The role of power equipment companies in shaping the industrial Microgrid in the Dutch context

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July, 2013

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Creating an analytical framework based on explorative research.

Master thesis
August 2013

Keywords
business ecosystems, industrial Microgrid, innovation development, strategic role

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Course: SPM5910 Master Thesis Project
Graduation Section: Energy & Industry
Master's Program: Systems Engineering, Policy Analysis and Management (SEPAM)
Specialization: Energy
Faculty: Technology, Policy and Management (TPM)
University: Delft University of Technology

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Foreword

Climate and Energy issues have never been so high on the political agenda all around the world as they are today. Recent newspapers related to energy topics inform us about the dynamics of how energy markets and regulations are structured and how they will change over the cause of time. At the same time those newspapers inform us about how those structures, regulations and changes affect our society.

In Europe we encounter political, technical, economic and social forces that stimulates the development and implementation of decentralized energy sources, efficient fossil fuel generators, efficient energy users and storage. Those developments have a significant affect on the power quality, reliability and energy price, as we have learned already from our German neighbours. In order to implement those developments successfully in our current grid, we need to restructure our energy system as well organisational as technical. One of the technical changes we will encounter in the near future is an increasing amount of intelligence that will be added to our decentralized energy grid, in order to measure and control also on a decentralized level. Generation and usage will be balanced on a more decentralized level in order to reduce energy losses, keeping it manageable and reduce capacity problems in the grid in combination with our rising energy demand. Furthermore our new decentralized renewable energy sources will only be limited manageable, which means that demand should respond to our energy production in the future as well. I believe that smart micro grids will be one of the future solutions to handle the above developments in good manner. However scientific research on micro grids is mainly focussed on public grids and lack the private industry domain. Therefore I believe the research of Almira has an added value for as well the scientific community as the energy industry.

To the person Almira, it was a pleasure to work with her during her graduation period. Almira is a very analytical and well-organized person, who is not quickly satisfied. Only the best is acceptable for her. She is able in putting her research work in a structured and readable way on paper. Almira can work good on an individual basis, but I believe she will also succeed in a team. Humour is part of her daily communication, which makes it fun to work with her. From what I have observed during the past six months, I am confident that Almira will be successful in her future career. I wish Almira all the best.

Randolf Weterings, Business Developer Smart Grids, Siemens Netherlands N.V.

The Hague, June 2013

Preface and acknowledgements

The report that lies before you is the result of my Master Thesis project conducted at Siemens Smart Grid. As a final step in my master study, Systems Engineering, Policy Analysis and Management, it has proven to be a very interesting and challenging project. I had never worked on a project of this complexity and had to shift my limits to end it successfully. The Microgrid is part of an inspiring transition in the energy system in a world where our habits have resulted in serious challenges like fighting global warming and lessening our dependence on energy from fossil fuels. Technical innovation helps, however this is not all. Cooperation, awareness of energy consumption and willingness of people and organizations to change are needed to tackle these challenges. The Microgrid embodies this idea, since both a technological and a social transition are required for the adoption and implementation of this system. The impact of such a transition in the industry could be especially valuable in our society, for it consumes a large part of our energy. However, such a social transition is difficult to achieve if economic or operational benefits are not generated as fast as industries want.

Several people have been very important during my research. First of all I want to thank all the respondents of the interviews to provide me with useful, practical insights. I want to thank my colleagues at Siemens for making my time there meaningful and pleasurable. Then I want to thank Margot Weijnen for chairing the graduation committee and for providing me with constructive criticism helping me improve my research. I want to thank Randolf Weterings, my supervisor from Siemens; not only for providing the opportunity to perform this research, but also, and mostly, for his enthusiasm and trust to let me work independently and to guide me during this process. Then I want to thank Zofia Lukszo and Mark de Bruijne, the perfect combination of first and second supervisor. Zofia was always positive and full of encouragement. She gave useful advice beyond the research and something to live by. She supported me with contents, but even more valuable, with useful hints around the process. Mark was always willing to discuss the contents of my research together and provided new angles about the project. Thus greatly improving the scientific approach and contribution in the research. Of course, I want to thank my friends and all others who supported me in many different ways during this research.

There are some that supported me not only in this research but throughout my study years. I want to thank my mom for helping me through every phase in every way possible. I want to thank my dad for helping me in a hands-on way and for being patient. I want to thank them for believing in me, for their love and support. Then I want to thank my sisters, for providing me with support, laughter and company over the years and these last six months. I want to thank our new addition, Gigi, for lighting up the mood every time. I want to thank my roommates for this last stretch. And last, Jeroen, for standing by me, for providing me with relaxation, fun and comfort, for being proud.

As this is the final part of my last phase of education, I simply conclude with many thanks to all my family and friends for an unforgettable and inspiring life as a student. I would not change it for a thing. On to the next phase!

Almira Brahim,

Delft-Milan, August 2013

Summary

This research aims to shed light on two main questions:

- How will the innovation of the industrial Microgrid develop in the Netherlands;
- What role should power equipment companies play in this development?

Thriving on a mix of literature, desk research and interviews with operational managers in the industry, it became clear that the industrial Microgrid is a complex radical innovation, combining a transition in technology with change of behaviors and the need to cooperate among several actors in the industrial energy ecosystem. It is still very early days for the industrial Microgrid in the Netherlands and this research makes it abundantly clear that it is not likely that this innovation will takeoff soon.

This might look surprising, because the industrial Microgrid has a lot to offer to Dutch industry. The value proposition builds on three major drivers - the Microgrid will offer industries:

1. Protection against the growing instability of the Macrogrid;
2. Cost advantages since combining industries in a Microgrid will be energy efficient;
3. Cleaner energy since generation will/can be done with low-emission sources.

However a closer look clarifies why adoption is stagnating in the Netherlands:

1. The Dutch grid is very stable, which will only be threatened in a further future by the advent of more and more DER generation;
2. The cost advantage is not there, due to the high gas price which makes electricity generated locally in the Microgrid simply more expensive then the coal-generated central grid supply;
3. Cleaner energy is a good driver, but unfortunately not decisive if the price is prohibitive.

It is important to notice that each of these factors, might reverse themselves in the future, and therefore the current stagnation is not a given.

The analytical framework, building on theories about technology transition and adoption, offered a lot of subtle tooling, which clarified the slow adoption, but in the end didn't fully explain the stagnation. With hindsight more analysis on the financial part of the business case might have been insightful. Having said that, this would be far from easy, since the development of the price of natural gas would require an amount of modeling that is obviously out of scope.

In the final round of the research the rather granular and often non-decisive drivers and barriers derived from the theoretical framework could be clustered in a few meaningful clusters: knowledge & perceptions, complexity & allayment; grid intelligence & DER; prices & regulation.

Knowledge & perceptions as a category entails most of the detailed factors pointed at by the technology innovation literature. These are factors that help to understand how in an ecosystem around the innovation, researchers and entrepreneurs make the first steps and get traction in a larger community, with knowledge diffusing and perceptions changing positively. In fact this process is already in full motion globally, but in the Netherlands there is little movement because some major drivers in the other categories are missing.

Complexity & allayment zooms in on a series of topics that clearly stood out in the interviews: energy managers are looking for service providers to take care of more of the energy tasks in their production process, regarded as vital but secondary. Only in case of full-scale diffusion of this innovation, once new service concepts with superior allayment have entered the market, the needle in this cluster will move from red to green.

Grid intelligence & DER is the cluster that identifies the larger technological context for the Microgrid to develop in. At first there is the classical one-directional, passive, Macrogrid with an established ecosystem that is cautious about shaking up things by moving to a Smart Grid that in essence opens up the game to lots of new competitors. Then there is the bi-directional, open Smart Grid, which will facilitate the Microgrid but also competes with it. If the Smart Grid is adequately able to handle the destabilization coming from DER's, there is less fertile ground for Microgrids. However, if the Smart Grid is unable to do so, Microgrids will offer a welcome solution. In such scenario Smart Grid diffusion opens the door for the Microgrid and the Smart Grid could develop naturally into a Smart Grid of Microgrids.

However, the Price & regulation cluster, could still block this, since the industrial Microgrid in essence gears around electricity and heat generation from a local natural gas-fuelled midsize energy plant. If only the price of the gas would be low enough to generate electricity at rates that could compete with the ones generated from the classical grid, mostly coal-fuelled in the Netherlands. However, this is precisely the opposite today after coal prices collapsed thanks to the US shale gas revolution. Without the government compensating with energy tax policy, gas centrals in the current pricing conditions are uneconomical. This holds true for both the giant national centrals in the classical Macrogrid and the midsize ones driving Microgrids.

Reasoning from these categories four scenarios or development paths, which the industrial Microgrid innovation might follow in the Netherlands, were identified. The first is a Stagnation path in which the current no-growth continuous. The driver of Stagnation is a fatal combination of high gas prices and continued high stability in which the Smart Grid succeeds in handling the instability of increased DER production. The second scenario will lead to the Pervasive path. In this scenario a low gas price combines with the need to divide the Smart Grid in a set of smaller Grids in order to avoid killing instability coming from increased DER production. In this scenario the Smart Grid will connect a series of Microgrids, especially industrial Microgrids. In this scenario knowledge diffusion from universities & labs and the proliferation of easy service concepts coming from big energy & equipment providers will be triggered by the huge opportunity to build industrial Microgrids everywhere. Less extreme and less easy to predict are two middle scenarios: Exception and Common. Behind both scenarios will be a non-decisive combination of gas price and grid stability development. Effectiveness of the knowledge process and a proactive attitude of the providers will determine whether the balance goes in the direction of Exception or Common.

The choice for power equipment companies for which role to play depends on three things:

- Their understanding of the scenarios and their ability to help shape developments (knowing that the two main driving clusters are not really in their hands);
- Their courage to carve out a yet unknown position in the new ecosystem, cooperating or competing with the classical utility companies for the energy demand from the industries;
- Their ability to play a global game in which their investments in the Netherlands can be lowered thanks to efforts made in geographies that are more favorable to the Microgrid.

The recommendation to power equipment companies is unequivocal:

- Bet heavy on this new innovation, because sooner or later a large part of the Smart Grid will be energized by a series of Microgrids;
- Play a global game and opt for the long run in geographies such as the Netherlands that have a reliable grid and relatively cheap electricity from the classical grid;
- Think hard about entering a consortium with either one of the large utilities with global aspirations or with one of the oil companies;
- Develop easy, no-hassle, service concepts with the partner, to allay the industries participating in Microgrids;

- Move from one-time power equipment construction to long term risk-taking pay-per-use service provisioning.
- Anticipate on one of the two in-between scenario's, either "exception" or "common", but not on the most positive "pervasiveness" scenario;

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Abbreviations

B:B	Business to Business
CHP	Combined Heat and Power
DSO	Distribution system operator
DER	Distributed Energy Resource
EMS	Energy Management System
ETS	Emission Trading System
EU	European Union
EV	Electric Vehicle
FIS	Functions of Innovation system
ICT	Information and Communication Technology
IC	Internal Combustion
IPIN	Innovation Program Intelligent Grids (Innovatie Programme Intilligente Netten in Dutch)
IS	Innovation system
NIS	National Innovation System
NPV	Net Present Value
PCC	Point of Common Coupling
RES	Renewable Energy Sources
RIS	Regional Innovation System
SIS	Sectorial Innovation System
SCADA	Supervisory Control and Data Acquisition
SNM	Strategic Niche Management
SWOT	Strengths, Weaknesses, Opportunities, Threats
TIS	Technical innovation system
TSO	Transmission system operator

CHAPTER 1: INTRODUCTION

In this chapter the research is introduced and a research design is constructed.

1. Introduction

1.1. Motivation

There are many changes and developments going on in the energy system. New technologies are being developed that make the energy system more sustainable through decentralized and renewable generation (e.g. microturbines, IC engines, wind turbines and PV (Banarjee, 2012; Pepermans, Driesen, Haeseldockx, Belmans, & D'heaseleer, 2005)), storage (e.g. batteries, supercapacitors, SMES and flywheels (Hall & Bain, 2008) and the use of new forms of energy (e.g. algae, microbes, electromagnetism and hydrogen (AE Future Energy, 2013). Many chances lay ahead for companies that are innovative enough to benefit from this opportunity. This research starts with the notion that one specific group of companies, power equipment companies, wants to benefit from one specific innovative system in the energy system, the industrial Microgrid. This system is considered an innovation that can change the way the industries are energized. It has been proven a successful emerging system in different countries in various parts in the world, e.g. United States of America and India (LaMonica, 2012; Sanyal, 2013). This report discusses the exploration of the potential and development of the industrial Microgrid in the Netherlands and focuses on how power equipment companies can shape this development.

1.2. Background

1.2.1. The power system

The current electricity system is a centralized electricity system which moves electricity generated at large, primarily fossil-fueled generating stations through passive transmission and distribution networks to end-users in a one-way delivery system (Arnold, 2011; Driesen & Katiraei, 2008; J. G. H. Slootweg & Veldman, 2011). Several developments of the last years and upcoming trends increase the possibility of inefficiencies and instability of the current system and grid. First of all, a significant rise in the demand (Farhangi, 2010; Molderink, Bakker, Bosman, Hurink, & Smit, 2010) and future developments of energy efficient technologies, e.g. large scale introduction of EV and heat pumps, will lead to higher required capacities of the grid and increased peaks of demand (Molderink et al., 2010; Verbong, Beemsterboer, & Sengers, 2012). Since the electricity system as a whole and its grid components are over engineered to withstand maximum anticipated peak demand, the minimal capacity in the chain will have to be increased to deal with the increased variance in system states that can be expected (Farhangi, 2010; Molderink et al., 2010). Second, the contribution of renewable energy and consumer-produced electricity in the electricity system is currently growing (Netbeheer Nederland, 2009; Verbong et al., 2012). This leads to an increased need of flexible supply to balance supply and demand in the grid (Molderink et al., 2010; Verbong et al., 2012). The resulting inefficiencies and instabilities can endanger the availability, reliability, affordability and the security of supply of electricity. A promising solution has come in the form of a Smart Grid (Farhangi, 2010).

A Smart Grid, a so-called intelligent grid, is made possible by the introduction and use of new technologies such as distributed sensors, two-way secure communication, advanced software for data management, and intelligent and autonomous controllers (Gharavi & Ghafurian, 2011). While there are various definitions (Gharavi & Ghafurian, 2011; Giglioli, Panzacchi, & Senni, 2010; J. G. (Han) Slootweg, 2011) of what a Smart Grid is, in the literature similar functions and benefits can be summarized (Verbong et al., 2012). The Smart Grid is a bi-directional electric and communication network, which converges cyber-secure information technology, communication technology and computational intelligence over the entire electricity system, which is generally broken down in three separate subsystems 1) electricity generation, 2) transmission, substations, and distribution and 3) consumption. It supplies electricity to the final consumer while integrating all users connected to it in a more active manner.

Even though it is integrated into the entire value chain, the Smart Grid is a more distributed and dynamic approach than the current way of electricity provision. It involves networking a vast number of sensors, smart meters, monitor & control systems, back-office systems, and management devices in the grid, which all generate large amounts of data (Arnold, 2011; European Commission, 2012; Farhangi, 2010; Gharavi & Ghafurian, 2011; J. G. H. Slootweg & Veldman, 2011). These technologies also allow actors to play a more active role in the system, e.g. consumers can generate and supply their own electricity to the grid or manage their consumptions based on the insights created by meters. The technologies, data and active participation of all the players enable distribution automation, active load management and real-time metering, which should make the grid self-healing, flexible, predictive, interactive and optimized, hence the term intelligent. This new paradigm enhances the presence and responsibilities of consumers in the power system. Smart Grids thus promise to improve the physical, economic and sustainable operation of the electricity system and contribute to a more clean, safe, secure, reliable, resilient and efficient system (Arnold, 2011; Gharavi & Ghafurian, 2011; Gomez-Exposito, Abur, Jaen, & Gomez-Quiles, 2011; Verbong et al., 2012). The Smart Grid can be considered radically different from the current centralized power system given the shift to a decentralized power system and the active involvement of consumers. Thus both on a social and on a technical level the Smart Grid is therefore considered innovative.

1.2.2. The Microgrid

A specific application of the Smart Grid is the Microgrid. The Microgrid entails the idea of an aggregation distribution network sub-system (Barnes et al., 2007). This sub-system can be seen as an geographically integrated system consisting of a cluster of interconnected loads, distributed energy resources (DERs), storage and an Energy Management System (EMS) which can operate parallel to the grid or in an intentional island mode (Lasseter, 2011). Within the system there are many degrees of freedom related to the components, functions and technologies. A Microgrid can thus have many system configurations by differing in size, class, location, components, control etc. (DNV Kema, 2012). Furthermore, different types of Microgrids can be distinguished based on the environment in which they are applied: commercial & industrial Microgrids, island & remote Microgrids, military Microgrids, community & utility Microgrids (Siemens, 2006). The Microgrid is a fairly new concept within the scientific community. The Microgrid has only been a topic of discussion since the past decade. However, it increasingly captures the discussion at forums and symposia. Currently several studies and pilots of various Microgrids have been conducted globally. Lessons can be learned concerning the functionalities and available technologies (Barnes et al., 2007; Hatziargyriou, Asano, Iravani, & Marnay, 2007; Piagi & Lasseter, 2001). Furthermore, there are various positive news stories of Microgrids applied in real life (LaMonica, 2012; Sanyal, 2013; Wald, 2012), where energy was available while it was not elsewhere.

The Microgrid is a system of systems, since each of its elements are elaborate systems on its own. It is considered a socio-technical system[1], since the actors owning and operating the technical systems interact with the technical systems. While many of the literature focuses on the technical systems and that interaction, not a lot of attention is given to the social aspects of the system. This can be explained due to the fact that it is still a “young” innovation that emerged through developments on the

[1] A system is a collection of different sub-systems, consisting of elements and relations, so related as to produce a result greater than that its parts, separately, can produce. A socio-technical system consists of a technical and a social sub-system. Through the interactions between the system elements and interfaces of the sub-systems, the behavior of the whole system comes into being. In a socio-technical system multi purposive actors and material artifacts interact in such a way that they co-evolve by enabling and constraining each other (Bauer & Herder, 2009; Herder, Bouwmans, Dijkema, Stikkelman, & Weijnen, 2008; Rechtin, 1992)

technological side. It is thus considered technology-push, rather than demand pull[2]. The Microgrid is innovative in both its domains; on the technical side the configuration of decentralized energy technologies and control is new, making decentralized elements in the power system function as a controllable entity; on the social side the innovative aspect is the active role of the participants of the technologies can play in the system (e.g. cooperation, consumers and controllers).

Several aspects of the Microgrid are different from the current system, representing a radical departure from existing approaches to provision of electricity, e.g. the social dependencies and interactions differ from the passive centralized grid. Other aspects are outgrowths of existing systems, or even returns to ways of doing business commonplace to the industry during earlier times (mostly from a technical perspective), e.g. the possible use of CHP and local use of PQR control . However, the configuration of the Microgrid with its existing and radically different elements, make it a radical innovation as opposed to an incremental innovation (Marnay, Asano, Papathanassiou, & Strbac, 2008).

In the Netherlands several pilots and projects surrounding Microgrids have started, but all are focused on small power applications, e.g. holiday parks (Bronsbergen (Cobben, 2011)), small islands (Texel, (TexelEnergie, 2013)) and communities (European Science and Business Park Avantis (Gerards & Schijns, 2009)). As is the case with Smart Grid projects, the applications focus on the household or community applications. This is rather peculiar given that focusing on applying the Smart Grid and Microgrids on an industrial level could have a much greater impact on the energy system. In total 109 billion kWh of electricity is consumed, of which 24% by Dutch household and 28% by the Dutch industry. The crux is that there are 7.386.000 Dutch households against 335.000 industrial consumers (Energie in Nederland, 2011). Thus making the consumption of a group of household or communities flexible and more efficient, as is done in Smart Grids and Microgrid, would not achieve the same impact as changing the consumption patterns of an industry. Applying a Microgrid to industries could increase the impact and relevance for both its consumers (industries) and the whole power system. The Microgrid applied in the industry is called an industrial Microgrid. It is a geographical cluster of industrial energy users and it supposedly has several benefits, e.g. highly efficient energy delivery and supply system, secure and reliable supply configurations, high degree of power quality (Driesen & Katiraei, 2008).

1.2.3. The opportunity

An innovation often brings new possibilities and opportunities for potential suppliers that are somehow linked to that innovation with their products or services (Teece, 1986). In the case of the industrial Microgrid this new system may bring new chances for the existing suppliers that currently support and deliver products to the power grid system or for Smart Grids, e.g. power equipment companies or IT companies, to expand their businesses activities in the Microgrid area or industrial sector. For new entrants it may bring the opportunity to start developing business activities in a fairly new playing field. The question that logically arises from the described situation is how companies can benefit from this new and fairly unknown innovation, the industrial Microgrid. To bring more focus to the research, the perspective of one type of companies is used, namely that of power equipment companies. This is the starting point of the problem exploration.

[2] Technology push entails that the stimulus for new products and processes comes from (internal or external) research. The impulse is caused by the application push of a technical capability. A certain demand does not exist per se. Demand pull innovations are caused by dissatisfaction of customers and comes from individuals or groups who articulate their subjective demands. The first can be characterized as creative, while the latter is considered a replacement (Brem & Voigt, 2009)

1.3. Problem exploration

1.3.1.Taking advantage of an innovation

In general, capturing the value of innovation by individual companies, thus determining how a company can benefit from an innovation, can be achieved by means of a business model. A business model defines how a company creates and delivers value to the customers, and then converts payments received to profits (Teece, 2010). It is a useful tool for a company to mediate the value creation process of an innovative technology due to its conceptual character (Teece, 2010). Uncertainty of both the technology and the market is often reality when dealing with innovations. A strategy, a fully elaborated and defined plan of action, is too rigid to deal with these uncertainties. A business model is only an initial exploratory foray into a market, which can adapt to new information and possibilities (Chesbrough & Rosenblom, 2002; Teece, 2010).

The term business models is relatively new, the development of the theory started just over 10 years ago, but many researches have already been conducted in the field of business models and its elements (Bouwman & MacInnes, 2006; Morris, Schindehutte, & Allen, 2005). This has resulted in a handful of different types of business models each developed for a particular modeling task (Cifuentes, 2012). Regardless of the differences in these frameworks, there are several elements that are common in each business model. In its simplest form a business model clarifies the way a company makes money (Teece, 2010). However, it is not a financial model of the business. It is rather a conceptual model which includes the unique combination of products, services, image and distribution that the company carries forward and the underlying organization of people and the operational infrastructure used to accomplish the work (Chesbrough & Rosenblom, 2002; Teece, 2010). Economic value is created by the inherent characteristics of the technology and the economic and social structure of the situation. It can be seen as a modern variation of the classic definition of the strategy of a business unit[3]. There are several functions defined in the business model, as can be seen in Figure 1Figure 1 The business model (Chesbrough & Rosenblom, 2002).

