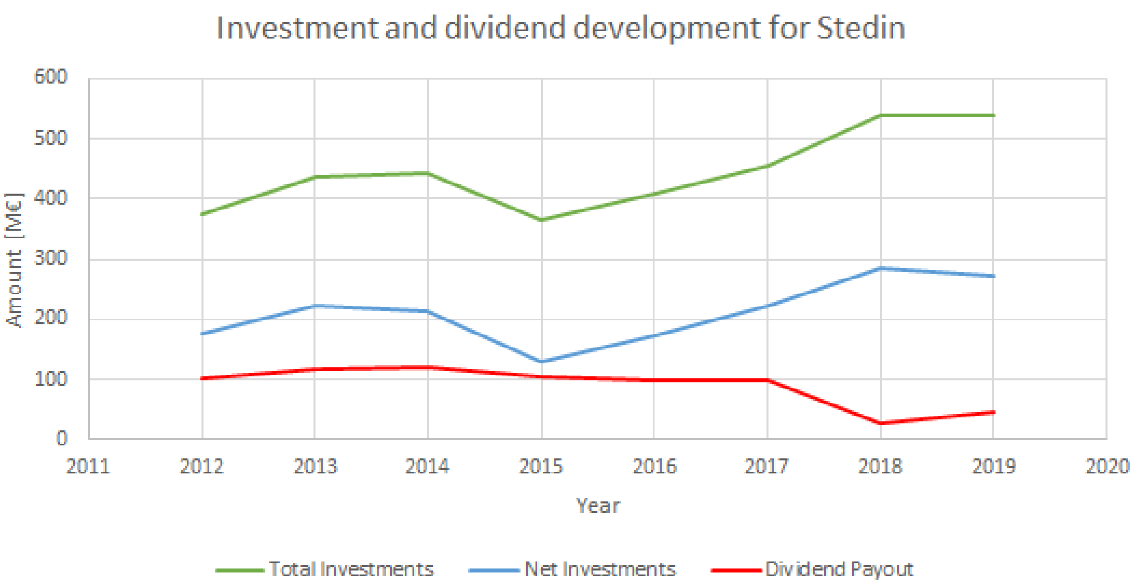

Figure A.23: Overview of the investments and dividend payouts for the firm Stedin

Firstly, a substantial increase in both total and net investments can be seen in Figure A.23, along with a recent reduction in dividends paid. Note that this reduction can also be due to the accounting changes that occurred in 2017, given that the dividends up to 2017 were Eneco dividends, and the dividends of 2018 and 2019 are Stedin Group dividends. Along with the increase in investments, a significant increase in annual depreciation can be observed in Figure A.24.

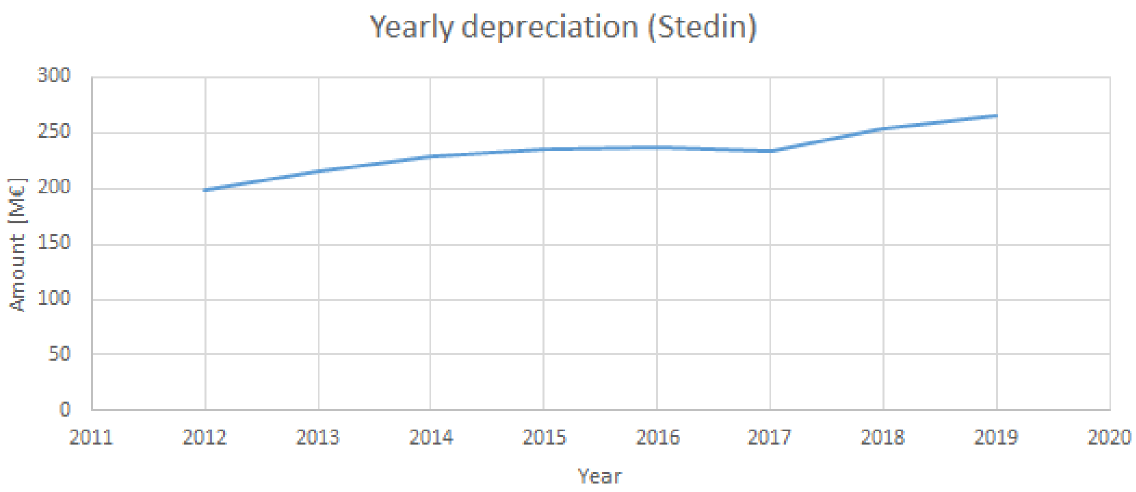

Figure A.24: Overview of annual depreciation for the firm Stedin

Lastly, it is interesting to observe the ratio of dividend and investment, as shown in Figure A.25. Here, the clear dividend change does take a slightly discontinuous look, so using the Stedin data-set to make quantitatively significant assessments is arguable.