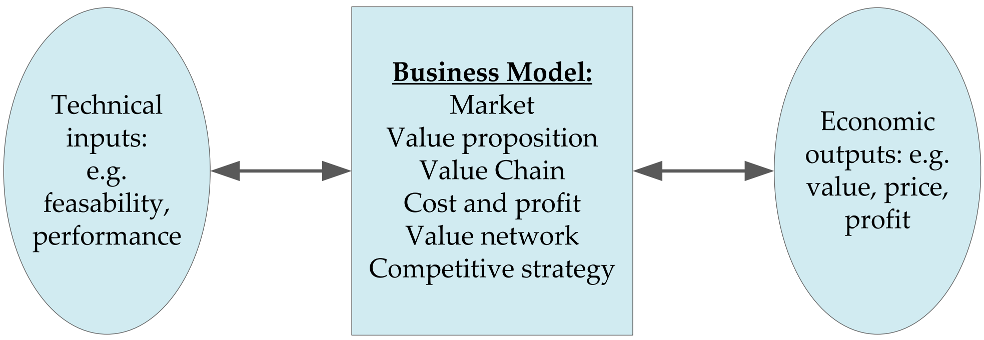


Figure 1 The business model (Chesbrough & Rosenblom, 2002)

In a business model the market segment in which the company is going to operate is established. This is necessary because the segment shapes the technical attributes and development of the product or

[3] The definition of a strategy is "the direction and scope of an organization over the long term, which achieves advantage for the organization through its configuration of resources within a challenging environment, to meet the needs of markets and to fulfill stakeholder expectations" (Johnson, Scholes, & Withington, 2008). There are different levels of strategy, e.g. corporate strategy, business unit strategy (Johnson et al., 2008; Porter, 2002; Slack & Lewis, 2002). The one corporate strategy of a firm focuses on a company's course of action for an indefinite time (Andrews, 1987). While there is only one corporate strategy, there can be several Business Unit strategies, which are the product-market choices made by division or product line management in a diversified company (Andrews, 1987).

service. Determining the value proposition entails the articulation of the value created for users by the use of the innovation. This can inter alia be cost reduction, offering a solution to a problem currently experienced by the user, or the ability to create new possibilities and solutions for the user. The structure of the value chain within the company should be defined which elaborates on how the value is added by the company. The cost structure and profit potential of producing the product or service should be estimated based on the value proposition and the value chain. Furthermore the position of the firm in the value network should be described. The value network shapes the role that suppliers, customers and third parties play in influencing the value captured from commercialization of an innovation. Lastly, a competitive strategy should be formulated so that the company can gain and hold advantage over rivals (Chesbrough & Rosenblom, 2002).

In the case of innovations, either existing business models are used as to incorporate the innovation in the current business or new business models are designed as to launch new ventures that exploit the innovation in new business arenas (Chesbrough & Rosenblom, 2002). Familiar or existing business models however often do not fit the circumstances of the arising opportunity. Old ventures do not hold into account the new innovation and therefore these business models are inadequate to use. Designing a new business model should thus be the appropriate course of action if there is the intention to take advantage of innovations.

1.3.2. A business model for the industrial Microgrid in the Netherlands

In this research the innovation is the industrial Microgrid. In theory, power equipment companies, or any other company, that wants to profit from this innovation, should as a first step design a new business model. However, in the case of the industrial Microgrid, designing a business model is a complicated task.

First of all, even though the business model is not as rigid and crystallized as a strategy, it still requires initial insights in the basic configuration of an innovation and its potential markets as is discussed previously. In the case of the industrial Microgrid, this information or knowledge is not yet available. The industrial Microgrid is still in its early phase of development, meaning that the introduction, generation and diffusion has only just started. The development is very unpredictable due to the fact that the development is subject to a complex interplay of actor strategies, institutional settings and developments in their socio-technical context. In this early phase, there is no basic configuration of, or market for, the industrial Microgrid which can be used as a basis for the business model. The different technologies behind it do exist, but since it is a socio-technical system which would be implemented in an existing system, technical and social factors of the industrial Microgrids' environment would shape the system into a basic configuration. These factors are currently unknown. Due to these uncertainties no prediction can be made which could be used as a starting point for the business model.

Second of all, as discussed before, the Microgrid is an innovative system rather than a specific technological innovation like a battery cell, which makes it a rather different perspective. Multiple technical elements and actors are involved in the functioning of this system. It requires a wide range of disciplines, knowledge and commitment before a Microgrid comes into being. For power equipment companies to design a business model would not suffice, since several more actors (e.g. customers, operators) should be involved. From the perspective of the system more than one company should have a positive business model in the industrial Microgrid. From the perspective of the power equipment company, a business model can be designed of only a smaller aspect of the system.

At this particular moment power equipment companies cannot design a business model for the innovative industrial Microgrid. The system is too undeveloped in the Netherlands and it requires the commitment of other actors, which is currently not there yet. With current knowledge it is unknown when designing a business model will be possible. Power equipment companies have two options at this point: 1) wait for the development to come through to a point where a business model can be designed or 2) take an active role a influence the development so that it comes at a point where business models can be designed and commitment is given. Choosing option 1 would ultimately mean risking stepping in too late and losing the potential to become a real competitive market player in the industrial Microgrid area as competitors gained important knowledge and relations. The focus in this research then logically shifts towards option 2: taking an active role as to influence the development of an innovation.

1.3.3.Role in innovation development

At this point in the problem exploration the focus of the research shifts towards the development of the industrial Microgrid in the Netherlands and how power equipment companies can influence this development. In the literature theories on the development of (radical) innovations extensively describe how an innovation is introduced and generated in local niches, loci protected from the normal market selection in the regime (Geels, 2002), and is diffused on a larger scale in the existing environment. With regards to influencing the development, theories on strategy formation have been counseled, since influencing the development requires a plan (strategy) of some sort by the power equipment companies. Literature on strategies for companies is extensive, covering strategies for different purposes and different levels of the organization. However within this extensive available literature, there does not yet exist a theory or framework which elaborates on, and provides guidelines for strategy formation on influencing the development of a (radical) innovation. Thus after consulting theories on technological transitions, strategy formation and design of socio-technical systems, it may be concluded that a gap exists in the current literature which focuses on, or describes, influencing the development of an innovation from a company's perspective.

1.4. Problem statement

Taking everything previously discussed into account, the following problem statement can be formulated.

The industrial Microgrid is a demarcated application of the Smart Grid, which is supposed to have the capability of improving the reliability and affordability of the energy needed on an industrial site. The industrial Microgrid could be an interesting innovation for power equipment companies to profit from. However, these companies are not yet capable of designing a business model due to the fact that the innovative system is too undeveloped in the Netherlands. The industrial Microgrid should be developed further before any company can take advantage of this innovative system. The challenge at this point for power equipment companies is to influence the development process so that it may be successfully diffused in the current environment. A problem arises due to the fact that there does not exist a framework yet that provides guidelines to determine how a company should influence the development of an innovation. The objective of the conducted research is to give recommendations to power equipment companies on how they can influence the development of this innovation for a possible successful diffusion.

1.5. Research questions

Following the objective of this research, the main research question is:

What should the role of power equipment companies be in the development of the industrial Microgrid in the Netherlands?

This question has come about by turning the desired objective of the research into a question. To answer the question adequately several sub-questions have been formulated. The relevance of each sub-question in this research is discussed.

1: What determines the development of an innovation and the role of a company within this process?
The first step in this research is to gain and create knowledge in the development of an innovation and on how companies can influence it. As a result an analytical framework is developed which covers these subjects. It is formulated in an abstract manner so that it can be applied to similar issues. From this framework guidelines should be derived that help to systematically analyze the development as to determine strategic roles for companies in the development of a radical innovation. This framework is then applied to this research, in order to determine the role of power equipment companies can take to influence the development of the industrial Microgrid.

2: What is the current state-of-the-art research regarding industrial Microgrids?
The industrial Microgrid, the innovative system of systems, is the focus of this research. The state-of-the-art research contains all knowledge of the (industrial) Microgrid up until the writing of this report. It is important to collect, bundle and summarize all the important insights to create a clear understanding of the envisaged future energy system. It covers the technology, institutions and relevant actors involved in the technology.

3: How are the Dutch energy and industry system organized?
The answer of this sub-question will create an extensive insight into the energy system that is currently in place and describes how the Dutch industry uses the vital resources. It will function as the knowledge base to understand the environment and the system in which the industrial Microgrid will be implemented. Again, the technical (energy) system, the institutions in place and the relevant actors in the energy system and industry are discussed.

4: What are the opinions and perceptions on the industrial Microgrid in the Netherlands?
Since the industrial Microgrid should be implemented in a social environment, it requires the active cooperation of industries and other actors that are active in the energy system. The perceptions and opinions of these actors are important to take into consideration in this research. These insights complement the public and written knowledge of the current energy system in the industry and of the industrial Microgrid.

5: How might the industrial Microgrid develop in the Dutch industry?
After collecting knowledge and insights regarding the current playing field, the industrial Microgrid, the Dutch industry and energy system, and the perceptions and opinions of relevant actors, insights should be created in the possible development paths of the Dutch industrial Microgrid. These paths give a dynamic insight into the development of the system and affect the role power equipment companies can play.

6: What roles could power equipment companies play in the development of the Dutch industrial Microgrids?
The last sub-question focuses on an inventory on potential roles of power equipment companies in shaping the development of the Dutch industrial Microgrid. Based on this inventory and its analysis, a recommendation can be given on how they should influence the development of the innovative system.

1.6. Research approach

The research approach consists of two elements: its structure and the methods used to gather all relevant data, thereby determining how this research will be executed. The structure is shown in a framework which is a schematic representation of the research objective and all the necessary steps that need to be taken to achieve the research objective (Verschuren & Doorewaard, 2010). The necessary steps are deduced from (sub-)research questions that have been formulated in the previous paragraph. For every step (several) method(s) are used to collect relevant data. First the complete research structure is shortly explained. Then for every step the methods used and intentions are clarified.

1.6.1. The research structure

As discussed earlier the objective of this research is to give a recommendation to power equipment companies about the role they could play in the development of the Dutch industrial Microgrid. To form such a recommendation several insights need to be gathered first, which are derived from the formulated sub-questions. A first step is to create a theoretical basis to gather insight in the development of the Dutch industrial Microgrid and for alternative strategies in the development of an innovation. Based on the theories an analytical framework is proposed which provides a perspective on how strategic roles can be determined based on the development of an innovation. The theoretical basis is established through literature research. The second step is to create in-depth knowledge of the playing field of the industrial Microgrid in the Netherlands. A literature and desk research is used to synthesize knowledge on the industrial Microgrid and the Dutch industry & energy system. Exploratory interviews are used to gather and analyze input from relevant actors in the Dutch industry & energy system regarding the industrial Microgrid in the Netherlands. The insights of the playing field are inputs for the analyses conducted to determine development paths of the Dutch industrial Microgrid and to determine possible roles of power equipment companies. As a final step, recommendations can be made regarding the role of power equipment companies.

As can be seen in Figure 2, every sub-question creates new insights and has its own set of methods to gather data for the analyses. Subsequently each of these steps and use of the research methods are more elaborately explained.

1.6.2. Data collection

In this research three research methods are used to collect data. A literature research is the search and analysis of written literature concerning the researched subjects (Verhoeven, 2007). Literature mainly consists of scientific articles and books. To find these works scientific search machines are used, e.g. Scopus, Sciencedirect and Google scholar. A desk research, a method similar to the literature research, covers all publicized knowledge, not only literature. The internet has been the major source to find relevant data. Exploratory interviews is a method to collect data regarding the perceptions, motives, experiences and importance attached issues of a situation of respondents (Verhoeven, 2007). The process consists of five main steps; 1) defining the population and determining the sample, 2) formulating the topics and questions of the interview, 3) testing the quality of the interviews, 4) executing the data collection process and 5) analyzing the data.

1.6.3. Analytical framework

The framework functions as the basis of the research, both in the contents and in the steps to be taken. This part of the research creates the theoretical background to conceptualize the development of radical innovations and strategies of companies in that development, thereby answering sub-question 1. Analytical steps are derived from the theoretical background in order to provide a systematic approach when regarding the development and strategy. A literature research is conducted to determine which theories are incorporated in the framework. In this literature research an exploratory search has first been done in order to determine which theories could be of interest in this research. In the literature search terms like “transition”, “innovation” and “adoption” are used to find relevant theories that consider the development process of an innovative technology. Lastly the strategy theories are identified by using terms like “strategy in early stages of development” and “strategy in business ecosystems". The analytical framework resulting from this literature search can be found in Chapter 2.

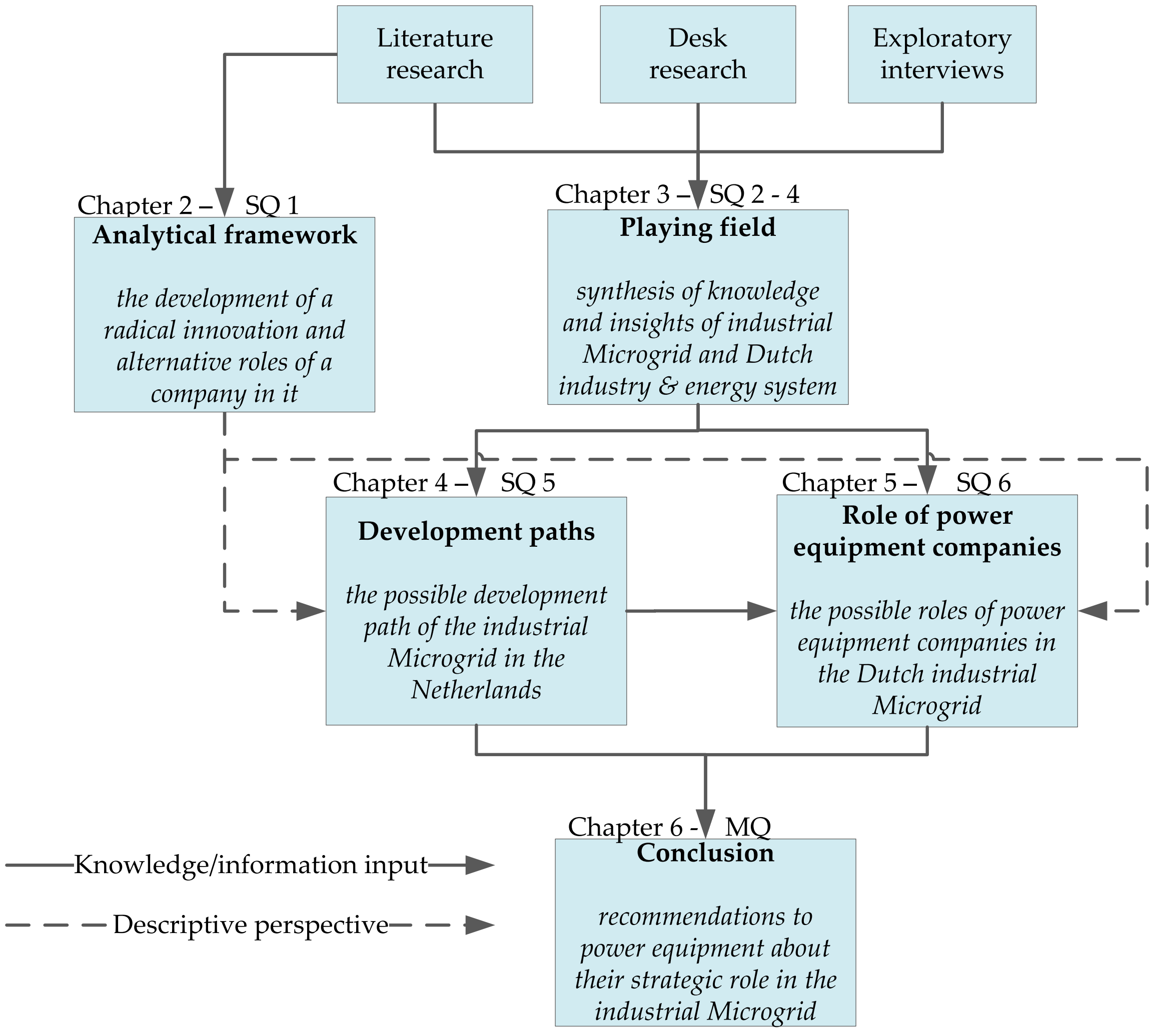


Figure 2 Research structure

1.6.4. Playing field

The playing field is an overview of the Dutch industrial Microgrid, the Dutch industry and energy system and the opinions and perceptions regarding industrial Microgrids. The objective is to create a base of knowledge regarding these three subjects in order to give an in-depth understanding of the industrial Microgrid in the Netherlands. This base of knowledge is furthermore required as an input for the analyses of the development of the innovation and the creation of a development path. Furthermore it is used as an input for determining the role of power equipment companies. Data is collected through literature research, a desk research and exploratory interviews. The literature research mostly covers insights of the industrial Microgrid by searching for terms like "Microgrid" and "industrial Microgrid". Desk research has been conducted by consulting different sources, e.g. experts and the search engine Google. This created more valuable insights into the industrial Microgrid but moreover insights into the Dutch industry were also gathered. The exploratory interviews focused on the opinions and perceptions of actors in the Dutch industry and energy system regarding the industrial Microgrid. The playing field can be found in Chapter 3.

1.6.5. Development paths

The development paths are, as the name suggest, possible paths for the development of the industrial Microgrid in the Dutch context. The objective of this step in the research is to create insight in possible future scenarios, based on factors that are relevant to its development. Thereby giving insight in both the external environment in which it takes place and the sequential path of actions that can be executed for the further development. Based on that path, a strategic role can be determined for power equipment companies. The development path can be found in Chapter 4.

1.6.6. Role of power equipment companies

The final step leading to recommendations is to understand the possible strategic roles of power equipment companies is analyzed. The analyses conducted in this step are derived from the proposed analytical framework. As is the case with the previous question, no new data is required. Only data discussed in the playing field are used as an input. The role of power equipment companies can be found in Chapter 5.

1.7. Research relevance

Based on the previous paragraphs the potential relevance of the research can be established on different levels. This research intends to contribute to the scientific community (academic), companies involved in industrial Microgrids (practical) and to society (social). In the first section of Chapter 7 the achieved relevance is discussed.

1.7.1. Academic relevance

The scientific relevance is established by two aspects in this research. First of all knowledge is added to Microgrid literature. This information is intended to be added, is to clarify the concept of the industrial Microgrid and to focus on how the industrial Microgrid is organized in the Dutch context. It thus not only focuses on technical matters, but also on social. Second, another contribution is the development of an analytical framework which creates a perspective on how a single company or a group of companies can form a strategy that deals with developing a radical innovation in its early stages.

1.7.2. Practical relevance

The premise of this research is recommending power equipment companies on how they can influence the development of the Dutch industrial Microgrid. The research gives the companies a point of application to develop an individual strategy on how they can support the successful proces of an innovation that can bring new opportunities for them. However, relevance should be found beyond that specific recommendation. Due to the approach taken in the research, only the last step "the strategy" is translated specifically for power equipment companies. This ensures that the practical relevance is not only achieved for power equipment companies, but for other interested actors as well. The description of the playing field, the analyses of the development and the insights created in possible development scenarios create important and objective insights with regard to 1) the Dutch industry and their energy system and 2) the development of industrial Microgrids in general. It gives an overview of important characteristics of both aspects and it identifies important variables to create a rich understanding of the Dutch industry and the innovation. Various actors, e.g. governments, DSOs, engineering companies and even industries themselves, can acquire this information to gain knowledge on the industries which has not yet been gathered before and on the development of a new innovation. They can use this according for their own objectives.

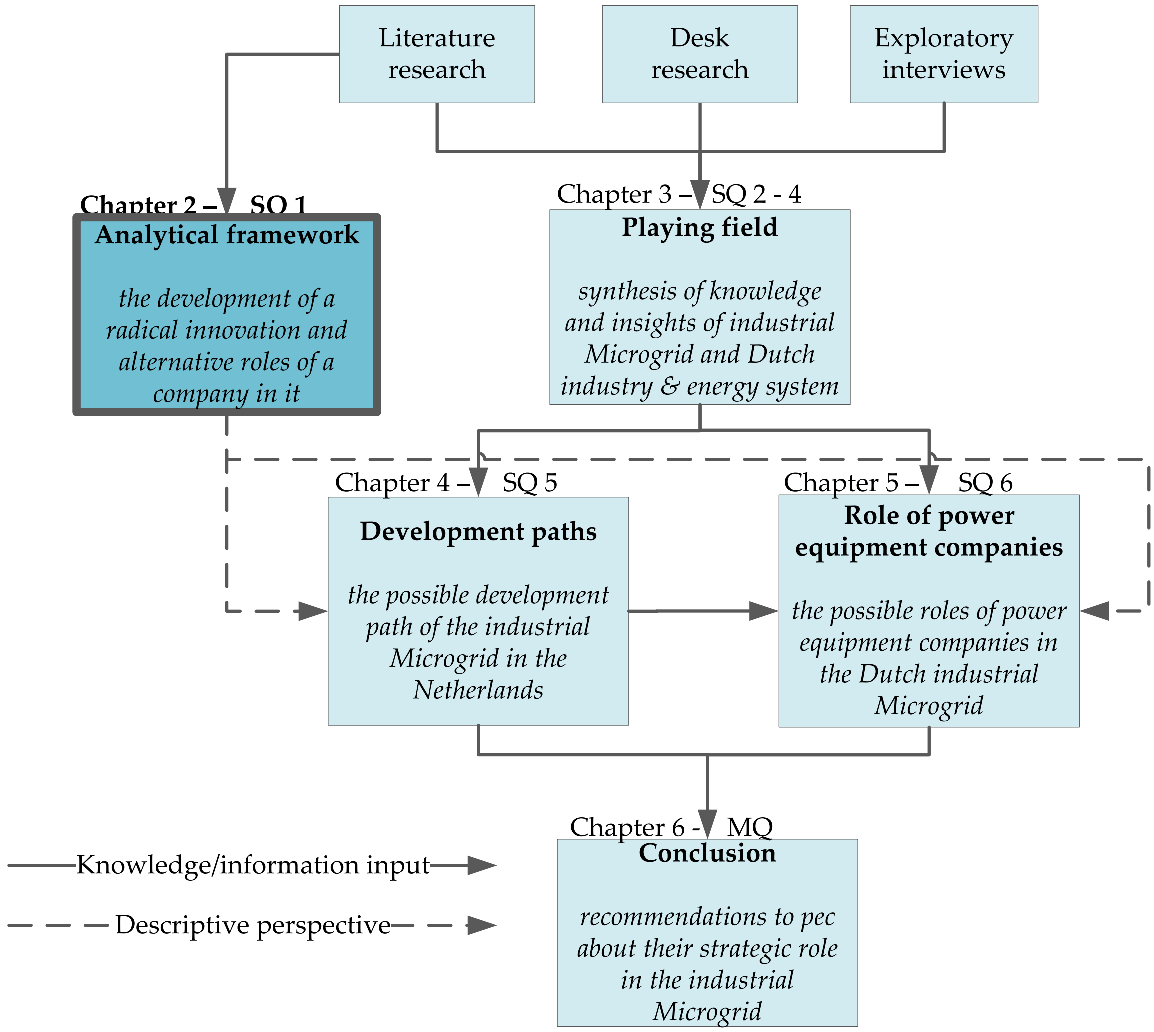
1.7.3. Social relevance

This research is relevant for Dutch society since it works towards the diffusion of an innovative system which embodies the sustainable path aspired by Dutch government and society. Through industrial Microgrids energy efficiencies and the integration of DER can be achieved, which in turn may result in lower emissions of industries and increased reliability of the entire national grid. Even on the economic side, this can result in lower production costs and a better competitive advantage for industries in the Netherlands.

1.8. Outline report

The structure of the report, as is discussed earlier, follows the steps taken in this research (*Figure 2*). In Chapter 2 the analytical framework is created, thereby providing an answer to sub-question 1 *"What determines the development of an innovation and the role of a company within this process?"* . In the subsequent chapter the playing field of the Dutch industrial Microgrid is discussed, thereby covering the answers of sub-question 2 *"What is the current state-of-the-art research regarding industrial Microgrids?"*, sub-question 3 "*How are the Dutch energy and industry system organized?*" and sub-question 4 *"What are the opinions and perceptions on the industrial Microgrid in the Netherlands?".* The development path of the Dutch industrial Microgrid is constructed in Chapter 4, thereby formulating an answer to sub-question 5 "*How might the industrial Microgrid develop in the Dutch industry?*". In Chapter 5 the alternative roles of strategic companies are analyzed. Thus formulating an answer to sub-question "*What roles could power equipment companies play in the development of the Dutch industrial Microgrids?*". The conclusions and recommendations of this research are discussed in Chapter 6. The main research question "*What should the role of power equipment companies be in the development of the Dutch industrial Microgrid?*" is thereby answered. The report end with reflections on the research, which is discussed in Chapter 7.

CHAPTER 2: ANALYTICAL FRAMEWORK



In this chapter an answer is formulated for sub-question 1:
"What determines the development of an innovation and the role of a company within this process?"

2. Analytical framework

In the introduction of this report it became apparent that there does not yet exist a framework which elaborates on the concepts of strategic roles for companies in the development of an innovation. Still the objective of this report is to give a recommendation to power equipment companies with regard to the role they should adopt in the development of the Dutch industrial Microgrid. Thus, as is stated in the research structure, the first step is to form an analytical framework which does elaborate on these concepts. According to Bergek (Bergek, 2002, p. 17) an analytical framework is "a way of conceptualizing the world, with the purpose of providing a basis for the collection and interpretation of empirical data; it resembles a jigsaw puzzle frame in which pieces are laid down to form a picture." The world which is of interest here is the development of a radical innovation, as is the industrial Microgrid, and a strategic role that power equipment companies can play within this development. The concepts within the analytical framework are based on theories that focus on technological transitions, on adoption of innovations and on business ecosystems.

The structure of this chapter is as follows. In the first section (2.1) the structure of the analytical framework is introduced. In the subsequent section (2.2) a short insight is given in the process of selecting the three theories of which elements are derived for the analytical framework. The third section (2.3) focuses on the theories behind the development of radical innovations and the relevant factors are chosen as elements in the analytical framework. Thereafter section 2.4 focuses on the theory behind determining a strategy and the resulting elements for the analytical framework. In 2.4 the constructed analytical framework is proposed and explained. Also the analytical steps derived from the constructed framework are discussed. Then the question will be addressed how the framework is applied in this research (2.5). The chapter ends with a short summary (2.6).

2.1. The theories

During the first explorative literature research, no theories could be identified which elaborated on phenomena where companies would influence the development of an innovation. For the creation of an analytical framework, the focus of the literature research has been on finding theories which elaborated on the two aspects separately: the development of a radical innovation and the strategy of companies in the (early) development of an innovation. For the development, the perspective chosen is that of radical innovation, since the industrial Microgrid can be considered a radical innovation. The development of innovation entails the processes of the introduction, generation and diffusion.

During the research two different theoretical perspectives on the development of a radical innovation could be found: technology transition and technology adoption. The first theory covers technological transitions: major, long-term technological changes that affect user practices, regulation, industrial networks, infrastructure, and even symbolic meaning or culture. An example is the transition from punched card technology and small office technology to digital computers (Geels, 2002). Thus the radical change is considered from a socio-technical perspective. The views on technological transition focus on the transformation process from one socio-technical configuration to another. In this research the focus is on the transition from the current energy system to the future energy system in which the Microgrid is thoroughly embedded. Knowledge from this perspective would result in valuable insights of the process in which a technological innovation in a niche stage[4] evolves into a technology which is used and accepted in the existing socio-technical regime[5].

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[4] A niche is the locus where radical innovations are initially developed and are protected from the normal market selection in the regime, according to the theory of MLP (Geels, 2002).
[5] The socio-technical regime is the locus of established practices and associated rules that stabilize existing systems (Geels, 2011)

The second theory is that of technology adoption, where the focus is on "the stage in the innovation-decision process where the choice is made to make full use of the innovation as the best course of action available" by Rogers (Cowan & Daim, 2011; Rogers, 1962). According to the theory the adoption of an innovation follows an S-curve plotted over time. Within the technology adoption different views can be identified, which can be distinguished by macro-level theories and micro-level theories. The first, innovation process research, zooms in on the process of diffusion and innovativeness of an organization. The latter, innovation research variance, is about understanding and examining the organizational determinants of innovation adoption and the effects of innovation adoption on organizational performance (Hameed, Counsell, & Swift, 2012). In this research the first is of most relevance. The insights created from this theory help to understand how and why innovations diffuse by taking into account the perceptions of potential adopters.

The third theory focuses on possible strategies of a company to influence this complex development process. In the theories on technological transition and technology adoption several factors are identified which can be categorized into actors, institutions and technology. These theories consider the interaction between these factors to be key, not just the technology itself. A stand-alone strategy of one company may not have the desired effect due to the strategic actions of other actors. A company is active in a network of actors in such a development. It is therefore required to understand the network, or ecosystem, and the company's role in it (Iansiti & Levien, 2004). The theories focus on strategy formation within the ecosystem in which the company is active and its respective role in it. Insights can thus be gathered on how a company can influence the development of an innovation.

As is stated in the introduction of this chapter, the framework that is used to help identify companies to analyze their role in the development of an innovative technology is based on three strands of literature: theory on technological transitions, technological adoption and strategy formation in business ecosystems. The first two bodies of knowledge are used to systematically explore the development of innovations.

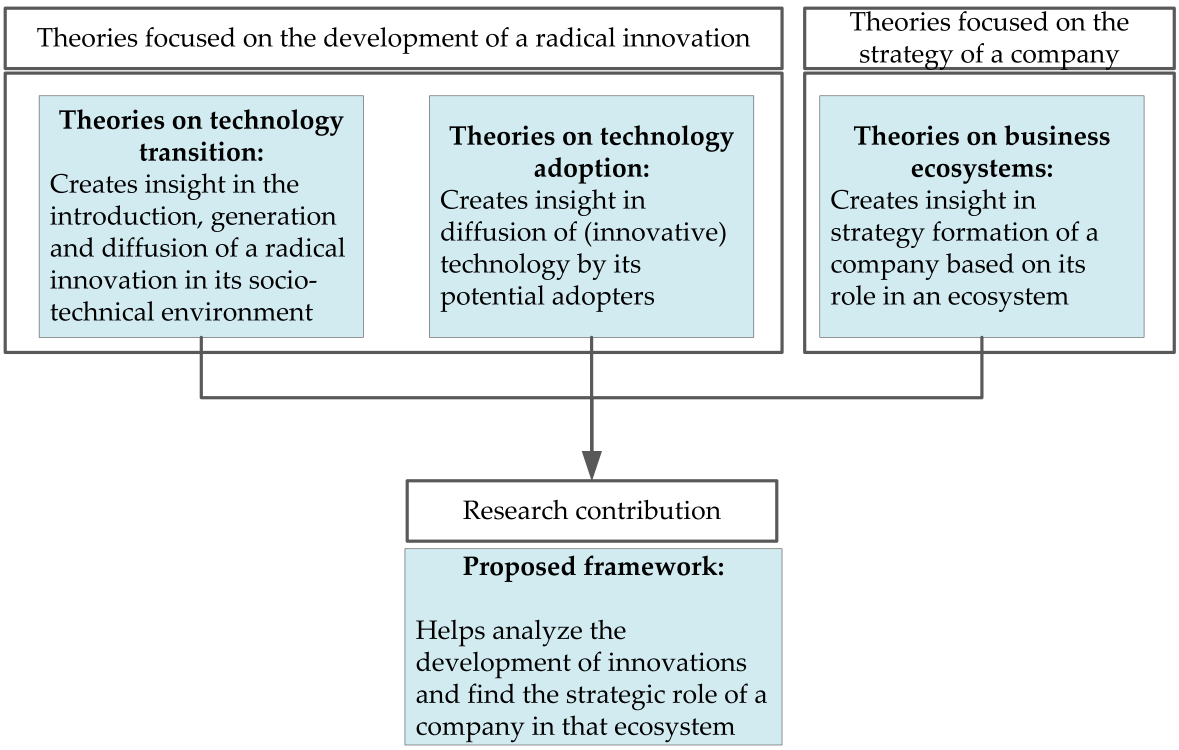


Figure 3 Theories present in the analytical framework

In the following sections the three theories are discussed so that a thorough understanding of the concepts is created. Later on the proposed framework is introduced.

2.2. The development of a radical innovation

Two theories have been found in the literature research that touch upon the development of radical innovation. These theories will be discussed and subsequently it is elaborated which elements are to be taken into account in the analytical framework regarding the development. Together these theories will help to address the first research question: what determines the development of an innovative technology and the role of a company within this process.

2.2.1. Technological transition

According to this theory, successful radical innovations go through a development in which they are introduced, generated and diffused into society, thereby transforming one socio-technical configuration into another. This entails that not only the technology changes, but also other interrelated societal domains, e.g. economics, politics and culture. Thus society changes in a fundamental way (Elzen & Wieczorek, 2005; Geels, 2002; Rotmans, Kemp, & Asselt, 2001a). The process is extremely complex and involves a multitude of technological and social factors on different aggregation levels -micro, meso and macro (Rotmans et al., 2001a).

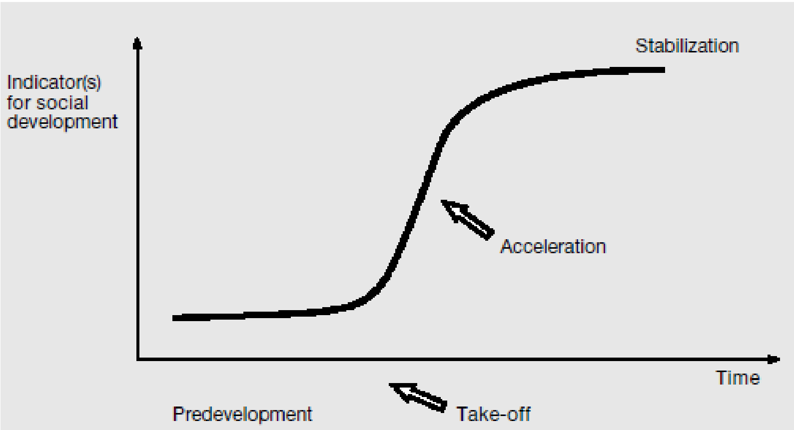


Figure 4 The four phases of transition (Rotmans, Kemp, & Asselt, 2001b)

A transition only occurs when the developments of several of these factors come together and align. However this does not happen simultaneously and instantly, but takes a long period of time (Negro, 2007; Rotmans et al., 2001a; Suurs, 2009). There are four different transition phases; 1) the predevelopment phase in which new options and varieties are established by laboratories, universities and between stakeholders, 2) the take-off phase in which the process of change starts to occur, 3) the break-through phase in which visible structural changes take place due to the accumulation and reaction of socio-cultural, economic, ecological and institutional changes, 4) stabilization phase in which a new dynamic equilibrium is reached (Figure 4) (Negro, 2007).

Two views
In the literature two main views on innovation processes can be found: the innovation system perspective and the multi-level perspective (Markard & Truffer, 2006; Negro, 2007; Suurs, 2009), each having their own framework to analyze innovation processes. However, both focus solely on the first two phases of the transition process, also called the innovation process. The first perspective focuses on the prospects and dynamics of a particular innovation (e.g. the industrial Microgrid) that has the potential to contribute to far reaching changes. It identifies the most important drivers and barriers for a successful diffusion of a particular technology or product. The latter perspective focuses on the

broader transition process at a more aggregated level (e.g. energy supply in general). It is concerned with the identification of factors which drive the transformation processes. The one has an emergent technology perspective, while the other has a more transitional perspective (Markard & Truffer, 2008). After analyzing both perspectives, Markard & Truffer (2008) concluded that the two perspectives have very similar concepts in their frameworks but also have significant differences. However, according to them these differences can complement each other. Thus they proposed an integrated framework, here called the Markard & Truffer framework, to analyze the innovation process from both perspectives. In this research the Markard & Truffer framework is used for the contribution of theories on technology transition in the proposed framework, which is explained henceforth. A more elaborate explanation of the two perspectives can be found in Appendix I**Fout! Verwijzingsbron niet gevonden.**.

Markard&Truffer framework

The framework of Markard & Truffer is based on "the concept of technological innovation systems (cf. Bo Carlsson & Stankiewicz, 1995; Edquist, 2005; Hekkert, Suurs, Negroa, Kuhlmanna, & Smitsa, 2007) but also draws on the literature on socio-technical regimes and transitions (e.g. Boelie Elzen, Geels, & Green, 2004; Geels, 2002; Rip & Kemp, 1998)" (Markard, 2008). The framework is shown in Figure 5.

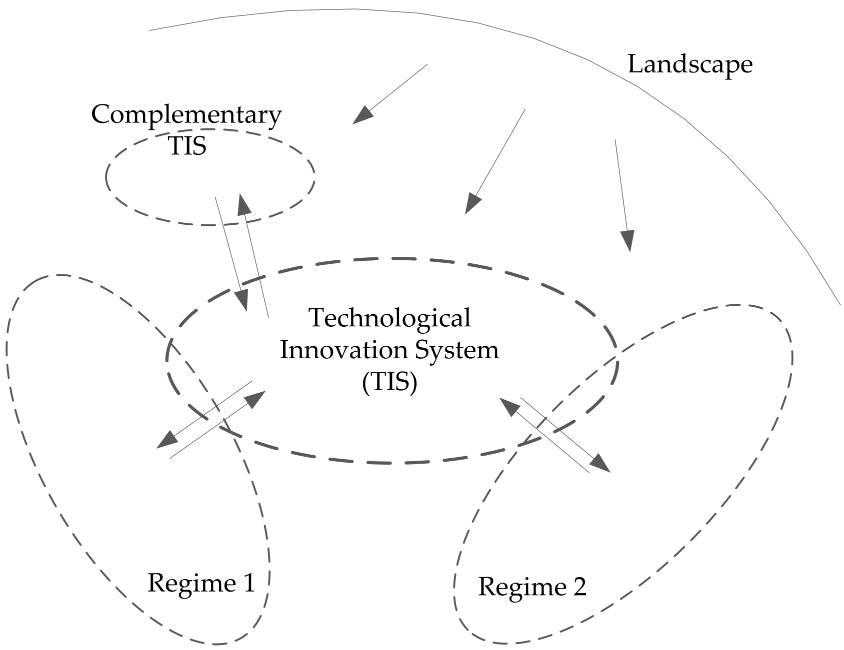


Figure 5 Markard & Truffer framework (Markard & Truffer, 2008)

The central point of this framework is the Technical Innovation System (TIS). The TIS, more elaborately explained hereafter, is a network of institutions and actors in the public and private sectors, whose activities and interactions initiate, import, modify, and diffuse new technologies (Carlsson & Stankiewicz, 1991; Edquist, 2005; Freeman, 1987). It applies a technology specific perspective and restricts the system to actors, institutions and networks that are supportive to the innovation process (Markard & Truffer, 2008). The TIS can interact with its environment, also more elaborately discussed hereafter, consisting of its landscape, socio-technical regimes and/or other TIS.

The socio-technical regimes may represent barriers and drivers for the development and diffusion of the innovation. Depending on the institutional overlap or the shared set of actors of a TIS with a certain regime, resistance will be more or less intensive. Furthermore, the central TIS can interact with other TIS through two basic modes of interaction: competition and complementation. According to Markard & Truffer "If the products or technologies in two TIS serve similar purposes in similar application contexts, the interaction will have a competitive character. If, on the other hand, the innovations support each other, e.g. like network technologies, the interaction is rather complementary." The landscape level consists of factors on the macro-level that influence or transition processes. However, in contrast to the regimes and other TIS, the landscape is hardly affected by the innovation and transition processes (Markard & Truffer, 2008). Analyzing both the TIS and its environment will result in insights in the introduction, generation and diffusion of an innovation in its socio-technical context. It focuses on both the innovation process and the factors influencing this process.

Technical Innovation System (TIS)

The TIS is a network or networks of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilize technology. These agents can be firms, R&D departments, educational institutions and policy-making bodies (Carlsson & Jacobsson, 1997). In this approach technological change and economic performance is established by the ability to develop and exploit new business opportunities, thus to be innovative, and to exploit knowledge flows, to actively recombine knowledge in order to create new business opportunities (Suurs, 2009).

A TIS is considered an emerging system since the configuration of actors and institutions change over time. The system consists of several static elements: actors, institutions, technological factors, relations and networks (Suurs, 2009). They are defined as is done by Suurs (2009) in Table 1. The dynamics in a TIS, and thus its development, arise from a combination of structural tensions (conflicts between actors, institutions and technologies) and synergies (complementarities) that are constituted by the various relationships within and between networks. Analyzing the TIS would give insight in the dynamics within the network that is active with the introduction, generation and diffusion of an innovation.

Table 1 Factors of the TIS and their description according to Suurs (2009).

Structural factors	***Description***
Actors	Actors are the organizations involved that contribute to the emerging technology in focus either directly (developer, adopter of technology) or indirectly (regulator, financer). The choices and actions of actors generate, diffuse and utilize technologies.
Institutions	Institutions are "the rules of the game in a society". These institutions shape and constraint the human interaction. In the TIS these factors are important since they indirectly influence the presence, skills and willingness of the actors
Technological factors	Technological factors are artefacts and infrastructures in which the artefacts are integrated. Especially the techno-economic workings of such artefacs, e.g. cost structures, safety, reliability etc are important to understand the progress of technological change.
Relations	Relations are the linkages between the three structural elements. These relations are actions (agent-agent), design (institutional-institutional & technology-technology through misalignment and alignment) and subject-object relation (actor-institution/technology).
Networks	Networks are a group of linkages that is stronger than outside the group. Networks facilitate the exchange of knowledge and are thereby an important part of the TIS.

The environment

The environment of the TIS consists of other TIS, regimes and landscapes. As discussed previously the focal TIS can interact with other TIS. This interaction can be of competitive nature, of complementary nature or even of both in the case where the development of one TIS weakens the current regimes.

Regimes account for the stability of existing large-scale systems (Schot & Geels, 2008). It refers to rules enabling and constraining activities within communities (Geels, 2002). The regime consists of three interlinked dimensions: 1) a network of actors and social groups, 2) formal normative and cognitive rules, and 3) material and technical elements (Verbong & Geels, 2007). The landscape refers to wider technology-external heterogeneous factors, e.g. oil prices, economic growth, wars. These factors have an impact on innovation and production processes without being influenced by the outcome of innovation processes on a short to mid-term basis. Analyzing the environment of the TIS would result in the identification of interactions and influencing relations. Identifying and mapping these relations and influences will create insight in factors that can either hinder or stimulate the innovation process (Markard, 2008)

2.2.2.Technology adoption

The second perspective on the diffusion of innovations is that of technology adoption. While the previous theory focused on how an innovation is generated, introduced and diffused, this theory focuses more on why this is. Rogers, one of the most influential researchers in this field, defines technology adoption as the stage in the innovation-decision process where the choice is made to make full use of the innovation as the best course of action available (Rogers, 1962). Many separate theories exist that explain the adopter's attitude, innovation adoption behavior and various determinants in different context of an innovation adoption, e.g. Diffusion of Innovation (DoI), Technology Adoption Lifecyle (TALC), Bass Model of Diffusion (BMD) and the Technology Acceptance Model (TAM) (Cowan & Daim, 2011; Hameed et al., 2012; Jeyaraj & Sabherwal, 2008). When examining the mentioned theories it became apparent that many are focused on the actual adoption process within an organization or individual, while the interest here is creating insight in the diffusion of an innovation on a systematic level. The theory that covers this is the DoI theory, which is introduced by Rogers. It is of origin a communication or social theory used to describe patterns of adoption. In this theory Rogers' explains that the diffusion of an innovation follows a S-shape, which similar to the previous theory. Only here time is put against cumulative number of adopters.

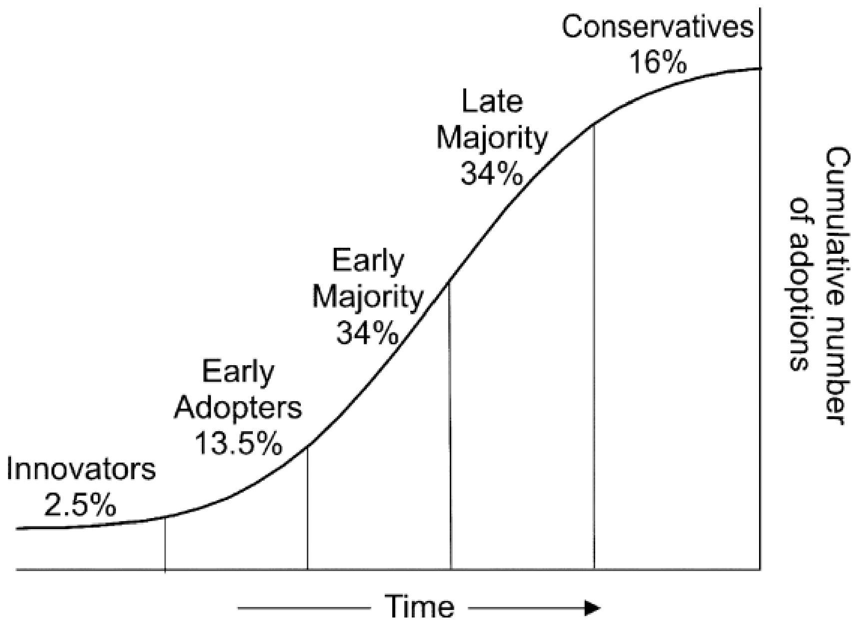


Figure 6 The diffusion curve according to Rogers (adopted from (Rogers, 1962)) (Patenaude, 2011)

In the figure can be seen that Roger's identifies five distinct adopters: innovators, early adopters, early majority, late majority and conservatives. Depending on when they adopt an innovation, they belong in a certain category. According to the theory the rate of adoption of an innovation, the slope of the S-curve, depends on five attributes, or characteristics. These being 1) relative advantage, 2) compatibility, 3) complexity, 4) trialability and 5) observability.

Table 2 The attributes of Rogers (Patenaude, 2011)

Attributes of Rogers	Explanation
Relative advantage	Perceiving of the new innovation superior to the idea it replaces
Compatibility	Consistency of new innovation with existing belief systems, values and experiences
Simplicity	Complexity or simplicity linked to the introduction and usage of the new innovation
Triability	Option of easy experimentation with the new innovation prior to adoption
Observability	The wide visibility of benefits resulting from the adoption of the new innovation

Analyzing these attributes could comprehend the rate of adoption or even predict it.

2.2.3.Elements in the framework

Both discussed theories offer a perspective on diffusion of an innovation, thereby focusing on the development of that innovation. Both theories assume a S-shaped diffusion curve of innovations. While comparing these, it may be concluded that these are based on the same phenomena, which is the researched development of an innovation. Only the theoretical transition theory looks more at how the development is established, while the discussed DoI of technology adoption takes a more explanatory perspective.

Taking both perspectives into account the following can be said. At the beginning radical innovations originate from developments in the technology rather than developments in the demand. In the predevelopment phase a long process of experimentation in pilot plants ascertain that market and technology can develop in a process of co-evolution (Mourik, R. and Raven, 2006). This happens in so-called niches, loci protected from the normal market selection in the regime (Geels, 2002). After its first successful developments, distinct application domains can be identified and basic configurations can be established (Mourik, R. and Raven, 2006) corresponding to the take-off phases. Assuming the theory of Rogers with regards to technology adoption, in the beginning solely innovators are working on the development of the innovative technology, while in the more advanced phase where distinct application domains can be identified, early adopters, actors who have different preferences than mainstream users, also become active (Rogers, 1962). By developing it even further the radical innovation will take off through the break-through phase in which the early majority of the adopters will become active, thereby becoming established in the meso-level. The late majority adopters will come in at the end of this phase and in the beginning of the stabilization phase. As a last group, the laggards will only become active when the innovation is already far in its development and is used by about 75% of the market (Rogers, 1962).

The development of innovation has three characteristics: speed of change, size of change, time period of change (Rotmans et al., 2001b). The main focus of the research is the development itself and not so much the time period. Therefor the “the speed of change” and the “size of change”. In the two theories different elements have been introduced that can create insights on these two characteristics, as is shown in Table 3. Thus when regarding the development of an innovation, the discussed three elements can create a complete overview of the development.