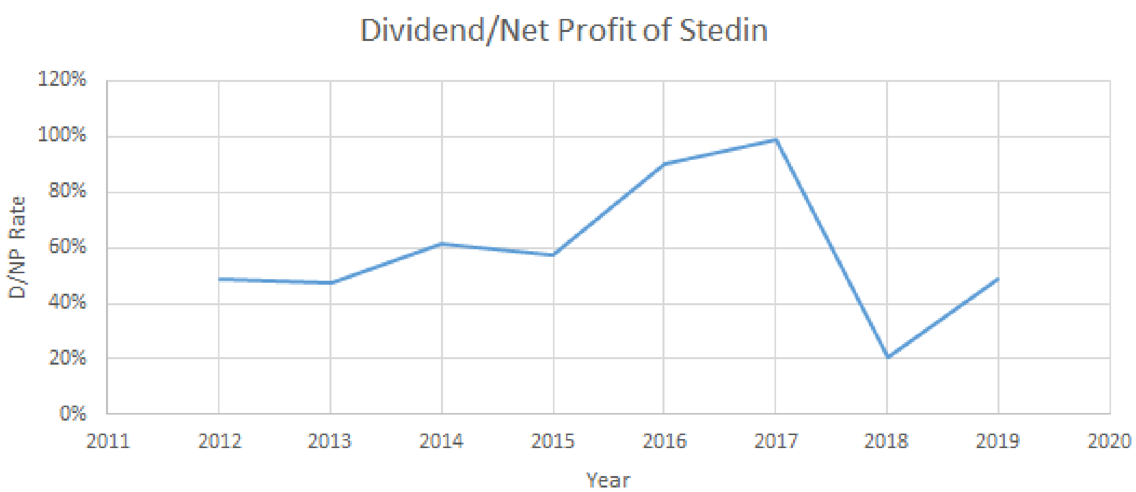

Figure A.25: Dividend/Net Profit for the firm Stedin

Accounting Beta

For the earnings beta and asset beta the same methodology as described for the earlier firm analyses was used. Once more the change in operating profit was compared to market changes, leading to the following results:

$$\sigma(\Delta_E) = 0,0292$$
$$COV(\Delta_E, \Delta_M) = 0,0010$$
$$\beta_E = 0,0350$$
$$\beta_A = 0,3567$$

A.2.7. Westland Infra Netbeheer B.V.

For the firm Westland Infra Netbeheer B.V., annual reports can be found from 2018 up to 2019. For this analysis, the reports listed in Table A.8 were used.

Table A.8: List of annual reports used for the Westland Infra Netbeheer B.V. analysis

Year	Title	Reference
2018	N.V. Juva - Jaarverslag 2018	
2019	N.V. Juva - Jaarverslag 2019	

As can be seen in the table, the holding company for Westland Infra Netbeheer B.V. is N.V. Juva. They have only two annual reports available, but these annual reports do contain historical data tables that go back to 2011. However, investment data is not included in these tables, making the total variables for which we have a complete set slightly smaller. These tables have been used in this analysis.

Revenue

The development of Westland's revenue can be found in Figure A.26. Both total revenue and gross revenue have been shown to give an indication of the total transport costs for the firm.