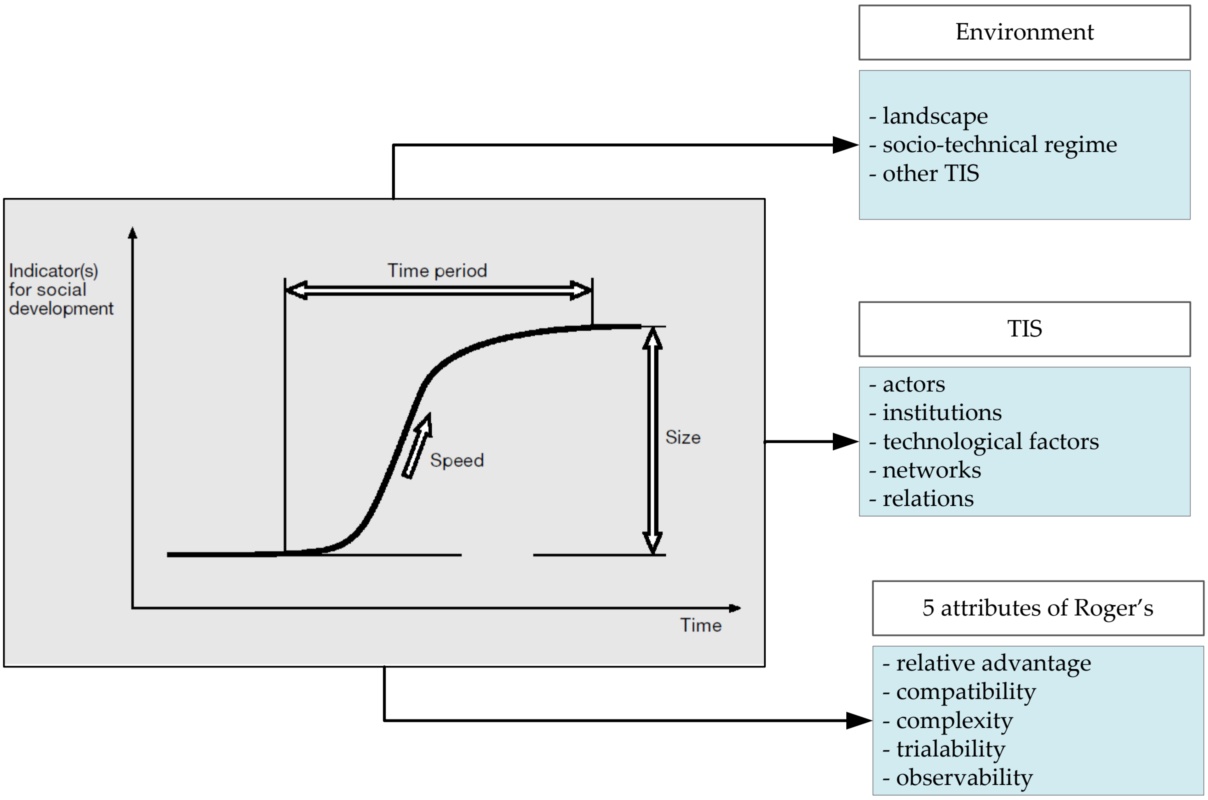


Figure 7 The development process

2.3. Alternative strategic roles

The objective of the analytical framework is to provide a perspective on strategic roles for companies in the development of a radical innovation. In the previous section the elements that create insights in the development path have been identified. The theory on strategic roles must be compatible to this perspective.

Even though the premise is that the strategic role should influence the development of an innovation, there are (too) many factors in play. A stand-alone strategy of one company may not have the desired effect due to the strategic actions of other actors, or institutions and technological factors in play. It is therefore required to understand the network, or ecosystem, and the company's role in it (Iansiti & Levien, 2004), before deciding on actions regarding the development of an innovation. The theory on business ecosystems focuses on the context in which a company operates and the respective roles and strategies it could adopt. First the theory is discussed. Then it is elaborated which elements are to be taken into account for the purpose of this research.

2.3.1. Business ecosystems

Networks are large coalitions of firms around a common technological platform. These networks are very similar to biological ecosystems where different species, or firms, work together and interact by performing their own functions (Gawer & Cusumano, 2008; Iansiti & Levien, 2004). Such networks are also called business ecosystems (Iansiti & Levien, 2004).

The notion of a business ecosystem is defined as "the term circumscribes the microeconomics of intense coevolution coalescing around innovative ideas"(Moore, 1996). Thus a network consists of several companies, suppliers and customers, around a specific technology, that depend on each other for their success or survival. Each of the companies executes its own functions, has its own needs and contributes to the survival and growth of the business ecosystem (Hartigh & Asseldonk, 2004). Determining the boundaries is challenging. Hartigh proposes to determine which company is part of the ecosystem by the degree of compatibility and complementarity of the products or technologies the actor offers or adopts. An ecosystem evolves over time affecting the size and composition of the ecosystem. The ecosystem has four life cycle phases: birth, expansion, leadership and self-renewal or death. The ecosystems in this research are still in the first phase, in which radical (or cumulative incremental) innovations lead to a new technology. The ecosystem is small and is populated by small pioneering companies. The relations are volatile and manifold (Hartigh & Tol, 2008). The health of an ecosystem is important since it represents the longevity and propensity for growth (Hartigh & Tol, 2008). Its health is measured on two levels, partner and network, by means of three critical measures. The first measure is productivity, which is the ability to consistently transform technology and other raw materials of innovation into lower costs and new products. The second measure is robustness, which is the ability to survive disruptions such as unforeseen technological change. The last measure is niche creation, which is the ability to increase meaningful diversity through the creation of valuable new functions, or niches (Iansiti & Levien, 2004).

Companies can influence the ecosystem in such a way that the development of innovations serves the strategic interest of the company (Hartigh & Asseldonk, 2004). There are different strategies in an ecosystem based on type of company an organization is or aims to be. Different researchers have their own classifications, but many overlap. In this research the classification identified by Iansiti&Levien (2004) is used and complemented by Hartigh&Tol (2008).

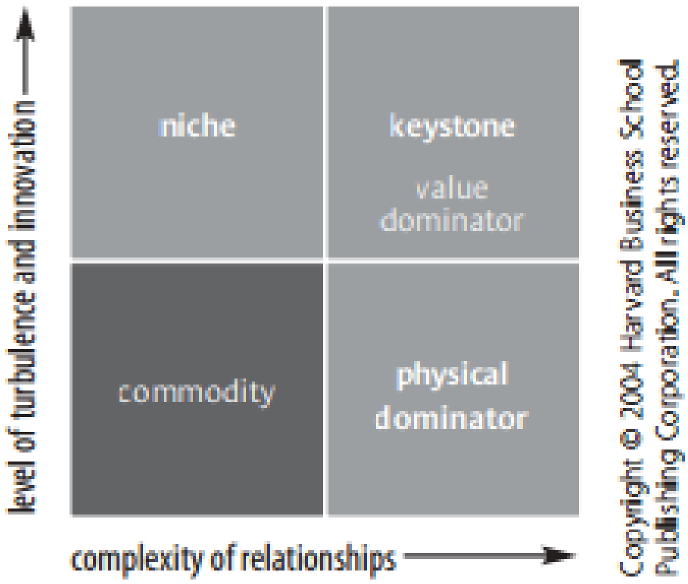


Figure 8 The strategic roles in a business ecosystem

- If a business faces rapid and constant change, and by leveraging the assets of other firms, can focus on a narrowly and clearly defined business segment, a niche strategy may be most appropriate. (Iansiti & Levien, 2004)
- If a business is at the center of a complex network of asset-sharing relationships and operates in turbulent environment, a keystone strategy may be the most effective (Iansiti & Levien, 2004)
- If a business relies on a complex network of external assets but operated in a mature industry, one may choose a physical dominator strategy. (Iansiti & Levien, 2004)

- If however a business chooses to extract maximum value from a network of assets that you don't control – the value dominator strategy- one may end up starving and ultimately destroying the ecosystem of which it is part. (Iansiti & Levien, 2004)

2.3.2. Elements in the framework

The objective of the analytical framework is to provide a perspective on strategic roles for companies in the development of a radical innovation. In the previous section the elements that create insights in the strategic role have been identified. The theory on business ecosystems conceptualizes the network of actors surrounding a technological platform. In the case of this research the network is the people that are active around the industrial Microgrid. This coincides with the actors in the TIS, since these are the actors that are actively interact with the institutions and technological factors to diffuse the innovation. The elements taken to the analytical framework are the four strategic roles in business ecosystems identified by Iansiti & Levien.

2.4. The proposed framework

The three theories have been discussed and the elements are chosen that on the one hand give a perspective on the development of a radical innovation and on the other hand give a perspective on strategic roles. However, these are two separate aspects at the moment. Thus in this section the two aspects are linked into a proposed analytical framework.

2.4.1. Framework

The objective of the analytical framework is to give an perspective on the strategic role of a company in the development of a radical innovation. The following elements are taken into consideration:

- Development: based on the technological transition theory and the technology adoption theory three elements are identified that give a rich description of the development. These elements are the innovation system (TIS), the 5 attributes of the innovation and the innovation's environment.
- Strategic role: based on the business ecosystem four types of strategic roles can be identified, that give possible strategic roles in the business ecosystem of an innovation.

These four elements must be coupled together to make a complete framework. Thus a jump has to be made between the development and the strategic role. The development alone of the innovation is not of interest for determining a strategic role. Rather the way it can develop over the years is more important to, since then the development is actually shaped. Thus the construction of a development path or paths is used to link the development concepts of an innovation to the strategic role in its business ecosystem. The analytical framework can be seen in Figure 9.

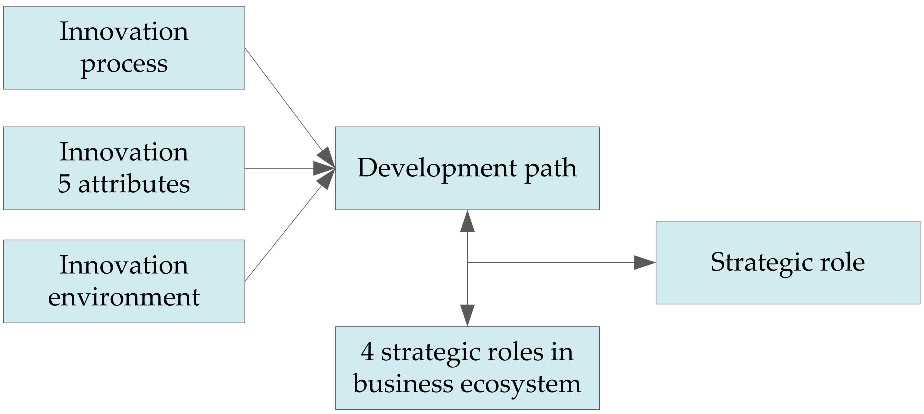


Figure 9 Analytical framework

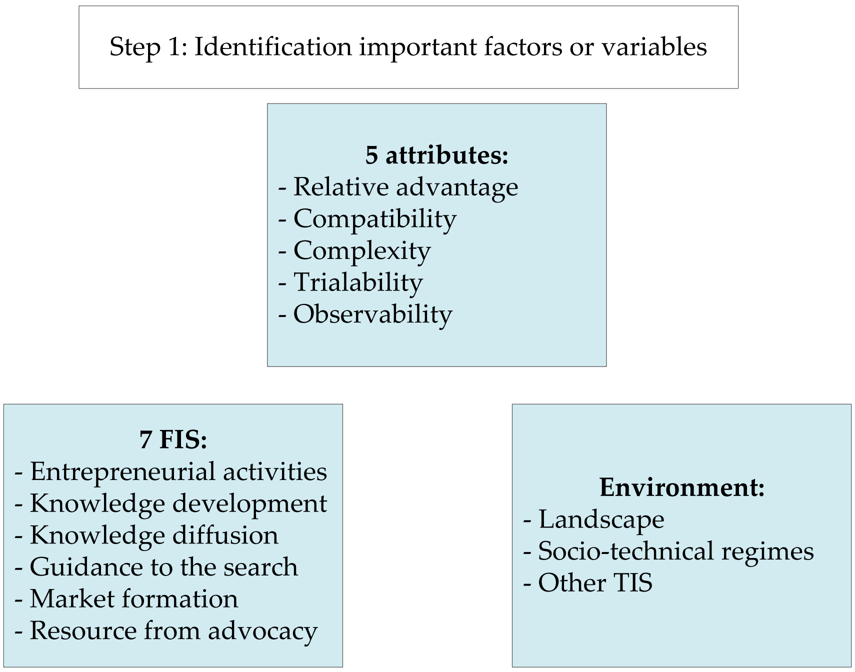
This framework achieves the objective as is described above. A perspective is given on the strategic role of a company in the development of a radical innovation. The strategic role is dependent of the business ecosystem, which surrounds the innovation's platform, and the development path(s). On its turn, the development path is dependent on the size and speed of the development, thus the three elements as shown in the figure above.

2.4.2. Analytical steps

The analytical framework gives a perspective on the strategic role of a company in the development of a radical innovation. Derived from this framework several analytical steps can be prescribed that enables researchers, or companies, to determine the strategic role. Four steps are identified: 1) identify the drivers and barriers in the current development stage, 2) establish (various) development path(s), 3) analyze the business ecosystems and finally 4) determine the strategic role.

2.4.3. Step 1: identifying the existing issues

A development path can be established by using important environmental factors to map scenarios and internal variables or factors that can either mitigate or support the development. These factors or variables can be derived by analyzing the three elements of a development, since the current development stage gives insight in how an innovation is being established and why.



Analyzing the functions of an innovation system (FIS)

A structural analysis, an analyses solely focusing on the components is not sufficient since the TIS is an emergent system. In such an analysis the dynamics in the TIS and its performance are not covered. The Functions of Innovations Systems Approach addresses these issues (Suurs, 2009). The notion behind this approach is that the structural factors contribute to the goal of an IS, which is to induce the innovation process by means of fulfilling a set of functions. A system function, or key activities, is in this sense the (positive or negative) contribution of a (set of) structural factor(s) to the generation, diffusion and utilization of an innovation (Bergek, 2002; Edquist, 2001; Liu & White, 2001; Suurs, 2009).

Research has been conducted to identify sets of functions, key activities, that speed up the innovations diffusion. The set of functions used in this research is based on the work of Bergek and Jacobsson (Jacobsson & Bergek, 2004) which has been has been specified during numerous discussions between researchers from Utrecht University and Chalmers University (Sweden) (Hekkert et al., 2007). Furthermore it is validated and used in studies by several researchers (Alkemade et al., 2007; Negro, 2007; Negro et al., 2007; Negro et al., 2008; Van Alphen et al., 2008a; Van Alphen et al., 2008b) and master thesis researches at the Delft University of Technology. The set consist of seven functions and is summarized according to the description of Suurs (2009).

1. Entrepreneurial activities
The function involves projects aimed to prove the usefulness of the emerging technology in a practical and /or commercial environment (experiments or demonstrations). These activities are important to overcome uncertainties. Suggested indicators used to analyze this function: projects started and stopped (M. Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007), diversifying established firms (Bergek, et al., 2005).

2. Knowledge development
Learning activities (learning-by-searching & learning-by-doing) are the essence of this function. Examples are R&D activities, laboratory experiments and adoption trials. The indicators used to analyze this function are R&D projects and their investment (Hekkert, et al., 2007) and education and support material (van Alphen, et al., 2008).

3. Knowledge diffusion
Knowledge diffusion focuses on transporting knowledge to heterogeneous actors as to increase overall knowledge of the innovation system, an important aspect of networks. Indicators to measure this FIS are networks existent (number, size and intensity over time)(Hekkert, et al., 2007), joint research projects (Kamp & Quist, 2011).

4. Guidance of search
This function consist of activities that shape the needs, requirements and expectations of actors with respect to their (further) support of the emerging technology. The indicators used to analyze this function are specific targets set by governments or industries (Hekkert,et al., 2007), and articles in professional journals that raise expectations about new technological developments.

5. Market formation
Activities that contribute to the creation of a demand for emerging technology. This is often fulfilled by the government or firms. The indicators used to analyze this function are specific tax regimes (Hekkert, et al., 2007) and marketing efforts from firms or government (van Alphen, et al., 2008).

6. Resource mobilization
This function refers to the allocation of financial, material and human capital. These are typically investments and subsidies. The indicators used to analyze this function are whether or not inner core actors perceive access to sufficient resources as problematic (Hekkert, et al., 2007) and financial lending or specialized credit instruments (van Alphen, et al., 2008).

7. Support from advocacy coalitions
This function involves the activities to counteract the inertia of actors in the incumbent technology system. These are often political lobbies and advice activities on behalf of interest groups. The indicators used to analyze this function are support by the government (Hekkert, et al., 2007), the rise and growth of interest groups (van Alphen, et al., 2008)

These seven key functions are needed in a TIS so that it can develop en perform successfully. By mapping these functions, insight in the dynamics of the innovation system is created. Weak functions and blocking mechanisms that prohibit good system functioning can as a result be identified (M. Hekkert et al., 2007).

Analyzing the 5 attributes

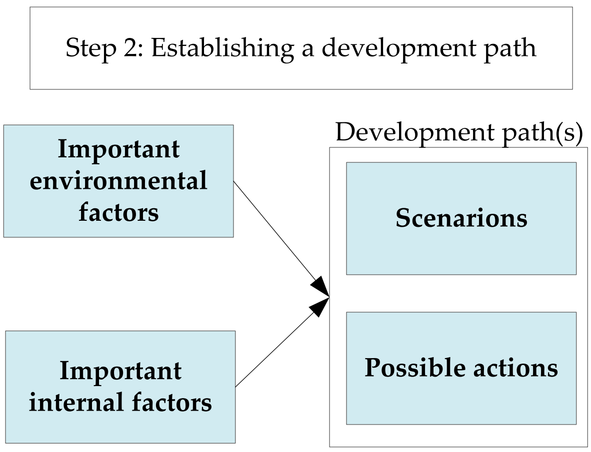
While analyzing the innovation system brings a new set of factors to analyze, in this analyses it is tested how the innovation is perceived on the basis of the 5 attributes: 1) relative advantage, 2) compatibility, 3) complexity, 4) trialability and 5) observability.

Analyzing the environment

As is the case with this analysis, the environment of the Dutch industrial Microgrid is systematically analyzed on three levels: 1) landscape, 2) socio-technical regimes and 3) other TIS. It should be noted that the previous two analyses prescribe a specific list of factors to go through. In this analyses it is first a task to determine which factors are relevant, and only then, to analyze what the impact is of these identified on the innovation system and attributes and thus on the innovation's development.

2.4.4. Step 2: establishing development paths

The second step in the analysis sequence is to establish the development path(s). From the previous analyses important environmental factors and important internal factors can be identified. The first are factors that cannot be influenced directly by actors, while the latter are the factors that can be considered actions. These factors can be combined in development paths which describe a scenario and possible actions. It is not prescribed how this should be done scientifically, since it is dependent on the research and the factors in play. It is a result of a creative session in which the factors are put together to make likely predictions of the future development path.



2.4.5. Step 3: analyzing the business ecosystem

With this third step the focus shifts towards determining the strategic role. This steps entails analyzing the business ecosystem which surrounds the innovation. This is done via an actor analysis. The objective is to create insight in the actors and their visions present in the business ecosystem.

2.4.6. Step 4: determining the strategic role

The last step is determining the strategic role. The strategy can be formed by taking into account the development paths of the innovation, the business ecosystem and the vision and strategy of the company in the analyses. By combining these three elements, different alternatives can be identified on how a company should establish itself or act in its business ecosystem

2.5. The framework applied

Up to this point the framework and the steps to be taken have been discussed in a generic matter. Since the framework has been constructed to be used in this specific case, it is explained how it is applied in this research. Purpose is not only to clarify the use of the framework, but also how the different elements relate to the formulated research question.

2.5.1. The current development stage of the industrial Microgrid in the Netherlands

As a first step in the framework the current status quo of the development process of the industrial Microgrid is analyzed (sections 4.1-4.3). First the innovation system of the industrial Microgrid is analyzed. This analyses gives insight in which actors, institutions and technologies are in place that work together through relations and networks as to induce the positive development of the industrial Microgrid. This is done based on the seven function identified in the FIS analyses. Each of the seven functions describe activities that should take place to induce the industrial Microgrid. Depending on the activity level and which activities have been executed, the development proceeds in a positive development spiral or in a negative one. It is expected that, since the industrial Microgrid is still in an early development stage there will not be many activities yet. However a base of activities should be present. The results of the FIS analyses is thus an indication of how far the development process is on its way.

The second analysis focuses on determining to which extent the industrial Microgrid possesses the 5 characteristics identified by Rogers as perceived by actors in the Dutch industry and energy system. If the innovative system is positively perceived by actors, e.g. industrial consumers, service providers, policy makers, on all 5 characteristics, it is discussed by Rogers as being a probable successful innovation which actors are willing to adopt. For example, the more compatible it is perceived with the current business processes, the more likely it is for adopters to actually adopt the innovation. Regardless of its novelty, it is expected that the innovation has indications of favorable characteristics. Otherwise, the development of the industrial Microgrid would come to a stand-still since no one would see its value. The outcome of this analysis thus gives an indication of why actors in the innovation system or adopters would want to induce or adopt the industrial Microgrid.

In the third analysis, environmental factors on the landscape, regime and niche level, that influence the development of the industrial Microgrid, are analyzed as to determine which external drivers and barriers exist for the development of the innovative system. For any innovation in its early stages, as will probably also be the case for the industrial Microgrid, it is expected that there is more resistance from incumbent technologies, institutions and actors. The more the environment adopts, the lesser resistance is expected from environmental factors. This analysis thus gives an overview of which factors are resisting or driving the development of the industrial Microgrid and why.

Based on the three analyses the first step of the circle constructed in the analytical framework is identified: creating an overview of the current development stage of the industrial Microgrid in the Netherlands (4.4). This entails that at that point it is known how for the development is, which factors drive it and which factors resist it.

2.5.2. The development paths of the industrial Microgrid in the Netherlands

As a second step the development paths of the industrial Microgrid may be constructed. This is done based on the factors identified in the previous step. Two types of factors are identified: internal factors and external factors. The internal factors are factors that lead to actions for the actors in the business ecosystem. For example, it could be that in the analysis of the innovation system it comes forward that there is little knowledge development (one of the seven functions) regarding the industrial Microgrid and that industries know little about the innovative system. An internal factor can thus be knowledge development for industries. Based on all the internal factors a sequential path of actions can be identified which can be executed by the business ecosystem as to influence the development process of the industrial Microgrid. The external factors are those that have an important shaping role in the development of the innovative system, but cannot easily be influenced. Based on possible scenarios of the external factors, alternate futures may be constructed in which the industrial Microgrid may be encroached. Together, the possible actions and scenarios are the development paths of the industrial Microgrid in the Netherlands.

2.5.3. The strategic roles for power equipment companies

As a last step the strategic roles of the power equipment companies should be established. First an overview of the business ecosystem of the industrial Microgrid is given. This corresponds to the actors working on the inducement of the innovative system, which are identified in the first analysis. In the business ecosystem theory four different roles have been identified. For every role it is analyzed how good or bad it fits with the profile of power equipment companies.

2.5.4. Data collection

In the introductory chapter it is already explained which methods have been used to collect the data for the analyses: 19 exploratory interviews with industrial and non-industrial actors, desk research and literature research are used to systematically analyze all the factors making up these three elements. Due to the lack of information and knowledge present regarding the Dutch industry and the Microgrid, the interviews have proven to be the main source for collecting data. Hereafter the interview process consisting of four main steps: defining the population and determining the sample; the formulation of the topics and questions of the interview; testing the quality of the interviews and finally the data collection process. The steps are discussed hereafter. In Appendix IV a detailed description of the process is given.

Population and sample

The population of the interviews consists of two groups: the industrial actors and non-industrial actors. The industries are considered the consumers of the industrial Microgrid. Their opinions and perceptions are valuable since they are crucial to the diffusion of the system. Without their support or intention to adopt, there is no market for the industrial Microgrid. The non-industrial actors are those that are involved in the development of the system, e.g. DSOs, engineering consultants, research institutes. These actors are already or could be involved in the development of the Smart Grid or in the activities surrounding the energy system.

The sample consists of 19 respondents; ten from the industrial population, nine from the non-industrial population. Due to the fact that the industrial population is very large, it is chosen to create a sample from only two industrial branches. If the respondents all originated from different branches, it would be unclear whether or not their opinions and perceptions are related to the different production processes. Thus to ensure the validity and usability of the results, different sources within a branch are used to gather the qualitative data (data triangulation (Guion, Diehl, & McDonald, 2002)). The two branches that are chosen consume large amounts of energy and their energy costs are relatively high: the refineries & chemical branch and the base metals & metal production branch. Ten random companies are chosen from a list of potential companies (Appendix IV). The third party actor sample is not randomly chosen. These are the actors of whom it is already known that they have activities within Smart Grids or Microgrids. The final list of companies is shown in the appendix.

Operationalizing

In the operationalization the content of the interview is established. As mentioned before, semi-structured interviews are used to design the interviews. This entails that topics of conversation have been established, including a short set of questions to give the interview a direction (Verhoeven, 2007). This approach of conducting the explorative interviews gives both leeway to the respondents to answer and elaborate on the topics and questions, but also ensures that conversations do not randomly evolve.

Each population group had its own formulated questions, but the topics and questions only differed slightly from one another. The topics and questions of both interviews are derived from the insights needed to execute the analyses in the following chapter. In the industrial interview four main topics have been created. The topics are shortly discussed below. For the topics and questions for the industrial and non-industrial respondents Appendix V and Appendix VI **Fout! Verwijzingsbron niet gevonden.**can respectively be consulted.

Energy supply and infrastructure (not for non-industrial respondents)
This topic focuses on the current situation on the plants. It is derived from the first pillar of the framework: analyses of the playing fields. The objective of this topic is to understand the current role and importance of energy in the plants' processes. The results already give indirect information about the possible advantages and disadvantages of an industrial Microgrid.

Opinions industrial Microgrid
The second topic focuses on the advantages and disadvantages of the industrial Microgrid and motives to implement such a system, as seen by the respondent. It is derived from the second pillar of the framework: the development analyses. This information is used for the adoption and organizational analyses.

Organization industrial Microgrid
The third topic, insights on the organization, focuses on the organization and mainly on the cooperation and interaction between industries. It is derived from the second pillar of the framework: the development analyses. This information is mainly used for the organizational analyses.

Developments
The last topic, the developments, focuses on developments on the long term that influence the energy supply and infrastructure of the industries. This is mainly important to identify external variables that are of influence on either the adoption or organization of the Microgrid. The topic is derived from the second pillar of the framework: the development analyses. This information is mainly used for the innovation analyses.

Quality
To ensure the quality and credibility of qualitative researches, the reliability and validity of the methods is tested. In this research the semi-structured interviews only cover qualitative data. Instead of reliability and validity of quantitative data, the concept of trustworthiness is introduced for qualitative data (Morse, Barrett, Mayan, Olson, & Spiers, 2002). The essential criteria for trustworthiness are credibility, neutrality or confirmability, consistency or dependability and applicability or transferability (Golafshani, 2003; Lincoln & Guba, 1985; Morse et al., 2002). While it is difficult to actually test these criteria, in the literature there are different techniques and verification strategies described that ensure the trustworthiness of the conducted interviews (Golafshani, 2003; Guion et al., 2002; Morse et al., 2002). In this research the following techniques have been used:

Sample

- The sample has been selected according to the process of Verhoeven (Verhoeven, 2007);
- The sample has been reviewed by both the external supervisor as the first supervisor of this research.

Methodological coherence

- The topics and questions of the interview are based on the theoretical basis and structure of this research;
- The topics and questions of the interview have been reviewed by professionals within Siemens Netherlands and the Delft University of Technology.

Collection and analysis of data

- All respondents have verified the transcripts as a true summary of the interview;
- A software tool, Atlas.ti, is used to analyze and interpret the qualitative data.

Data triangulation

- Various companies within the two population groups have been selected to ensure that different sources of information are consulted.

Data collection process

The first step in the data collection process was to contact the companies and track the right respondent based on the discussed criteria. After making the interview appointment an interview protocol has been sent to inform the respondents of the procedure and confidentiality of the required data (Appendix VII). Furthermore an introduction into the subject of industrial Microgrids and the topics and questions were attached, due to lack of knowledge of the industrial Microgrid. During the interview a clear structure (introduction of the researcher, explanation of the research, building trust by explaining the procedures, reviewing the questions beforehand, asking the questions and closing the interview by giving a summary) was used to smoothen the meeting.

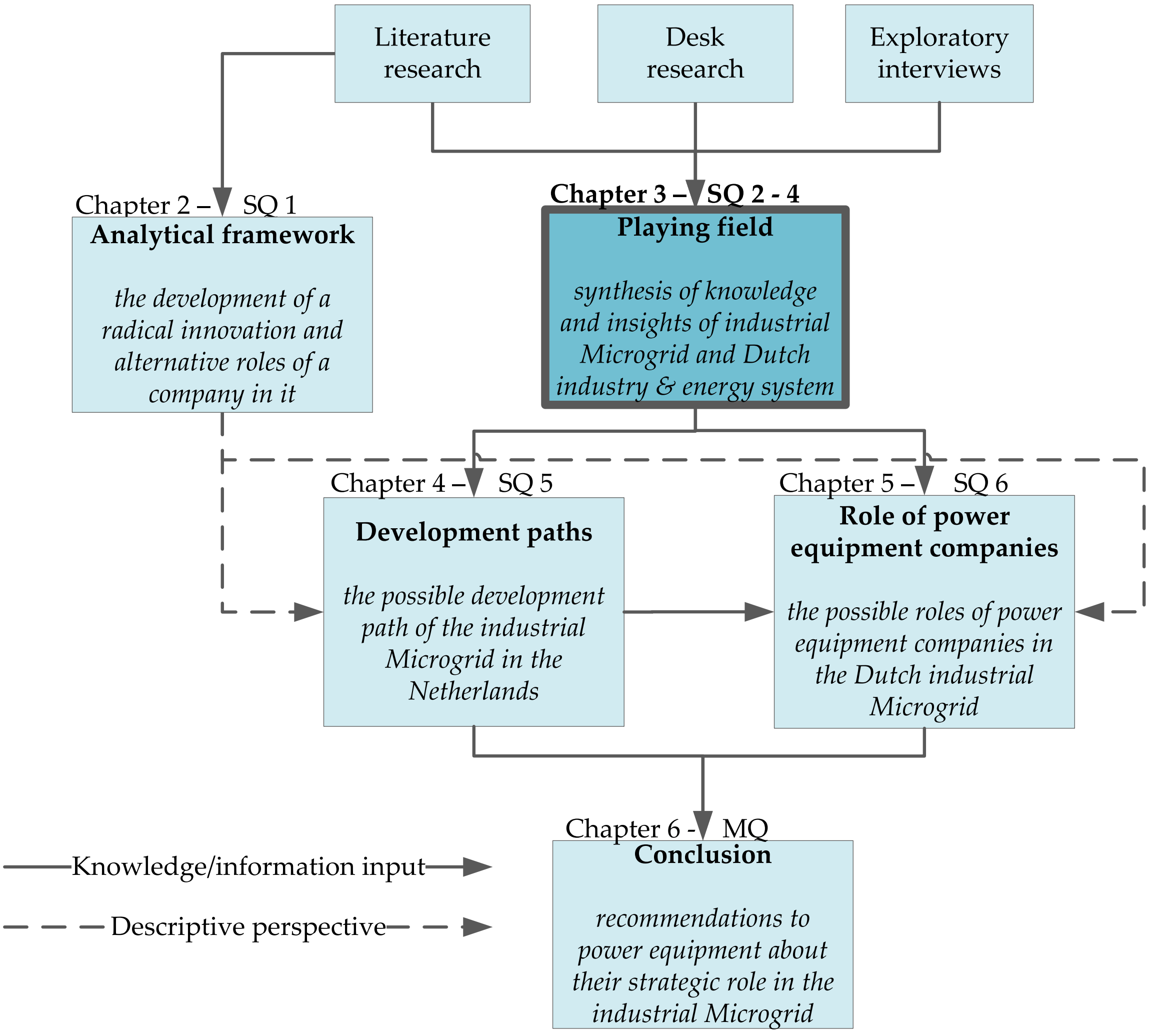
Data analyses

The required data is analyzed by means of the qualitative analyses program Atlas.ti. This software originates from the Technical University of Berlin and had has its first commercial release in 1993 by Thomas Muhr. The software helps arrange, reassemble and manage (qualitative) data (Grafton, 2005). The software thus does not comprehend or discerns the meaning of words or constructs(Smit, 2002), this is still done by the researcher, but it makes it easier to make sense of the data and to visualize this. The analyses only gives insights in the observations and conclusions based on the answers of the respondents. At this point these perceptions and opinions are not synthesized into general conclusions. They are thus a reproduction of the interviews. Five main themes of conclusions can be identified; the respondents, the perception of the system, the considerations for adoption, the organization of the industrial Microgrid and lastly the Trends and Developments.

2.6. Conclusion

In this chapter an answer is formulated for sub-question 2 "*What determines the development of an innovation and the role of a company within this process?"*. As a basis for the proposed framework three theories are used; two theories focused on the development of innovative technologies and one on the strategic role and position of companies in their business ecosystem. The development of an innovation is determined by three elements: 1) the innovation system, 2) the attributes of the innovation and 3) the environment of the innovation. The strategic role of a company is determined by the four roles that can be identified in business ecosystem. An analytical framework is constructed which links these two aspects together, thereby giving an overall perspective on the strategic role of a company in the development of a radical innovation. From this framework analytical steps can be identified which provide a prescriptive guidelines on how a researcher or company can determine the strategic role.

CHAPTER 3: THE MICROGRID INNOVATION



In this chapter sub-question 2-4 are answered:
What is the current state-of-the-art research regarding industrial Microgrids?
How are the Dutch energy and industry system organized?
What are the opinions and perceptions on the industrial Microgrid in the Netherlands?

3. Playing field

Before executing the various analyses derived from the analytical framework it is important to first build up a good understanding of the innovation itself, the industrial Microgrid in the Netherlands. While basic information about the industrial Microgrid was provided in the introductory chapter of this research, this chapter will go into deeper detail, exploring not only the functional and technical nature of the innovation, but also the social dimension within the Dutch context. The presented information is constructed of literature research, desk research and the conducted explorative interviews.

The structure of this chapter is as follows. The first section (3.1) describes the technical nature of the industrial Microgrid system. The second section (3.2) zooms in on the value proposition of this innovation, as described in the literature. In the third section (3.3) the Dutch industry is discussed. The fourth section (3.4) focuses the characteristics of the Dutch energy system. Thereafter, in section 3.5 the current perceptions on the industrial Microgrid in the Netherlands are discussed. In the sixth section (3.6) some insight is given on the possible configuration of such an industrial Microgrid. Conclusions about the playing field are drawn in the final section (3.7).

3.1. The Microgrid system

The Microgrid is an application of the Smart Grid concept, as is shortly described in the introduction. It is a fairly new system, which emerged via the application of emerging technologies, e.g. power electronic interfaces, modern controls and DER (Marnay et al., 2008). Due to its novelty it is insufficiently explored in the scientific world and the wider society. Just like the Smart Grid itself, it can take on many shapes and forms. It is a complex socio-technical system, and thus difficult to comprehend. In the following sections the separate elements of the system, with a focus on technology and functions, will be discussed to create an overview of the system.

3.1.1.Definition

The Microgrid is a regionally limited energy system. It can operate in grid-connected and islanded mode. It can operate as back-up of the grid or it can operate autonomously using DER for extended periods of time. Energy supply and demand is managed locally making it seem like a controllable entity for the Macrogrid[6]. The Microgrid can be seen as a miniature energy system optimizing the system's power quality and reliability, sustainability and economic benefits by intelligently coordinating generation and consumption of energy within close proximity of each other. The result is a cleaner and more efficient system (Lopes, Madureira, & Moreira, 2013; Siemens, 2006; Vandoorn, Zwaenepoel, Kooning, Meersman, & Vandevelde, 2011; G. Walker & Cass, 2007; M. Walker, 2012). Based on the research and projects which have been conducted over the last 15 years, different issues and challenges have been identified, e.g. a lack of established standards for Microgrid (Carey & Miller, 2012), safety concerns for unintentional islanding. Furthermore, the design, acceptance, and availability of low-cost technologies for installing, using and operating Microgrids (Kroposki, Lasseter, et al., 2008) have not yet reached the market, which is usually the case for incubating technologies.

3.1.2.Integrated energy system

The main energy flow in the Microgrid is electricity. However, since the Microgrid is geographically limited, generation and loads are in close vicinity of each other. As a result, the system can also cover heat demand. This is not possible in the centralized grid since heat is not easily transported due to energy losses that occur in the transportation. Heat is therefore always generated close to the source. The smaller size of the generation technologies in the Microgrid permits generators to be placed

[6] The Macrogrid is the main, centralized energy system, which is already present.

optimally in relation to heat loads (Chowdhury, Chowdhury, & Crossley, 2009; Lasseter & Piagi, 2004). Using waste heat through co-generation or CHP systems will increase the energy efficiency of the system, and can be seen as both an economic and an environmental advantage for the consumers (Hatziargyriou et al., 2007; Lasseter & Piagi, 2004). Due to the possibility of integrating both heat and electricity in the system, the Microgrid can be regarded as an energy system rather than a power system. In Figure 10 the possible energy flows within a Microgrid are shown. Overall two main energy flows can be seen as an input for the Microgrid: 1) electricity and 2) gas. With these also heat and more electricity can be produced and the three forms of energy can be used for processes. With regards to working in island mode, the Microgrid can run autonomously with regards to heat and electricity. Gas remains an energy source of which a Microgrid is dependable on the Macrogrid.

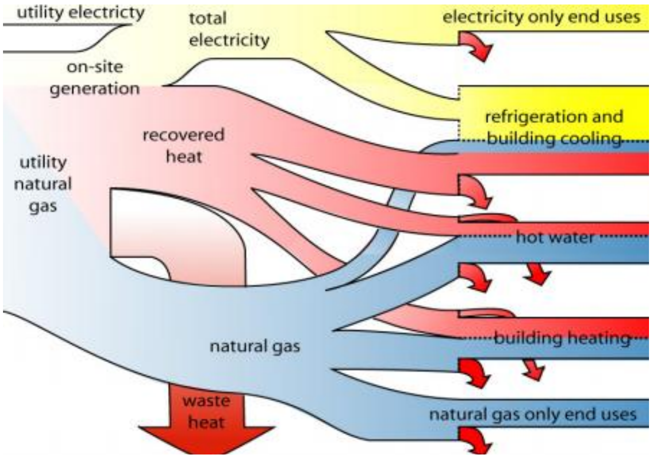


Figure 10 The possible energy flows in the Microgrid (Marnay & Bailey, 2004)

3.1.3.Modes of operation

A Microgrid has two steady modes of operation: grid connected operation and islanded. It also has two transient states, corresponding to the transition phase between these steady-states. The first two modes are considered the "steady" states of the Microgrid, while the latter is considered the short time period when the Microgrid is transitioning between the two steady states. During these four modes both the Microgrid as the Macrogrid should remain stable and should meet grid-code requirements (e.g. on real and reactive power flow and behavior during faults) (Barnes et al., 2007; Cobben, 2011)

In grid connected mode, energy can be imported and exported into Microgrid from the Macrogrid. The loads and generation sources within the system are controlled internally, so that the Microgrid appears a controllable single entity to the utility grid (Miret et al., 2010; Molderink et al., 2010). As it is connected to the Macrogrid, it is also controlled by the Macrogrid. All services to maintain grid and operation stability are done by the Macrogrid, while the Microgrid should adopt its guidelines and requirements. Economic decisions can be taken by the Microgrid operator, such as selling or buying energy depending on energy prices and the on-site generation capabilities (Siemens, 2006).

In island mode the generation sources and loads of the Microgrid are separated from the Macrogrid to isolate the generation and loads without harming the grid's integrity (Lasseter & Piagi, 2004). The Microgrid can transition to island mode either preplanned or non-planned. In the first scenario, events in the Macrogrid are presented that make island mode preferable, e.g. long time voltage dips and general faults. In the latter scenario unforeseen failures in the Macrogrid will force the Microgrid in unplanned island mode, thereby safeguarding sensitive, mission-critical electronics or processes from interruptions (Lasseter & Piagi, 2004). In both modes, the Microgrid control must take over the functions that are executed by the Macrogrid, e.g. frequency and amplitude of voltage, load balancing, and the power quality (Miret et al., 2010).

The transient mode occurs when the Microgrid is transitioning from the one steady state to the other. The additional costs of a Microgrid are determined by the requirements of this semi-autonomous operation. It is therefore an important aspect of the technical design to pay attention to. The main issue in this state is maintaining system stability by Microgrid control in the short period of time where this mode exists (Barnes et al., 2007)

3.1.4. Technical components

There are several basic components present in the Microgrid. As became apparent in the definition, the Microgrid is a miniature version of the current centralized energy system. Therefore all the components present in this centralized grid should be present in the Microgrid. The Microgrid contains (renewable) DER, loads, distributed energy storage and an interconnection switch connecting the Microgrid to the Macrogrid (Carey & Miller, 2012; Cobben, 2011; Driesen & Katiraei, 2008). The connection between the components is organized by the Microgrid operators. Expansion of the system can be realized by adding a new component and by adjusting the control of the Microgrid (Barnes et al., 2007). A simple figure of the components is shown in Figure 10.

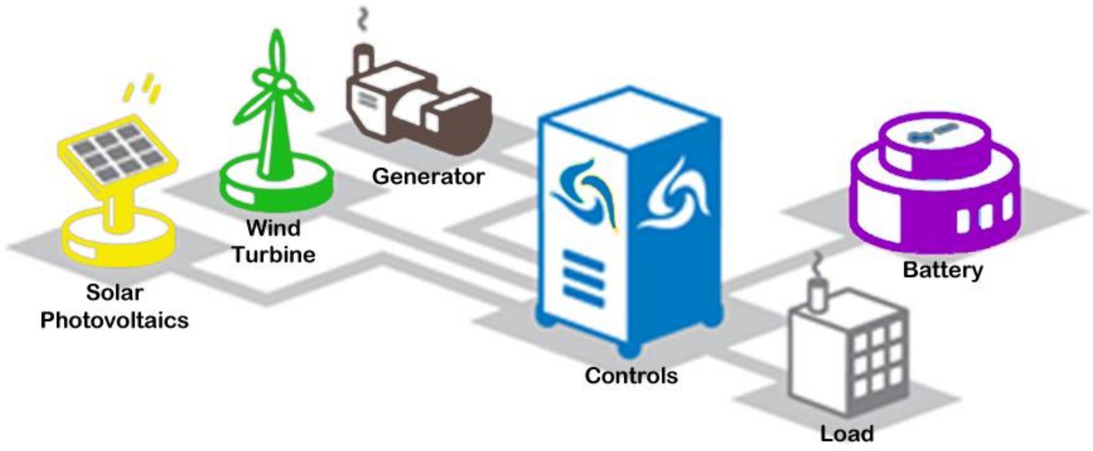


Figure 11 Technical components of the Microgrid (M. Walker, 2012)

DER

DER are small sources of energy located at or near the point of use. These are needed to generate and supply electricity and heat demand in the Microgrid. A wide range of technologies exists that are associated with generation of energy in Microgrids, e.g. microturbines, CHP, wind energy, photovoltaic and fuel cells. These systems may be powered by either fossil fuels (often natural gas) or renewable fuels (Kroposki, Lasseter, et al., 2008) and have lower emissions (Chowdhury et al., 2009; Lasseter & Piagi, 2004). CHP or co-generation systems capture and use the waste heat of the system as a product for heat loads, making it more efficient than a single energy production unit. Most of the DER require a converter (power electronics interface) to ensure that the power[7] generated has the proper characteristics to be distributed (Kroposki, Basso, & Deblasio, 2008; Lasseter & Piagi, 2004).

Loads

The loads are the consumers of the produced energy. The loads can be divided into critical and controllable, non-critical, loads. Critical loads are the loads which need to have a constant supply of electricity or heat, while the non-critical loads can be either shut down or are provided with variable power or heat consumption (Barnes et al., 2007). Managing the controllable loads makes the Microgrid

[7] Power has several characteristics, e.g. voltage and frequency. If the power doesn't have the right characteristics then this can lessen the quality of power on the grid.

flexible. To manage the loads, a control system can be used which is called load shedding. This system intentionally shuts down loads depending on the availability of energy or demand. The Microgrid control executes these types of systems.

Storage
Storage has several functions in the Microgrid. As said previously, the Microgrid is considered a controllable load. Storage makes it possible to control the net power flows to and from the utility as a controllable load, thereby assisting the utility with stable network operation. In the case that the Microgrid transitions to island mode, storage is needed to absorb energy from, or inject energy in, the grid. Furthermore, storage can be used to damp peak surges in electricity demand. Depending on the loads and generation sources the energy density –for medium and long-term needs- and power density –for short and very short-term needs- requirements are determined (Barnes et al., 2007; Kroposki, Lasseter, et al., 2008). The most common storage technologies are batteries, super capacitors and flywheels (Barnes et al., 2007).

Point of Common Coupling
The Microgrid is connected to the Macrogrid via the Point of Common Coupling (PCC) which is an intelligent switch (Kroposki, Lasseter, et al., 2008; Miret et al., 2010). This switch can break the electrical circuit of the network automatically or can be manipulated by humans, thereby separating the Microgrid from the Macrogrid when needed. Grid conditions are measured on both sides to determine the operational conditions (Kroposki, Lasseter, et al., 2008). There are different types of switches. A simple circuit breaker can be installed, but more advanced switches like solid-state switches and back-to-back (AC/DC/AC) power electronic inverters can also be used (Barnes et al., 2007; Chowdhury et al., 2009).

Microgrid control
The most complicated part of the Microgrid system is how the system is controlled. All the elements in the Microgrid must be controlled and coordinated the way for them to operate as a system (Barnes et al., 2007). While the different components of a Microgrid are physically connected to a low or medium voltage distribution grid, the control actually integrates the components to ensure that all the components function together so that the Microgrid is a stable and reliable system in all modes (Barnes et al., 2007; Lasseter & Piagi, 2004). It probably consists of a system which includes, power electronic interfaces, SCADA (computer controlled system that monitors and controls systems), energy management, generator and load management, system reconfiguration and black start after a fault, system efficiency monitoring, carbon dioxide contribution analysis, system health monitoring and other functions (Siemens, 2006). The literature on the control is extensive, since this is technically the most challenging and innovative part of the Microgrid system.

3.1.5. Worldwide development of Microgrid

With drivers like quality issues in the electricity grid, electricity infrastructure capacity issues, climate change and the limitedness of fossil fuels in the energy (infrastructure) and the development of ICT in the energy systems, the Microgrid has been proposed as a viable alternative to the current energy system. Both research and commercial developments have taken place around the world, thereby identifying not only its potential but also issues and challenges that need to be addressed.

Microgrid developments and researches have been ongoing worldwide. According to research worldwide more than 480 projects are proposed, under development or operating worldwide, representing nearly 3,8 GW (Martin, 2013). North America is most advanced with the number of projects that are already up and running and that are the pipeline. The main drivers to be frontrunners are the lack of reliability in the Macrogrid and the long distances between places. The CERTS research program is the most well-known research program for Microgrids in the United States. In Europe there have been the More Microgrids program which focused on Microgrid control and operations, thereby financing and setting up projects in inter alia Greece and the Netherlands. In Asia projects have started in Japan, China, South Korea and Singapore, due to the need for distributed energy resources because of earth quakes and renewable energy targets. (Barnes et al., 2007; Hatziargyriou et al., 2007; Marnay, Zhou, Qu, & Romankiewicz, 2012). As can be seen in Figure 12 and Figure 13, the expectations is that the market for the Microgrids grow rapidly worldwide over the coming years. The Microgrid development is moving into mainstream, with a greater focus on viable business models (Martin, 2013).