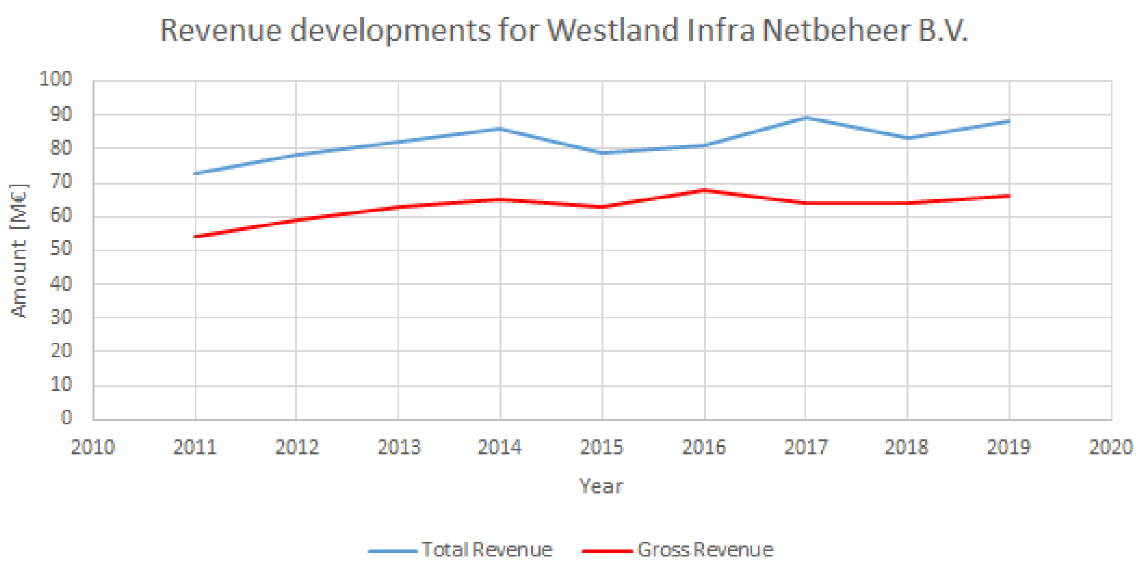

Figure A.26: Overview of the revenue development for the firm Westland Infra Netbeheer B.V.

Clearly, the revenues for Westland have increased over the past few years, from a level around 70 M€ to almost 90 M€. No clear changes can be observed for the start of the new regulatory period. Furthermore, the difference between total and gross revenue does seem to fluctuate a lot, indicating some tax changes or accounting changes over these years.

Accounting variables of interest

A complete overview of all the figures made for Westland Infra Netbeheer B.V. can be found in Appendix A. The most interesting results are presented below.

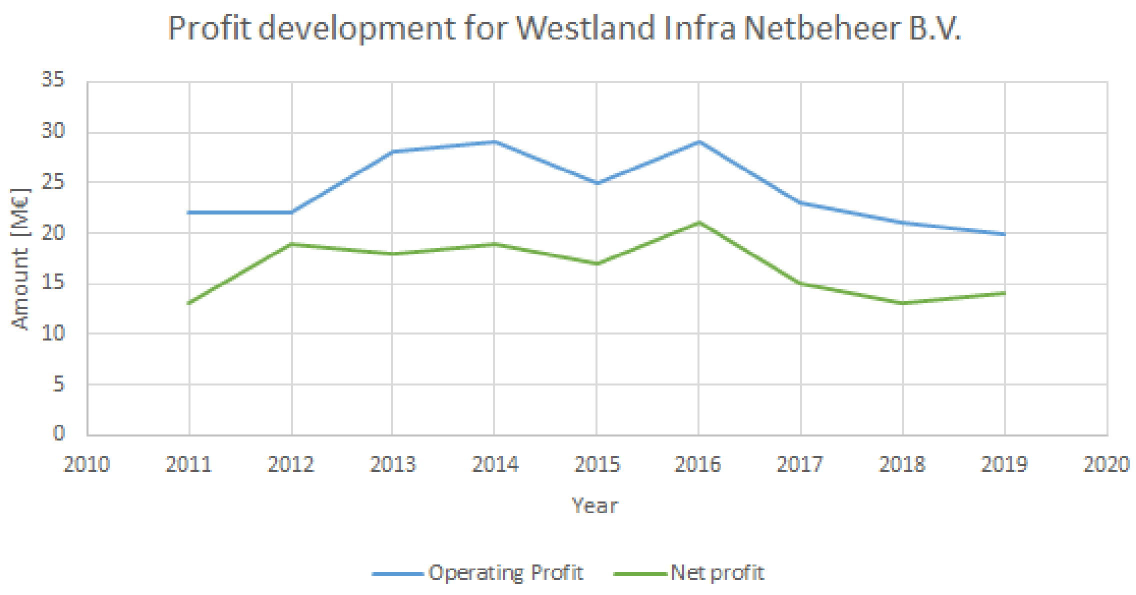

Figure A.27: Overview of the profit development for the firm Westland Infra Netbeheer B.V.

As can be seen in Figure A.27, the profit levels for Westland have remained relatively stable in terms of general trend, although a clear decrease can be observed since the start of the new regulatory period.