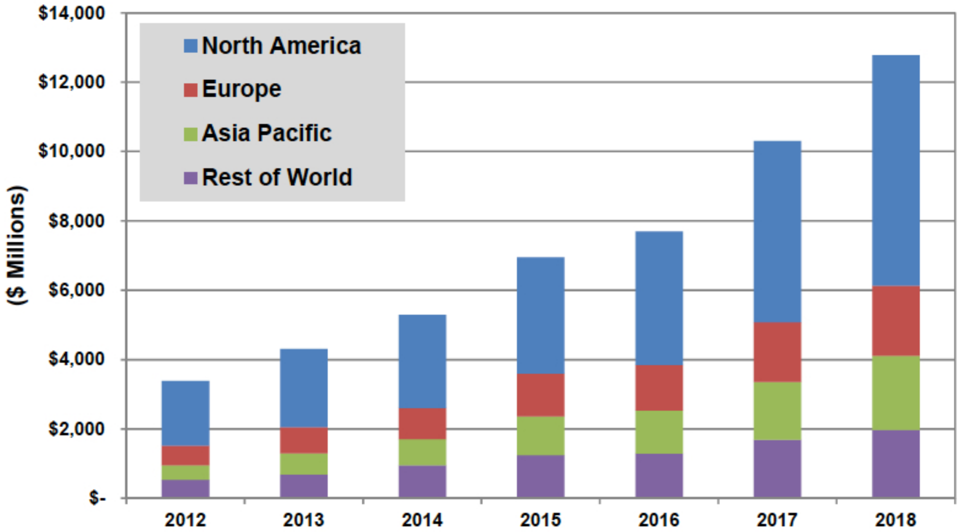


Figure 12 Total Microgrid Distributed Generation Vendor Revenue, Average Scenario, World Markets: 2012-2018 (Asmus & Wheelock, 2012)

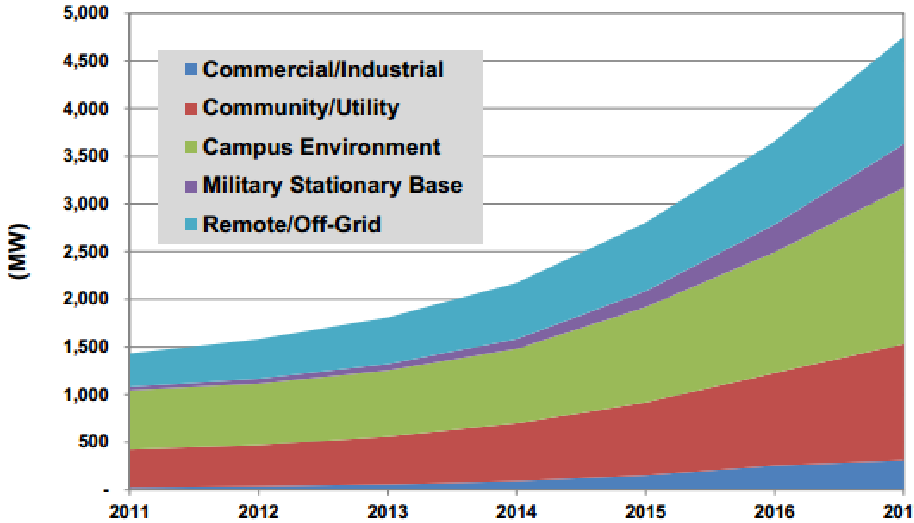


Figure 13 Total Microgrid Capacity by Segment, Average Scenario, World Markets: 2011-2017 (Asmus & Wheelock, 2012)

3.2. Value proposition

Implementing the Microgrid brings several value propositions according to literature. The parties that can theoretically benefit from the Microgrid are customers, technology providers, TSO/DSO and policymakers. The value proposition of these groups derive from the common thread motivations of cost, reliability, efficiency, clean energy, and climate change mitigation (Marnay et al., 2012). The first value proposition is increased reliability. This can be improved due to the fact that the Microgrid can switch to island mode whenever the Macrogrid is not reliable[8] (Kennedy & Wells, 2009; Kroposki, Lasseter, et al., 2008; Siemens, 2006). This can be both beneficial for the consumers of the Microgrid and for the TSO and DSO. Furthermore a higher degree of sustainability can be achieved due to energy efficiency by cooperating with other consumers and co-generation. Consumers, the TSO and DSO, and policy makers all benefit from increased sustainability. Thirdly, the Microgrid should also be economic attractive (Brian Carey & Miller, 2012; Hatziargyriou et al., 2007; Siemens, 2006). Through increased efficiency lesser amounts of fuels are needed. Furthermore by integrating DER cleaner fuels are used, which should result is a decrease in emissions. Both will reduce costs. Revenues are gained on the other hand by trading energy as dispatch power or when trading electricity results in higher revenues than gaining revenues from the production process (Kroposki, Basso, et al., 2008). This may be an important benefit mainly for the consumers in the Microgrid, but is also a goal of the policymakers. Another important benefit is increased power quality. Power quality is the quality of the supply voltage in a certain area, which strongly depends on the characteristics of the loads and the transmission and distribution grid infrastructure in this area (Siemens, 2006). Increased power quality can be achieved since the Microgrid is not dependent on actions from outside the system, rather it can operate and balance its own system (Kroposki, Lasseter, et al., 2008; Siemens, 2006). This is again a benefit important for the consumer and the TSO and DSO.

Beside the consumers, the TSO and DSO and the policymakers, the technology and service providers of the Microgrid may also wonder what is in it for them. Their benefits are briefly mentioned in the introductory chapter. The Microgrid can function as a new market in which new innovative products can be sold, so that eventually revenues and profits are increased.

The value propositions discussed here are theoretical. While interviewing two industrial sites, one containing all the characteristics of the industrial Microgrid and one having most characteristics of an industrial Microgrid, it became apparent that the perceived benefits depend on the consumers present in the Microgrid (e.g. their ability to be flexible, the complementarity of their energy profiles), their willingness and level of cooperation and the environmental conditions (e.g. energy prices, actual reliability of the grid, environmental laws). Every Microgrid have its actual benefits researched since they are dependent on many different factors.

[8] As has been discussed in the introduction there are several trends that increase the inefficiencies and instability of the electricity grid. One of these trends is the (large-scale) introduction of DERs on the low and medium voltage grids. This large scale introduction affects the traditional in several ways (Blažič & Papič, 2008). First of all, variations in the voltage levels in the grid are caused by the fluctuating power flows and complicated reactive power equilibrium. The traditional control strategies are insufficient to perform voltage regulation. Second of all, DER can have an impact on the protection operations by increasing fault currents in case of a fault. Furthermore a large scale introduction can lead to poorer quality if operation of the unit is not properly controlled and coordinated. Lastly, it can also lead to an increased uncertainty due to the intermittent nature of RES thereby requiring reserve capacity (Blažič & Papič, 2008). However, there are of course benefits to DER, e.g. environment/emission benefits, reduction in system losses, energy production savings and reliability enhancement (Iannucci, Cibulka, Eyer, & Pupp, 2003). In order to mitigate the technical impacts resulting from this introduction and to exploit their possible benefits a new control approach is needed which differs from the current centralized method (Lopes et al., 2013). A solution to this is the Microgrid.

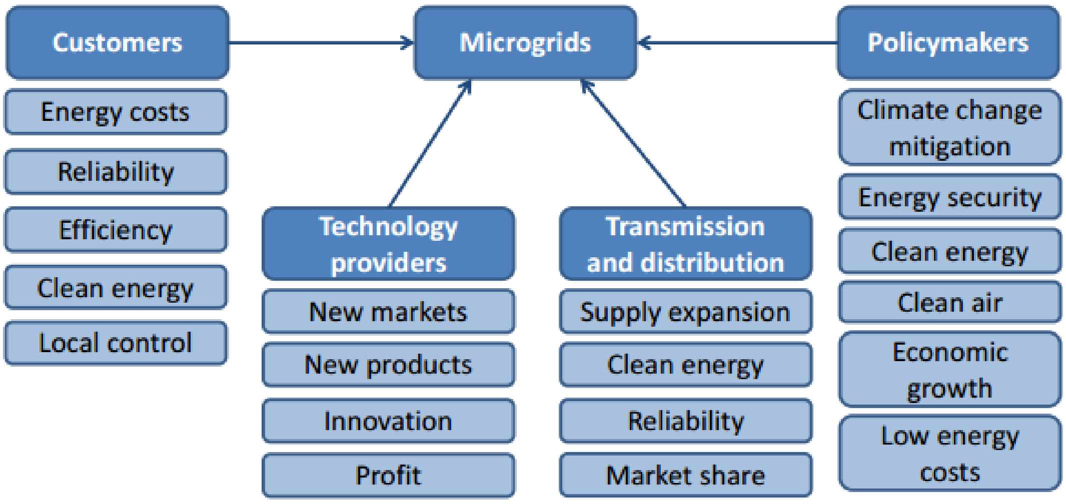


Figure 14 Value proposition of the Microgrid from a social perspective (Marnay et al., 2012; Siemens, 2006)

3.3. Industrial application

There are five applications of the Microgrid depending on the environment in which they are implemented: 1)institutional and campus Microgrid, 2) the commercial or industrial Microgrid, 3) military Microgrid, 4) community and utility Microgrid and lastly, 5) island and remote "off-grid" Microgrid (Driesen & Katiraei, 2008; Siemens, 2006). The environment, (technical) requirements and objectives of the involved actors in which the Microgrid will be implemented, will determine how the system is organized. In this research the focus is on the industrial Microgrid in the Dutch context. The industrial Microgrid is a Microgrid which links industries together. In this section an overview of the Dutch industry will be given, thereby giving insight in who the consumers may be in such an industrial Microgrid. Furthermore, the main Dutch industrial sites, which are already existing geographically limited areas which vest industries, are discussed. These are of interest in the industrial Microgrid since these seem logical places to implement the industrial Microgrid; the industries are already clustered together on these sites.

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3.3.1. Industries

An industry is a collective term for economic activities concerned with the processing of raw materials and manufacture of goods in factories (Google, 2013). Different branches can be identified based on the products that are manufactured. There are different ways to classify these branches (CBS statistics Netherlands, 2013). In this research the Dutch SBI (Standaard Bedrijfsindeling, SBI 2008) is used. This classification is based on the economic activity classification of the United Nations, the International Standard Industrial Classification of All Economic Activities (Buck, Blom, Smit, & Wielders, 2010; CBS statistics Netherlands, 2013; Siemens PTI, 2012). In Appendix II the full classification list can be found. The industry sector is only one category of the 21 defined. In Table 3 the industry sector and its branches are reported (CBS statistics Netherlands, 2012a).

Table 3 Dutch industries

SBI C –Industry sector	
Industry #	*Branch*
10-12	Food and stimulants industry
13-15	Textile, Clothing, Leather industry
16+23	Wood and building materials industry
17-18	Paper and graphic industry
19-22	Refineries and chemics
24-25	Base metals, metal production industry
26-28	Electrical engineering and machine industry
29-30	Transport industry
31	Furniture industry

In the industry five main energy flows can be identified: coal, oil, natural gas, electricity and heat (Coakley et al., 2010; COGEN Europe, 2011; Groot & Morgenstern, 2009; Siemens, 2011). Every branch consume to some degree natural gas; the use of the other energy forms depends on the existing processes in that specific industry. The outlier considering energy consumption are the refineries and chemical branch In Figure 15 the average energy consumption of the five main energy sources is depicted. The numbers are based on the total energy consumption of that branch divided by the total number of companies, all derived from CBS statistic numbers and can be found in Appendix III**Fout! Verwijzingsbron niet gevonden.**.

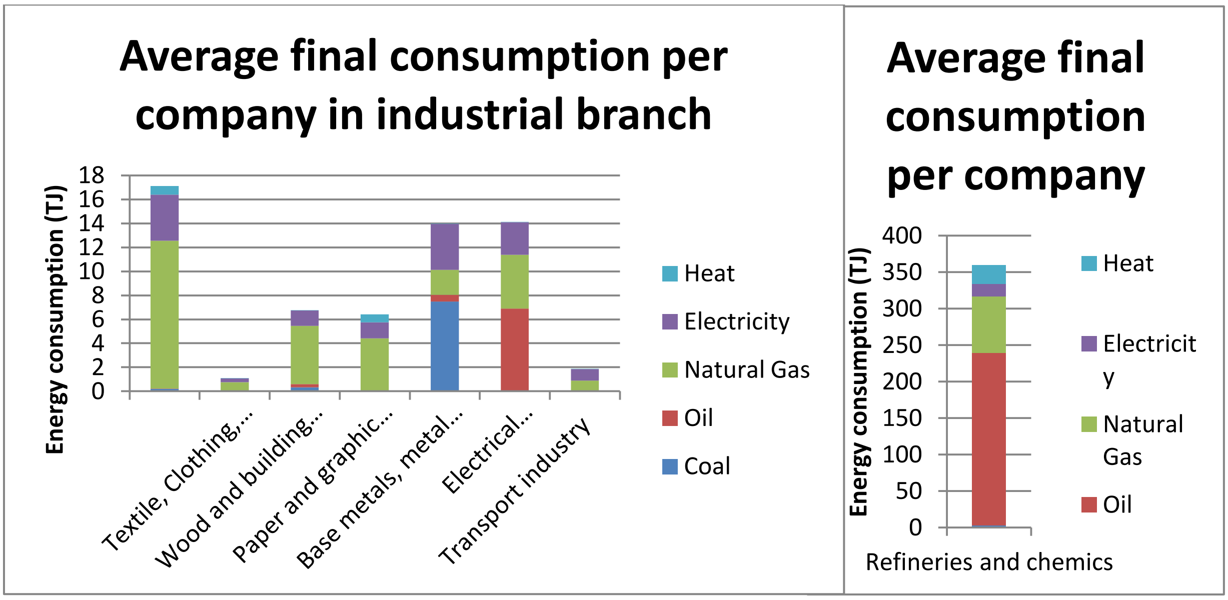


Figure 15 Average energy consumption per company per industrial branch in 2012

Each branch on its own has several different sub-categories of industries, each of them differ in the processes they use, the size of the plants and their energy profiles. Based on the figures presented above it is not possible to make claims on which industries would benefit most of the industrial Microgrid. While it would be interesting to analyze the energy profiles of each of the different types and sub-categories of industries as to find out if certain industries could be found well suitable for the industrial Microgrid, it would be impossible due to the number of differences in each industrial plant. As discussed previously, the achieved benefits depend on many different factors and not only on the characteristics of one plant. For every Microgrid the possible received benefits should be researched separately.

3.3.2.Industrial sites

In the Netherlands, industries are dispersed throughout the country. Sometimes they are standalones and sometimes they are clustered. Larger clusters can be found roundabout cities and in larger industrial sites (TNO, 2011). Examples of cities where a lot of industries are located are Eindhoven & Helmond (textile, tobacco & electrical engineering industries), Terneuzen (chemical industries) and Sittard-Geleen (chemical industries). Examples of larger industrial areas are Delfzijl & Eemshaven (chemical industry, metal industry), Port of Amsterdam consisting of several independent ports in Amsterdam Zaanstand, Beverwijk and Velsen/Ijmuiden (steel industry) (Port of Amsterdam, 2012), and the Port of Rotterdam (refineries). Industries usually come together in these larger industrial sites and cities due to the convenient location, easy accessibility, and the accommodations that are already in place. Due to the fact that clusters already exist in these industrial sites and that a large part of the infrastructures are already present, they can function as readily available points of demand for the industrial Microgrid.

3.4. The Dutch energy system

The energy sources present in a Microgrid are electricity, gas and heat. These energy forms are each part of an elaborate and highly complex socio-technical system, which is largely shaped by European energy policy. This policy has been on the move toward liberalized competitive markets that support and prote the development of cost-effective future systems (Marnay et al., 2008). In this section these systems are discussed, since these systems for a part shape the regulatory and economic environment in which the industrial Microgrid is implemented. Because the electricity and gas system are similar they are discussed together. Thereafter the heat system will be covered.

3.4.1.Dutch Electricity and gas system

Due to the liberalization of the 1990's the value chain of both the gas and electricity sector, which was previously vertically integrated, has been separated. With this separation several new functions were formed, executed and controlled by different actors. The system is depicted in Figure 16. Henceforth the electricity and gas system are explained (Dril, Gerdes, Marbus, & Boelhouwer, 2012; Energie in Nederland, 2011; Vries, Correlje, & Knops, 2010). For an elaborate explanation, the report "Energie in Nederland 2011/Energy in the Netherlands 2011" by Energie in Nederland can be read.

Supply chain

The supply chain has been divided into four straightforward steps; generation, transmission (national level), distribution (regional level) and consumption. Every step is controlled by different actors and different functions are identified to guarantee a smooth process.

The generation is subject to competition and privatization. A small set of private companies produce the electricity which is consumed in the Netherlands and is exported to other countries. Energy that is not generated by this set of producers is either imported or generated by large industries and farmers through CHP units.

The transmission and distribution is in hands of the TSO, TenneT, and DSO, e.g. Allianders, Stedin, who are regulated by the government. The transmission network is the national high voltage (380-150 kV) grid or high pressure network (67 bar), respectively for electricity or gas. The distribution is the regional low voltage grid (>150 kV) or low pressure network (>67 bar). Normally consumers are connected to the grid[9] on the regional level. Only several large (industrial) consumers are directly

[9] Whenever the electricity grid is mentioned, this also concerns the gas network unless mentioned otherwise.

connected to the national grid. The Dutch energy infrastructure is one of the most reliable grids in Europe (Netbeheer, 2013). The electricity grid is with a reliability of 99,99486%, one of the most reliable grids in Europe (Bogaert & Derksen, 2013; Dril et al., 2012)[10]. The average time of gas outages for the consumer in the Netherlands is less than a minute per year (Netbeheer, 2013). The different consumers of the Netherlands, both households as companies, consume the energy. In 2010 109.351 kWh electricity and 51.919 mil. m^3 was consumed.

Depending on the size of consumption the industries are either connected to the transmission grid (large industries) or the distribution grid (smaller industries). There is no clear cut threshold though.

Markets

There is a whole-sale market where gas and electricity is traded between the different actors. First there is the bilateral market where 85% of the energy is traded. These are long term contracts between producers and suppliers/large consumers/traders. Then there is the spot market, the APX-Endex, where energy is traded for the next day on an hourly basis. In addition there is the balancing market. Balance responsibles (Table 4) can either buy or sell energy based on the energy programs submitted to TSO/GTS. The prices for energy are volatile and high in comparison to the prices on the bilateral market.

The economic, institutional and technical organization of the energy system described above provides several important guidelines the industrial Microgrid should comply with. These guidelines are derived from the EU's Competition law (1998), the Electricity act (1998), the Gas act (2000) and the most recent Third Energy Package (2009). These EU regulations are a means to achieve an internal EU electricity and gas system. Relevant are the type of infrastructure, its access conditions and the connection to the main grid (Akkerboom, Buist, Huygen, Ottow, & Bommel, 2011).

The regional network

The Dutch grid is divided into three types of distribution infrastructures: the public grid, the closed distribution system (CDS; in Dutch the GDS, gesloten distributie systeem) and the direct line (in Dutch: Directe lijn). The public grid is controlled by the DSO and is regulated through both European and national laws and regulations. The CDS is "a system that distributes gas and electricity within a geographical limited commercial or industrial location with shared services and that does not distribute to households" (NMa, 2012a). A construction probable to be used for industrial Microgrids. The owner of the CDS is absolved of the obligation to appoint a DSO for its infrastructure. It prevents unnecessary administrative charges on these systems. The owners of the system can appoint their own party to operate and maintain their distribution infrastructure. The direct line is not a grid but it connects an isolated producer directly to an isolated consumer or connects a producer with one or more consumers with intervention of a supplier directly (NMa, 2012b). The public grid is the standard grid. However, if a grid satisfies specific set of requirements (NMa, 2012a, 2012b) it can request the status of either a CDS or a direct line. Depending on the type of infrastructure, several laws and regulations that constrain activities in the grid are not applicable.

Access conditions

In the Electricity act and Gas act several conditions, so called codes, are established. These describe the handling of network operators and customers with the (high voltage) networks. There are three types of codes: the technical codes, the information codes and the tariff codes (ACM, 2013a, 2013b). The technical codes, consisting of the measure codes, system codes and net codes (in Dutch meetcode, system code en net code respectively), describe how TSO and DSO should act to each other and to the

[10] In the high transmission grid outages are relatively sparse, most outages occur in the regional grid. An average outage of 27 minutes in 2012 has been measured in the Netherlands. Only England scores better with 22 minutes. Germany and France have an average outage of about 80 minutes (Bogaert & Derksen, 2013).

connected parties. This includes the operations of the grids, the technical preconditions that should be complied to by a connected party, the measurements and data flow of the energy consumption of the connected parties and the system services. The information codes describe the roles and responsibilities of the different actors when registering, exchange, use and keep data for administrative purposes. It clarifies the content of the data and states how and within which period the data should be exchanged. Lastly, in the tariff code it is laid down how the costs of legal tasks of the electricity grid and gas network are divided over the tariffs of the consumers. These codes prescribe a lot of rules that need to be taken into account when designing the industrial Microgrid.

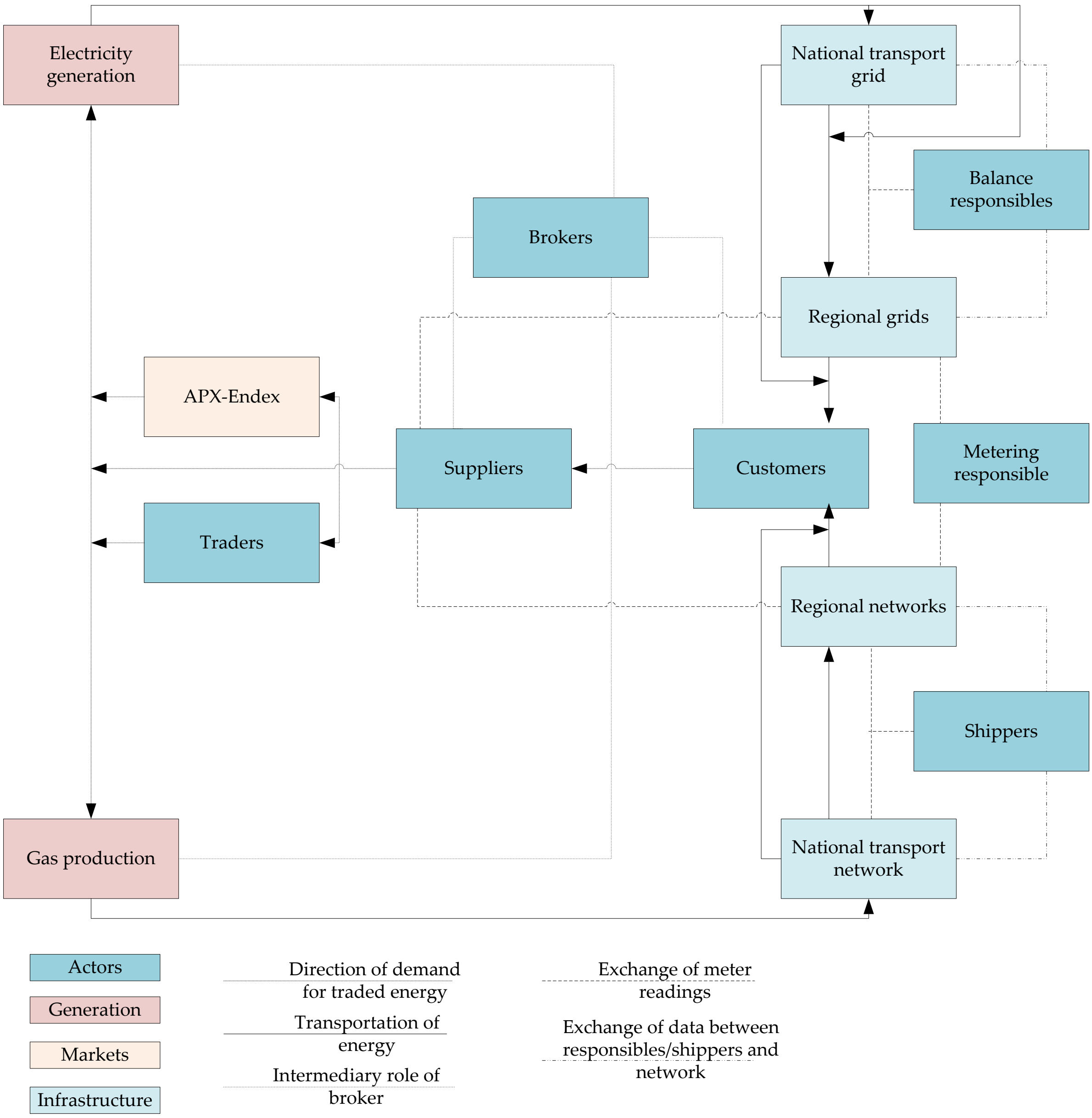


Figure 16 The Dutch electricity and gas system. Adopted by (Energie in Nederland, 2011)

Actors and functions

In the gas and electricity grid several actors and functions came into being due to the liberalization of the energy system. These are explained in Table 4..

Table 4 Actors in the Dutch electricity and gas system

Actor	Function
Producers	Generate electricity.
TSO (TenneT) / GTS (GasUnie)	Manage imports, balance supply and demand in the national grid and manage the grid (quality)
DSO	Manage the grid
Suppliers	The commercial and administrative link to the consumer; they supply the energy and collect the fee.
Traders	Sell and buy energy to exploit the margin between supply and demand.
Brokers	Intermediaries for the market players , bringing supply and demand together.
Balance responsibles/shipper	Submits on behalf of its users (consumers) energy programs to TSO/GTS and is responsible for the balance between supply and demand. Often supplier, trader or large consumer.
Metering responsibles	Install and maintain meters, pass on meter readings to suppliers and responsibles/shippers
Customers	Consume energy and choose their own suppliers

3.4.2.Heat system

The heat system in the Netherlands is not as organized and strict as the electricity and gas system, partly due to the characteristics of heat. It is difficult to transport the source without losing large volumes of the energy. The heat system is therefore a decentralized one. In dozens of locations in the Netherlands heat is consumed by making use of district heating, small CHP units, heat and cold storage or waste heat of the industry and waste treatment facilities (Energie in Nederland, 2011). It is more straightforward and handled on a smaller scale than the gas and electricity system.

3.4.3.Dutch energy laws and regulations

In the Netherlands laws and regulations that affect the Dutch industry are constructed on different subjects, e.g. spatial planning, air, water & energy, sounds, health & safety (Kenniscentrum InfoMil, 2013). Since the industrial Microgrid centralizes around the energy value chain (decentralized generation, distribution, usage and trading), environmental laws and regulation relating to emissions and energy usage are of utmost importance. Many of these laws effective in the Netherland origin from European Directives, e.g. Industrial Emissions Directive 2010/75/EU, European Trading System Directive 2003/87/EC, the Netherlands has to obey given the fact that it is a member of the European Union.

With regards to the emissions, the Netherlands has several obligations that are derived from these European Directives and other international agreements. These are the "Effort Sharing Descision (ESD), the Renewable Energy Directive (RED), the National Emission Ceilings-directive (NEC), the ETS and the international Kyoto protocol (Verdonk & Wetzels, 2012). The objective is to emit less and clean, thus cleaner sources or clean-up of emissions, and to be more efficient.

3.5. Early Microgrid perceptions of the Dutch Energy Managers

The 19 interviews conducted with actors in the Dutch industry and energy sector not only gave a good insight in the state of affairs in the Dutch industry energy system, but also reflected early perceptions about the industrial Microgrid.

3.5.1.Priorities Dutch industry managers

The interviews among other things painted a clear picture of the priorities of the Dutch industry with regard to their energy system. These criteria are derived from the interviews with both the industrial and non-industrial actors. While these priorities are not specifically related to the industrial Microgrid, they indicate the criteria to which this innovation will be judged in due time.

Criteria: Quality of energy

The quality of energy entails the preconditions to which the energy should satisfy for the production processes to run smoothly. For every energy flow these preconditions differ. For example the caloric value and the composition of the gas can be set as preconditions. For steam preconditions may cover pressure, low pressured or high pressured, or temperatures. Preconditions for electricity can be the frequency and power. If the quality does not meet the standards, the processes can be interrupted with all the consequences this entails.

Criteria: Reliability

Reliability is one of the most important criteria. Reliability means that the supply of energy flows must be consistent and is able to meet predicted peaks in demand. The consequences of unreliable energy flow can be catastrophic for some industries with regards to materials and environment. In the Netherlands the reliability is regulated in the Energy laws as described in earlier. Some industries, especially those whose production processes are extremely sensitive to disruptions, would prefer an even higher reliability than the Dutch grid currently offers. Others do not require such a high reliability.

Criteria: Costs

Next to the technical requirements, there are also economic criteria set for the energy system. For every business costs are a very important criteria. Energy is a hot topic at the moment, as can be seen in the laws and regulations regarding emissions and sustainability/renewable energy goals, and the carbon fuels are becoming increasingly expensive. The industries want to minimize their energy costs, this is especially true for the energy-intensive industries where energy is a large expense.

Criteria: Safety

Safety is a criteria that is applicable to every aspect of the production process, since glitches and mistakes can have catastrophic consequences on the production side and sometimes even on the social side. Energy supply, transportation, distribution, consumption and all related equipment must be as safe as possible to prevent problems.

Criteria: Autonomy and flexibility

Another criteria for industries is the industries autonomy and flexibility. They require the possibility to change production, and thus demand, based on the industries' needs. The industries attach great importance to their autonomy, to make own decisions, based on their needs.

Criteria: Sustainability

Sustainability is a criteria which is up and coming, butis not yet as vested in the industries as the the other criteria are. When investing in sustainability industries try to follow the trend in which both companies and consumers are increasingly required to become socially responsible. Furthermore, not pursuing sustainability and cleaner production can in the long run damage image and increase production costs due to regulations.

3.5.2. First perceptions Dutch energy managers

Based on the interviews, several considerations with regard to the industrial Microgrid can be discussed. The early perceptions of the respondents are skeptical about the innovative system, however, they are not yet supported by a lot of factual knowledge. It stood out that many of the considerations of the industries tally with each other. The following main considerations can be concluded.

Investing in the industrial Microgrid from an industrial perspective

Every industrial respondent discussed the fact that the departments they work for must fight for their budget to make new investments. Investments are reviewed according to several criteria. Thus not only increased revenues or taken into account consequences to people, e.g. their employers or residents in the neighborhood, assets, environment and their reputation. They see the Microgrid rather as an improvement, but not necessarily since the current architecture of the energy system is satisfactory. If they want to invest, they would probably first invest in upgrading the current system. Furthermore, it should also be noted that often a payback period of only one to three years is expected. Some industrial respondents let out that in the current economic crisis the payback period is more often one years rather than 3. On the other hand, other industries also mentioned that investments in more efficient equipment could have a payback period of a maximum of five years. Another consideration with regard to the investments are laws and regulations. Thus next to their own criteria and the wielded payback period, developments in laws and regulations help prioritize where investments should go.

Investing in the industrial Microgrid from an non-industrial perspective

The industrial Microgrid is a systematic innovation. For the system to be implemented different parties need to cooperate and for every one of them there should be an advantage. At this point several (non-industrial) actors are looking for opportunities in the line of Smart Grids and Microgrids within industries. These actors encounter several difficulties, e.g. regulatory issues with regarding infrastructures and third party access[11]. One of the most important difficulties is that it is unknown whether or not industries are open to these type of innovations. A certain amount of commitment is required of the industries before further developments with non-industrial actors will take place.

The value proposition of Microgrid over Smart Grid

In the interviews it became apparent that both the industrial respondents as the non-industrial respondents had great skepticisms towards the industrial Microgrid. They acknowledged most of the value propositions mentioned in this chapter, but seemed to have doubts about their validity applied in the Netherlands. For example, reliability and power quality are two of the main distinguished value propositions of the Microgrid, otherwise a "normal" Smart Grid configuration would suffice. Both groups stated that the Dutch industrial grid is already very reliable (low and medium voltage networks are less reliable than the high voltage transmission lines according to the industries) and quality is ensured in the national codes for energy. Thus the island model function is not necessarily considered added value. Furthermore especially the industrial respondents do not see a role for DER in the industry, due to the fact that they believe that the capacity potential of DER is not sufficient for the energy-intensive industries. The focus for industrial Microgrids may therefor lie with smaller industries for which DER are a possibility. The industrial respondents are furthermore reluctant to offer flexibility, due to the fact that they all have continuous processes. From the non-industrial perspective it can be concluded that more than half of them believe that the industries are far advanced in increasing efficiencies since it directly links to cost reductions. This does not entail that

[11] Third party access policies requires network operators to provide others access to the infrastructure. Thus for example, if a certain plant decides to take another supplier for energy, the owner should provide the access so this can happen.

the infrastructures are intelligent, but that the infrastructure is organized rather well due to the fact that the complexity from the Macrogrid and the internal processes make the plants susceptible for major risks.

Knowledge retainment in complex systems

An important aspect for some of the industrial respondents is the knowledge aspect of the industrial Microgrid. They relate automation and cooperation to complexity. As a result they weigh up the increased complexity to extra investments in gathering and retaining all knowledge. If the systems are too complex it would become harder to retain the required knowledge. If they would outsource it, a consideration is the investment and dependencies in hiring other companies.

Allaying energy on non – core business activities

Another important consideration is the potential to allay the industries from their energy activities. Energy management is not part of the core business of the industries. They are very keen on outsourcing these activities so that they are able to focus solely on their core activities. This could therefore be a very important aspect of the industrial Microgrid to pursue.

Institutions not yet in place for Smart Grids

The industrial Microgrid, or the Microgrid in general, has not been regarded as a system which is currently of interest due to the fact that the value proposition is not perceived as positive. What is of interest is the Smart Grid. However, in the Netherlands there are still many institutional barriers for a large scale diffusion of the Smart Grid. A large barrier at the moment seems to be the fact that the current market model of the current system, which is explained previously, only focuses on kWh sold and there is little price differences. These form a barrier for flexibility, since currently it is not rewarded to offer flexible energy profiles. Other barriers like the third party access policies and administrative hassles due to the national energy codes make even the diffusion of Smart Grids difficult. Since the Microgrid is an application, further advanced type of Smart Grids, it seems that these issues should be addressed first or at least parallel to the development of the Microgrid before different actors would consider the industrial Microgrid.

Synergy and flexibility

Most of the non-industrial respondents believe that synergy and flexibility are the way to go in an industrial Microgrid, since this would maximize the efficiency possibilities. The industrial respondents however were reluctant. According to them both cooperation and synergy is undesirable, since it creates undesired risks related to disruptions in the reliability and supply of energy. A less extensive form of cooperation would be more desirable, since the extent of the dependency is not as great. Next to that, flexibility in demand, a characteristic of Smart Grids and Microgrids, would be difficult to execute, according to the industries. It should be noted though that all industries believed that their plant would not be suitable, but other types of industries would be. It should be noted that the industrial respondents were large, energy-intensive, high risk industries. This consideration is therefore very colored, since the arguments of the industrial respondents were valid for their type of industries. It may however be concluded that these large industries may not be the focus industries for the industrial Microgrid.

Loss of autonomy and increase dependency (technological and social)

A last important consideration is the loss of autonomy and the increase in dependencies, both on a technical and on a social level, by cooperation in a Microgrid. As said previously, autonomy is important to a company so that 1) they do not have to rely on third parties to run their production processes and 2) they do not increase risks by mistakes of others in the system. This loss of autonomy however is inherent to the development of the industrial Microgrid. One overall management should operate and maintain the grid. And this party requires stability and security that the industries stay committed. This is a trade-off in which a balance should be found. Contracts are the means, according to the respondents, to take away some of the reservations. Both the technical (operational) requirements of the parties and the social requirements should be covered.

It should be noted that during the interviews there was a tendency of the respondents to be convinced of the robustness of the industrial system as they know it. The respondents were reluctant to believe that this new concept could be implemented in the Dutch industry. An explanation is that over the years not a lot has changed in the supply and infrastructure of the plants and the plants are believed to be efficient and robust. However, mainly the non-industrial respondents believe that there could be a change due to possible developments in the regulation area (stricter regulations, ETS working) and the energy system (decreased reliability)

3.6. Configuration

Due to the multitude of technical and social elements present in the industrial Microgrid, there is also a limitless number of possible configurations. However, throughout the literature many variables are identified that are present in the Microgrid. A handful of these variables is identified which are already shaped by the collected knowledge at this point as a part of the basic configuration. It is on a rather high abstract level due to the exploratory nature of the research.

Energy system

Both the non-industrial and industrial respondents think that an industrial Microgrid which incorporates only electricity is not attractive. The first group believes this because an important advantage is the increased efficiency of incorporating gas, heat and electricity. The latter believe this because in their processes different utilities work together, they should not be regarded separately. Therefor the industrial Microgrid will probably incorporate the three energy flows in an intelligent and flexible manner.

Components

For every component different technologies are available. With regards to the configuration of the industrial Microgrid, it can only be concluded that it is highly probable that the generation is some sort of gas-fired CHP production unit. These are installed plural in the Dutch industry and they produce both electricity and heat from natural gas.

Ownership of components

During the interviews it became apparent that not one single industry or non-industrial actor would bear the (financial) risk of exploiting the collective components of such an Microgrid. According to the respondents it is most likely that either objective, third parties should build and exploit the components that have those business activities as their core activities, or a form of a joint venture of the largest industry or all industries should collectively take on the responsibility of the components.

Actors

As stated earlier, the (industrial) Microgrid is not just an innovative technology, but also an innovative socio-technical system With regard to actors there are several parties active in the grid. First of all there are the consumers, the industries, that are clustered in the industrial Microgrid. Furthermore, based on the notion that allayment is an important aspect for industrial Microgrids, it is highly probable that some sort of new party, service providers or network operators, will ensure that the industries will not be bothered with the operation and maintenance of the energy flows through the Microgrid. This concept is not common or well-known in the Netherlands according to one of the non-industrial respondents. However in England they are already working with independent service providers, or network operators, that operate and maintain the grid through service concepts. Another group of actors that is of importance is the DSOs. The energy system is very complex and close cooperation between the Microgrid and Macrogrid should take place for smooth operations on both sides.

Industries

The industrial respondents made a point of identifying the ideal type of industry for an industrial Microgrid. Some are contradictory. The industries would have the following characteristics:

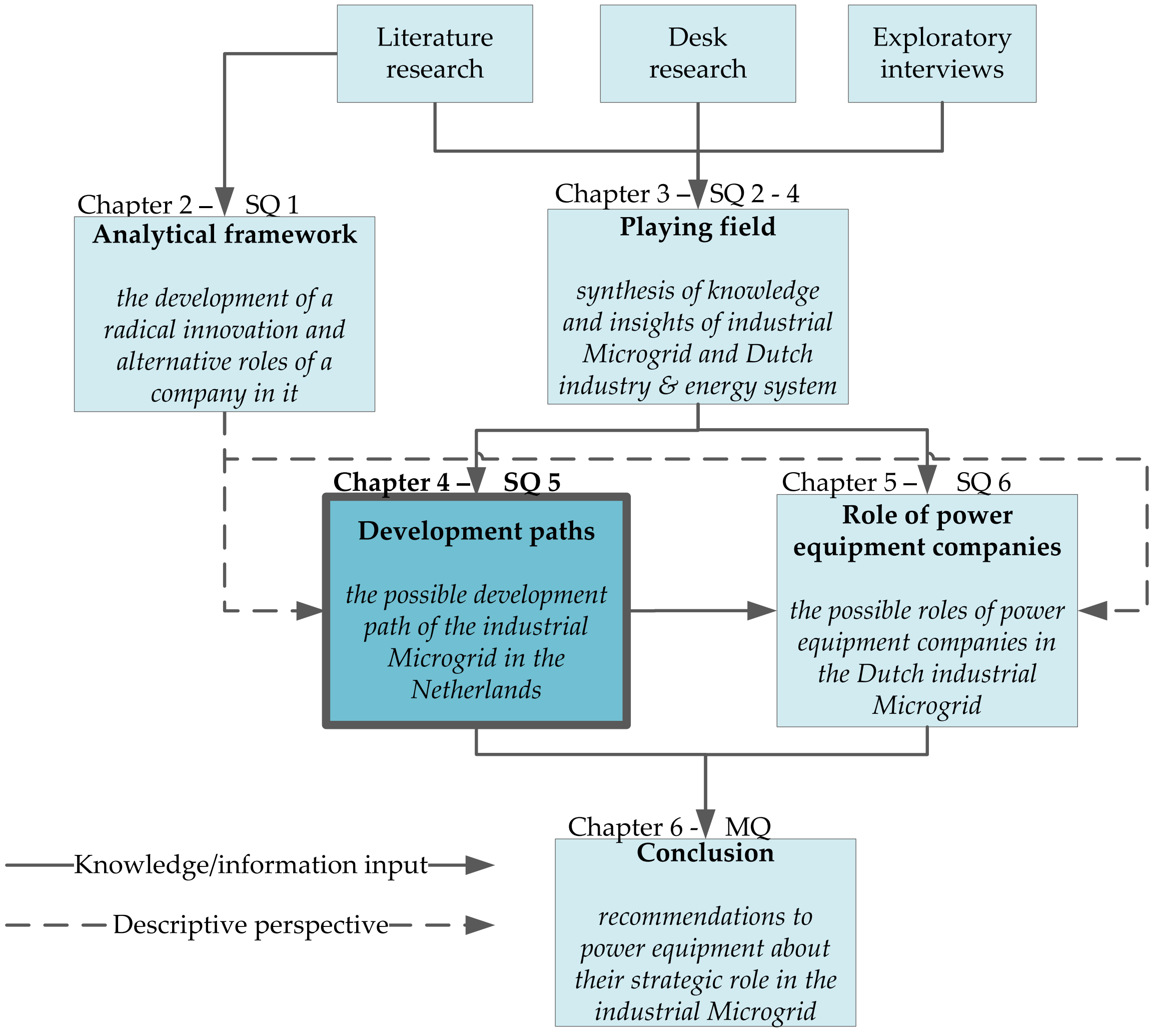
- Loss of energy would not have social and technical catastrophic consequences, meaning that restarting the production could be done immediately when the supply is up again and the environment does not suffer from explosions or other emissions
- Criteria of energy should be high availability and reliability, otherwise the benefits of the industrial Microgrid would be none-existent

It is most likely that the large energy-intensive industries, which have been interviewed for this research, are not the focus industries. Rather the smaller industries, whose energy costs are high, require a high reliability but whose production risks are not as high when something goes wrong, may have a higher interest and willingness to work together in such a system. Furthermore, within a Microgrid one should look for complementary energy profiles so that the highest efficiencies can be achieved.

3.7. Conclusion

In this chapter three sub-questions of this are answered. The first one, "*What is the current state-of-the-art research regarding industrial Microgrids?*", was answered with an elaborate body of evidence from literature. As always with technology innovations in an early state, literature gives more insight in the technology development than in the social dimension. The second sub-question, "*How are the Dutch energy and industry system organized?*", was answered with a view on the classical grid in the Netherlands and its main actors. The third sub-question, "*What are the opinions and perceptions on the industrial Microgrid in the Netherlands?*" was answered with a synthesis of early views from the Dutch operational energy managers interviewed during our research.

CHAPTER 4: THE DEVELOPMENT PATHS



In this chapter sub-question 5 is answered:
How might the industrial Microgrid develop in the Dutch industry?

4. The development paths

The purpose of this chapter is to create an overview of the current development stage of the industrial Microgrid, which are different scenarios that deal with the development of the system. By analyzing 1) the innovation system of the industrial Microgrid, 2) the attributes of the innovation and 3) the environment of the innovation as is prescribed in Chapter 2, an understanding is created of the key characteristics of those three elements. The goal is to identify the most important influential variables on the development. A set of external and internal factors can be derived that can either encourage or hinder the successful development of the industrial Microgrid in the Netherlands. These are consolidated into four main factors, which in turn lead to four development paths.

The structure of this chapter is as follows. In 4.1 the innovation system of the Dutch industrial Microgrid (the TIS) is evaluated by analyzing the FIS. The subsequent section analyzes how the Dutch industrial Microgrid is perceived by potential adopters (4.2). The third section focuses on the environment of the innovation (4.3). In section 4.4 an overview is given of the current development stage. Thereafter four development paths are determined based on the four main factors that influence the development (**Fout! Verwijzingsbron niet gevonden.**). The chapter concludes with a short summary (4.6).

4.1. The Technical Innovation System

The innovation system in this research is the network of agents interacting in the industrial Microgrid area in the Netherlands under a particular institutional infrastructure to generate, diffuse, and utilize the system. The successful development of the Dutch industrial Microgrid can be achieved by the ability to be innovative, to exploit knowledge flows and to actively recombine knowledge in order to create new business opportunities. Different activities induce the development. In the literature a set of seven activities, or seven FIS, is identified that enhance the innovation's development. The innovation system is analyzed to create insights in how and to what extent these seven FIS are present. This is an indication of the current development stage of the innovative system. Furthermore it may give a direction of what activities are relevant to focus on when further developing the Dutch industrial Microgrid.

For every FIS a short summary of what the function is and what indicators can measure the FIS are identified. Then the present activities in the Netherlands regarding industrial Microgrids are presented. Subsequently an analysis is made of how these activities compare to the theoretical intention of the FIS and how it may be improved. It is followed by a conclusion.

4.1.1. Entrepreneurial activities

The entrepreneurial activities cover projects aimed of proving the usefulness of the emerging technology in a practical and/or commercial environment. According to the literature entrepreneurial activities are necessary to overcome the fundamental uncertainties associated with the early developments of an innovation. It is one of the most essential activities in an innovation process. In this research two types of entrepreneurial activities have been identified: 1) commercial projects that were started and stopped and 2) diversification of established firms.

For as far publicly known, no live industrial Microgrids projects are running in the Netherlands. There is furthermore no knowledge of commercial projects in the making. There are however two commercial showcases that show the potential usefulness of the concepts behind the system: synergy, flexibility and the integration of energy infrastructures within the industry. The showcases are the

Chemiepark in Delfzijl and Chemelot in Geleen[12]. Both showcases are industrial parks that energetically connect large chemical industries. The two sites are organized differently and are initiated by the industries themselves. The Chemelot industrial park is not a Microgrid, since it cannot run in island mode. Furthermore, it is not "smart"; it does not provide flexibility, even though it could, because the industries claim to have no flexibility potential. The Chemiepark can be considered a Microgrid though; the location can run in island mode, even though it rarely happens, and some industries have the option to run flexible depending on the energy prices. These two showcases are not considered commercial projects since the cooperation stems from the fact that in the past the different plants belonged to one industry only. Their cooperation was therefore not a conscious project, it is rather a result from evolution. Even though the cooperation is not cannot really be considered entrepreneurial activity, it is commercial proof that the concept of cooperation, allaying and the industrial Microgrid, can work. It shows that both the economics and technical and social system can successfully be organized on industrial sites.