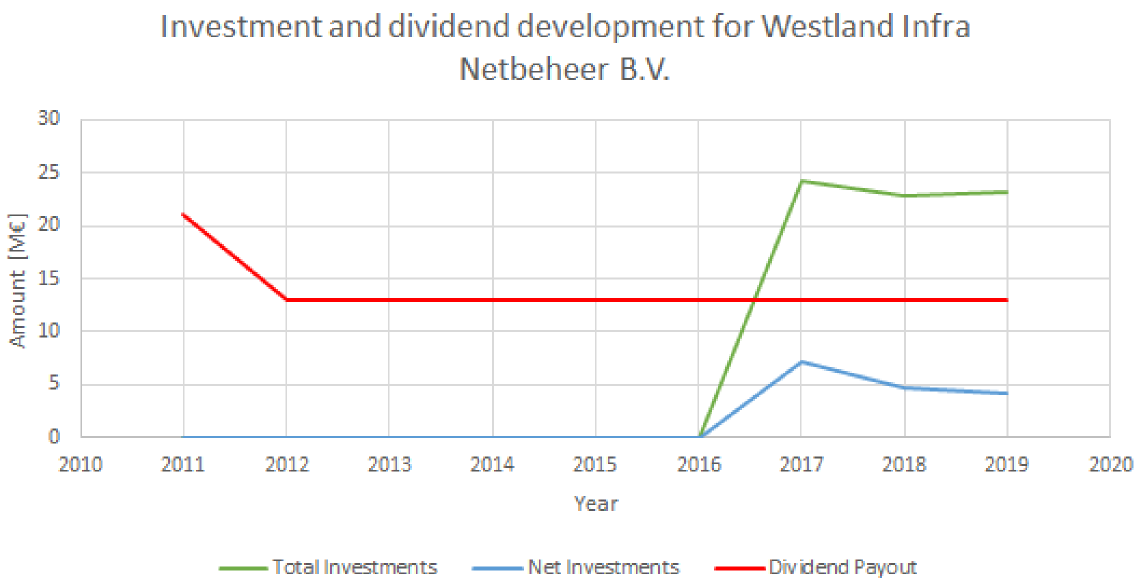

Figure A.28: Overview of the Investments and Dividend payouts for the firm Westland Infra Netbeheer B.V.

Clearly, the dividends paid (as seen in Figure A.28) by Westland have not changed over the years, whereas the total investments do not have enough data to indicate increases or decreases. However, what can be observed is that the level of dividends paid is rather high compared to the total and net investments. This can also be seen in Figure A.29.

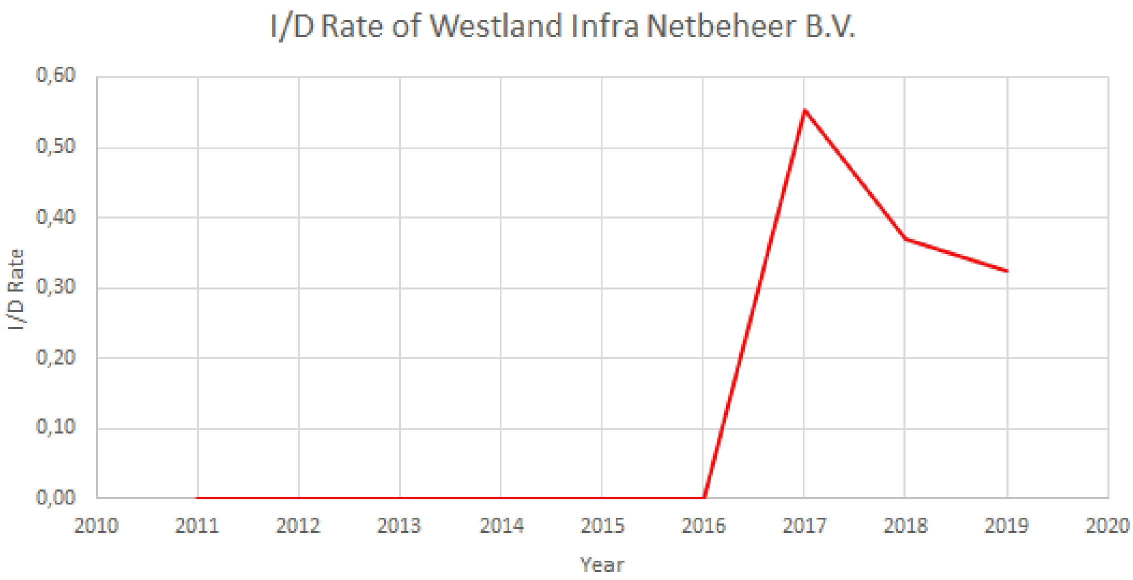

Figure A.29: Overview of the investment over dividends rate for the firm Westland Infra Netbeheer B.V.

Accounting Beta

For the earnings beta and asset beta the same methodology as described for the earlier firm analyses was used. Once more the change in operating profit was compared to market changes, leading to the following results:

$$\sigma(\Delta_E) = 0,0247$$
$$COV(\Delta_E, \Delta_M) = 0,0030$$
$$\beta_E = 0,1216$$
$$\beta_A = 0,4144$$

B

Transcriptions of the interviews

This appendix contains a complete transcription of all the interviews done for this thesis. The order of transcriptions is the chronological order of the interviews.

B.1. Stedin - Mr. Huub Halsema

REDACTED

B.2. Netbeheer Nederland - Mr. Andre Jurjus

REDACTED

B.3. Liander - Mr. Paul van Engelen

REDACTED

B.4. Smaller comments and conversations

In this last section of the appendix, the collection of smaller, e-mail based conversations are shown. Some of the contacted parties opted for this smaller and shorter version of contact due to availability or preference:

B.4.1. Enexis

REDACTED