The second activity is found in the diversification of the strategy of relevant actors in the energy grid and the entrance of new suppliers. As became apparent in the interviews and thourgh the webpages of potential suppliers (Capgemini, 2013; DNV Kema, 2012; Lockheed Martin, 2013; Siemens Energy Sector, 2012), several actors, e.g. Cofeley, Alliander, Cap Gemini and Siemens, identified the development of the Microgrid and are preparing or are already expanding their products and services portfolio to include Microgrid solutions. Furthermore, according to Agentschap NL new entrants are increasingly coming up in the development of Smart Grids and Microgrids. Thus eventhough projects have not yet started commercially, different actors prepare for the possible introduction of the Microgrid. It is unclear however, if this is because of positive international developments as have been discussed in the previous chapter, or because these entrepreneurs see potential for the system in the Netherlands.

Findings

According to the literature entrepreneurial activities are necessary to overcome the fundamental uncertainties associated with the early developments of an innovation. Currently the only entrepreneurial activities are the diversification of incumbent actors, the technology and service providers of (smart) energy infrastructures, and the entrance of new players. No commercial projects are currently live. With regard to the future, no signs of new projects have come up. Due to the fact that these projects often involve several actors, e.g. industries, suppliers, investors, and time that it takes to set up the project, it can be concluded that in the near future there probably will not be any commercial projects of the industrial Microgrid in the Netherlands.

The diversification by the actors should eventually lead to actual projects However the commitment of different actors is required for commercial projects due to the system nature of the industrial Microgrid. During the interviews it became apparent that there likely will not be sufficient commitment since the stakeholders lack knowledge of the system and, when discussing the system, they appeared rather hesitant of its potential. The reasons of this hesitation cannot be derived from this analysis. Without the commitment of industries, commercial projects will have a little chance to come through.

4.1.2.Knowledge development

Learning is identified in the literature as an important aspect in the development of an innovation. The FIS "knowledge development" focuses on learning activities: learning-by-searching (assessment research with no direct commercial orientation) and learning-by-doing (practical research with no direct commercial orientation). Over the last decade the Microgrid is increasingly becoming a subject

[12] From both industrial parks someone cooperated with the interviews, thereby creating in-depth knowledge of the organization of the cooperations.

of knowledge development internationally due to its potential for controlling large amounts of DER and for increasing the reliability of energy supply. In the Netherlands several knowledge development activities have also been taken place. This shows in the execution of various assessment and practical R&D projects.

The prevalent R&D project in the Netherlands is Microgrid Bronsbergen, which is implemented in vacation park Bronsbergen in Zutphen (the Netherlands). This R&D project is financed by the Dutch DSO Alliander and EU-subsidies. In the project the technical elements of starting and transitioning a Microgrid and its connection to the main grid have been tested (Agentschap NL, 2011). This project is part of the "More Microgrids Project" of the EU, which executes five other technical R&D projects for Microgrids in European countries.

Second, a project started in the Netherlands is the ModiNet project. This R&D project focuses on energy efficiency and synergy between industries, but not on Microgrid perse. ModiNet is one of the 12 pilot projects supported by the Dutch governmental innovation program Intelligent Grids (IPIN) whose aim it is to accelerate the introduction of intelligent grids (Agentschap NL, 2013). The project's aim is to make an "intelligent, local medium voltage level network and a thermal network with modular structure on a new business park in Deventer" (Agentschap NL, 2012). It focuses thereby on the social aspects of the energy system and the synergy between the energy flows. It has only just started and minor complications have arisen due to the fact that it is difficult to attract business or industries to the park in this difficult economic environment.

As for the non-practical research, different actors concentrate on knowledge development by learning-by-searching. Several technical universities (TU Delft, TU Eindhoven), colleges (Hogeschool Zuyd (Gerards & Schijns, 2009)) and companies (Siemens, Enexis, Royal HaskoningDHV) in the Netherlands are doing research on Microgrids, either through PhD students or grad students. Some of these researches concentrate on the technical aspects of the Microgrid, while some concentrate on the social aspects. These activities became known during the process of this research and are few. It could be possible that more learning-by-searching activities are not accessible to the main public. However, the interviews are conducted within the community that is actively working on DER, Smart Grids, industries and related subjects. These interviews did not reveal any other activities of such sort, so it may concluded that these activities are more rare than common.

Findings

In the literature knowledge development, an aspect of learning, is considered an activity which is at the heart of any innovation process. As can be seen in the activities discussed above, contributions to knowledge development regarding the industrial Microgrid is feeble in the Netherlands There are not many actors working on the development of knowledge, which means there is only a small knowledge base in the Netherlands. The knowledge development activities that have been discussed are mainly focused on the technical aspects of the Microgrid, rather than on the social or economic side. This trend can also be seen in international R&D projects. This is logical, because the innovation came into being because of technical developments and its main theoretical advantage is increased power quality and reliability (see previous chapter). Furthermore, developing knowledge about the technical system is easier than developing knowledge about the social system the latter depends on the location. The institutions in place and the actors that are involved. It changes with every separate application. However, the technical aspects are figured out and according to the DSOs Alliander and Stedin, technically everything should be possible. The problem will more often be the social system, as is emphasized by both industrial and non-industrial respondents in the interviews; how should the system be organized? How can all the involved actors be satisfied? Many interests play a part in the industrial Microgrid and everything should be managed. Thus next to the fact that there should be more knowledge development, assessment and practical research should also focus more on the social system of the industrial Microgrid.

After analyzing the activities, it can also be remarked that only a couple of actors are active in knowledge development. As is observed in the previous FIS, the industrial Microgrid is a system rather than a standalone technology. For the creation of such a system the commitment and involvement of other actors is required. The most important being industries, since they are the customers of the system. As can be seen in the activities, there are no industries working on knowledge development at the moment. It should be noted however that knowledge development is only possible, if industries are aware of the existence of the innovative system since it requires the cooperation of industries. In the interviews it became apparent that many of them do not know the existence. Only 2 out 12 had a slight idea of what the system is.

4.1.3. Knowledge diffusion

Activities related to knowledge diffusion involve the partnerships of heterogeneous actors, R&D departments, government, competitors and market, in the TIS. It is the essential function of networks. Knowledge transfer and the accessibility of resources are the focus of this FIS. Suggested indicators for knowledge diffusion are the number of workshops, conferences and research collaborations devoted to a specific technology.

Internationally various workshops and conferences have been and are organized with regard to Microgrids. However in the Netherlands, these types of activities are seemingly not taking place. This is confirmed while conducting the interviews. I During the interviews it became apparent that there is a only small network of actors that works on the development of intelligent grids; they work together and are in contact with each other. Their main focus is the development of the Smart Grids in the Netherlands, and not the Microgrid since this is considered by them as a step further in the development of the Smart Grid. The attention and efforts of knowledge diffusion activities therefor goes to Smart Grids. This is happening on a larger scale according to the desk research. Smaller networks do come up when different actors work together on projects like ModiNet (discussed in the FIS "knowledge development"), however since these projects do not occur often or on a large scale, the network will not grow. The only larger network actively working on knowledge diffusion is the European More Microgrid project, which is responsible for the Bronsbergen Microgrid project. However this is a European oriented network, and no diffusion activities in the Netherlands have been registered as a result of this network.

Findings

In the theory it is stated that knowledge diffusion is done by networks of heterogeneous actors that transfer knowledge and access each other's resources. After analyzing the innovation system, it is found that currently there has not formed a real network around the industrial Microgrid. As a logical result, no knowledge is yet transferred through the networks. This is supported by the knowledge that ten of the twelve industrial respondents had no prior knowledge of industrial Microgrid before the interview. The activities and networks will most likely grow naturally when there is more knowledge present to transfer and more (commercial) projects to link actors. Thus first activities focuses on the entrepreneurial and knowledge development level should emerge, before networks can be build up to diffuse knowledge.

4.1.4. Guidance to the search

Since resources are often limited in the development of an innovation, it is often important that specific focus points are chosen for further investments. Guidance for the focus points is given by the expectations concerning the performance of the innovation and how it contributes to solving problems. Activities that shape the needs, requirements and expectations of actors with respect to their (further) support of the emerging innovation should be present in an innovation system. Possible indicators are belief in growth potential of the market and articles in professional journals that raise expectations about new technological developments.

As was the case with the previous FIS, internationally there are many journals and institutions that raise expectations about and proclaim the success of the (industrial) Microgrid; positive market forecasts and the theoretical value propositions are given (see previous chapter). Both industrial and non-industrial actors are skeptical towards the benefits of the innovation (**Fout! Verwijzingsbron niet gevonden.**). In the case of the Netherlands, the most important advantages are most likely new business opportunities for product or service suppliers, financial benefits through energy efficiencies and smart deployment of production processes and allaying non-core business activities for industries at best. This conclusion is not based on pilots or projects tried in the Dutch industry. It is rather derived from the practical and deductive argumentation line of the respondents during the interviews. A catch-22 can be seen here; especially for the industries there does not seem to be a sense of urgency to adopt this innovation. The current system is satisfactory and the theoretical benefits are argumentatively taken out of the equation. As a result there is no incentive for these industries to start up pilots or projects. However, these pilots and projects should be done to create proof of concepts, thereby finding prototypes of the system so that for every party in the industrial Microgrid the question "what is in it for you?" can be answered. Companies like Cofely, Royal HaskoningDHV and Port of Rotterdam are interested in finding out what the benefits could be. Unfortunately, the participation of industries is required. Policymakers, especially the government, could have an important influencing opinion with regards to supporting the innovative system. Their opinion can be decisive for other parties. In the interview with Agentschap NL, a part of the Ministry of Economic Affairs, it became apparent that the concepts of energy efficiency, DER, sustainability behind the industrial Microgrid are desirable. They advocate this, but not specifically for the Microgrid; every type of intelligent grid solutions is just as welcome and they will not support one specific system configuration. Furthermore, they do not make a case of focusing on industries. The focus is rather on household levels.

Findings

In the theory it is written that activities for the guidance of the search can be either positive or negative. Positive will lead to a particular direction of the innovation's development, while negative will lead to a digression or rejection of the development all together. At this point t can be stated that the Guidance of Search has a negative impact on the development of the industrial Microgrid. Regardless of the fact that the industrial Microgrid is (somewhat) in line with the support of the Dutch government towards intelligent grids, the potential benefits do not create a sense of urgency for all involved actors to create positive support for the innovative system. Furthermore this is not likely to change if the potential benefits are not proven. The lack of knowledge and support of industries are seem to be the main obstacle for going towards a positive support feeling in the innovation system. Other beneficiaries of the innovation need the investment and cooperation of the industries to set up pilots and projects as to proof the benefits.

At this point it does not mean that the industrial Microgrid does not have a chance to develop, it is only an indication that it is still very new or that the current conditions are not right to create willingness. However, if this does not change over time, the development of the Microgrid will either digress or rejected by the actors in the innovation process all together.

4.1.5.Market formation

Incumbent systems compete with the new innovative system, making it difficult to break through. The innovative system is relatively crude and inefficient, offering only very small advantages or perhaps none at all, over previously existing innovations. Niche markets should therefore be created to facilitate learning processes. Market formation activities contribute to the creation of these niche markets, thereby creating a demand for emerging technologies or systems. This is often fulfilled by the government or firms. Possible indicators of this FIS are use of innovation by the government, marketing efforts from forms or governments and specific tax regimes.

In the "entrepreneurial activities"-analysis it became clear that even though commercial companies are preparing their product and services portfolio for the introduction and implementation of the Microgrid, in the interviews and desk research it is found that no market has been established for the Microgrid in the Netherlands. The formation of a market for industrial Microgrids is at this point largely dependent on the willingness of industries to adopt the system for their energy flows. For a market to form, the involvement of industries is required. However it already became clear that the industries do not have the knowledge of the Microgrid and are not triggered to invest in or become involved in a pilot or project based on the theoretical benefits of the system.

Service and product companies have, as can be found in the desk research and interviews, not yet approached Dutch industries that are open to adopt the innovative system early on in the development. In the TIS the only activity for creating demand for the industrial Microgrid is the governments intelligent grids projects innovation program "IPIN". This program makes it possible for companies to set up pilots and projects with regards to intelligent grids with support of the government and gives the option to circumvent hindering laws and regulations in its creation. However, this program is focused on 1) intelligent grids in general and not specifically on Microgrids and 2) on all possible applications. Since many applications are on the household level and focus on Smart Grids, this makes it not a very affective program for the creation of a niche market for specifically industrial Microgrids.

Findings
Market formation is difficult for innovations, thus specific activities by often the government or maybe interested firms are required to create a niche market. However, in the Netherlands no market has formed yet since there is little governmental activity and firms require the cooperation of industries first to create the innovation. Commercial activities will not take place if there exists no market.

4.1.6.Resource mobilization

For the development of an innovation, resources are required as a basic input to all activities within the innovation system. This FIS refers to the allocation of financial, material and human capital. These are typically investments and subsidies. Possible indicators are whether or not inner core actors perceive access to sufficient resources as problematic and financial lending or specialized credit.

Regarding this function, not a lot of insights have been created during this research. Public information could not be found on the mobilization of resources within companies, and the interviews did not go into depth on this subject. It can be noted that according to Royal HaskoningDHV it is difficult to start mobilizing resources if there is no commitment of industries. The cooperation of industries, thereby meaning at a minimum the insights in their energy characteristics, is needed to execute feasibility studies of the system covering the technical, social and economic benefits of a potential project. Furthermore, these feasibility studies costs money and time, which would need be covered partly by the industries.

Findings
It is unknown whether or not resource mobilization takes place. It can be noted though that according to the literature resources are required as a basic input for all activities within the innovation system. Since there can only be little activities identified in this innovation system, it can be deduced that currently no resources are really dedicated to these activities. Derived from the statement of Royal

HaskoningDHV an initiator is needed to get the process going; the service and product suppliers are waiting for the commitment of industries, while there seems to be no interest from the industrial site. This results in an apparent deadlock for the development of the industrial Microgrid in the Netherlands.

4.1.7. Support from advocacy

Activities regarding support from advocacy counteract the inertia of actors in the incumbent technology system. These are often political lobbies and advice activities on behalf of interest groups. Possible indicators are: support by the government, the rise and growth of interest groups.

During the interviews and desk research it became clear, and as is previously mentioned, that there is a large lack of knowledge on several levels regarding the industrial Microgrids, e.g. existence, possible advantages. Not many people are familiar with this innovative system and those that do are unsure of its potential in the Netherlands. As a result no actors can be found that counteract the inertia of actors in the current energy system.

Findings

In the early development much resistance can be experienced of the existing technology system. According to the theory activities are required to counteract this resistance. However, in the Netherlands there are no counteracting activities. Thus, if there are negative actions, which currently have not been witnessed, they are not counteracted. This could have negative implications to the development, since attacks of incumbent technologies will not be counteracted. The lack of activities in this FIS is mostly related to the fact that there are not many actors involved in the innovation system at this moment and proof of its potential is not known to any of the actors. Thus first the focus should be on other activities before the support from advocacy coalitions can take place.

4.1.8. Synthesis technical innovation system

The seven activities present in the discussed innovation system induce the development of the industrial Microgrid. These seven FIS are needed so that the innovation can develop en diffuse into mainstream. By analyzing these FIS, insights have been created in the actors, institutions and technological factors that interact in the innovation system. Overall this analysis has given insight in the current development stage, what issues are and what focus points are for improving the innovation system.

The development of the Dutch industrial Microgrid is still in an early stage. While analyzing the seven activities, it became apparent that the innovation system only consists of a small element base. This entails that there are not many actors, institutions and technological factors in place that work together to generate, introduce and diffuse the innovative system. There is little governmental support. It is more likely that the development of the innovation should come from the commercial side. Service and technology providers are mostly active with the inducement of the innovative system, but the involvement and commitment of industries are lacking. Due to the fact that this is an innovative system, all parties should be on board for its development to successfully take off. As a result the activity level of each FIS is very low, if existent at all. The activities that can be identified are attuned to small networks or individual diversification. At this moment it seems like a waiting game, a stand-still of the activities and thus also of the development.

At this point various issues have been identified with regard to the innovation system of the industrial Microgrid. First of all, the overall knowledge level of the actors in the industrial Microgrid is low. The actors are unfamiliar with the innovative system, what it entails and how it operates. Only a few non-industrial actors know of the innovative system, but they don't diffuse this knowledge. Focus seems to be on Smart Grids and skepticism exists towards its value proposition. Commercial and R&D projects are important for further development. However, the crux in this innovation system is that projects and pilots do not take place in the R&D departments of one company. This is the second issue. It requires the involvement of several actors. In this system, one of the most important actors are the industries that consume the energy, but they do not seem open or willing to actively commit to the industrial Microgrid. There does not seem to be a sense of urgency to do so. Without the commitment and involvement of these industries, there is no possibility to develop knowledge and it makes other non-industrial actors reluctant to really focus on the development of the industrial Microgrid.

The lack of knowledge (existence and potential) of the innovation and the non-involvement of industries can be mitigated by a variety of possible actions, each having their own impact. However, based on the previous analysis it is concluded that the main focus should be on developing knowledge, regarding the application of Microgrids in industries and the social implications and configurations of the system in the Netherlands. Houses of concepts can then be designed and proof of its existence. Furthermore, the value proposition should be tested and proven as to show all required and interested parties to present the added value for each of them. This can be done in the Netherlands, but it could also be done outside of the Netherlands.

4.2. The 5 attributes of Rogers

The 5 attributes of Rogers are five characteristics of an innovation that can indicate it potential success for diffusing into the main stream. The better it is perceived on those 5 attributes the faster it will be adopted. These attributes are analyzed so that insights are created in the current perceived attractiveness of the industrial Microgrid and in the reasons why.

Every attribute is analyzed separately in the subsequent sections. The important variables in influencing the adoption and possible actions to improve the perception are identified, thereby creating new input for the development paths. It should be noted that since the industrial Microgrid is a system, the perceptions of different actors are taken into account while discussing the attributes.

4.2.1.Relative advantage

The relative advantage of Rogers entails to what extent an innovation is perceived as being better than the idea it superseded. There are different types of advantages, e.g. economic profitability, social prestige. Depending on the actor and nature of the innovation different advantages are considered important. During the interviews, the innovative system and its potential advantages (over the current centralized system) have been discussed. Here the aspects which give the industrial Microgrid a positive edge are discussed.

Energy efficiency through co-generation and cooperation/synergy
According to both groups of respondents the amount of fuels needed for the processes can be reduced through co-generation (generating steam and electricity at the same time), synergy (using waste-stream from other plants) and cooperation/synergy (working together to generate heat and steam). The benefit for industries is that it can be economically attractive since it lowers the utility costs and energy costs. Furthermore in a society where sustainability and clean production becomes increasingly important, the decreased and efficient use of energy is a boost for the industry's image. For society and governments increased energy efficiencies will result in a cleaner environment, an improved competitive edge for industries. Lastly for utilities increased efficiencies will lead to decreased overall demand, which in turn leads to less investments needed to increase capacity of the Macrogrid.

Changes in safety and operations through automation

Automation is an important aspect of the control of the industrial Microgrid, needed to smoothly operate and balance the energy flows. Currently automation is not yet implemented in the industries processes according to several non-industrial respondent and which is confirmed by some of the industries themselves.

Through automation insights in energy consumption can be created and less humans are involved in the operations and balancing of the energy flows. Several benefits can be deduced; maintaining and operating the energy system from a central point makes these activities easier and more efficient; understanding is formed in the energy consumption of processes and costs that are related to them; less people are needed for the control of the energy system; origins of and actions to problems are identified faster and easier. However, several negative issues have also been discussed. Questions arise about the sensitivity of the system and the possible consequences if the automation technology does not function as it should. Especially for industries who have a lot to lose with unreliable continuity of business process and energy supply this can be financially or environmentally damaging. A second issue that has been discussed is the increased complexity of operations. This would lead to new investments either in acquiring required knowledge to operate the systems or service contracts and dependencies with service providers. Automation can thus also be seen as a drawback for the industries.

Smart economic deployment of energy usage through flexible demand

In the earlier years industries would trade energy when energy prices on the markets where high and offer flexibility to the TSO as to earn money as a separate business case next to its core business activities. For large industries millions could be earned by it. Furthermore at certain points in time they decided to run operations at times when prices would hit low points. Mainly due to current low energy prices[13], these extra activities are not economically attractive anymore. Despite the current situation, the respondents acknowledge that possible economic benefit can be achieved by offering flexible energy consumption. However, more than half of the industrial respondents are now hesitant. They claim not to have the possibility anymore to be flexible since their process are continuous rather than batch. Next to that they would not do it again since trading energy is not their core business. Postponing production activities is also not as interesting due to the lower prices and extra efforts required. In contrast, two of the industries showed that they could be flexible even though they also work with continuous processes. The non-industrial respondents who have knowledge of the industry support this; they believe that flexibility should be possible, only it would require the willingness of industries to search for these flexibilities.

Allaying of energy activities

As was shortly discussed in the previous chapter and above, industries experience their energy activities as secondary activities; it is not their core business but it is a very important secondary activity. Without their energy systems production processes would not work and unreliable energy supplies could damage the production and its environment. The industrial respondents made clear that one of the main advantages of a system like the industrial Microgrid would be the possibility of not being concerned about the energy flows, thus allaying the industries from their energy activities.

Increase in sustainability through integration of DER

The respondents see that the integration of DER makes it possible to increase the plant's sustainability. According to them technologies fueled by renewable or non-carbon energy sources or relatively clean carbon sources could reduce the amount of harmful emissions, thereby lowering their costs derived from these emissions. Furthermore improving the sustainability could also improve the image of the respective industry. According to the respondents this sustainability aspect is increasingly important.

[13] Currently coal-based power plants are running which provide relatively cheap energy. Low coal prices are the result of the abundance of coal in the U.S.A. since energy demand is filled by shall gas.

Not only consumers, but also more often other business customers require a degree of sustainability from their suppliers. However, not every of the industrial respondents see image as an important benefit to consider yet.

Hesitance towards renewable technology

Even though the industrial respondents see the potential of DER technologies when considering the sustainability and efficiencies, they have their reservations with regard to the practical application of this type of generation in the industry. First of all the amounts of energy consumed by the energy-intensive industries are large. This could not be covered by the installation of solar cells or wind turbines, CHP are needed to cover demand. Second of all, if that would be possible, risks are created since RES are intermittent. This intermittency could endanger the reliability of the Microgrid system. Storage to deal with these intermittencies is not something which has been considered though. Safety risks are furthermore created, according to the respondents, due to the fact that if major incidents occurred with the technology, e.g. exploding cells, ice falling off the … . It would have catastrophic consequences if it would happen in the vicinity of the production processes and materials. The reliability and safety is thus called into question. According to the industrial respondents, only limited alternatives exist for possible generation technologies applicable for in an industrial Microgrid is scarce.

Cooperation and synergy

Cooperation and synergy (a more extensive form of cooperation) are two of the variables previously mentioned which could increase the efficiency of the individual (and the overall) energy system. However, a major drawback is perceived by the industrial respondents. Cooperation and synergy entails committing to other industries and giving up responsibilities. This loss of autonomy is identified as considerable drawback to the industrial Microgrid. Choices cannot independently be made in the best interest of the company, the interests of others should also be regarded. Next to that, choices of others in the system could influence the industries' own system. An industry cannot act on its own, bears the risk of other parties not committing to or handling their responsibilities and can be influenced by others. This position is not desirable for the industries.

However, from the perspective of the service providers in the industrial Microgrid, a level of commitment is required of the linked industries. This commitment indeed results in a loss of autonomy, however it also ensures security for the other industries and service providers and operational continuity. From their perspective it is undesirable that industries can do whatever whenever since it affects operations and the business case behind the Microgrid.

Findings

With regard to the relative advantage, different advantages and disadvantages have been identified. These have been a result of the opinions of the respondents. The opinions are not based on extensive knowledge of the innovative system or proof of the advantages. It is rather based on their deductive and practical reasoning. The two main benefits of the industrial Microgrid are possible financial benefits (cost reduction by increased efficiency and increased revenues by trading of energy), and allaying energy on non-core business activities. However, these advantages are weakened due to the resulting dependencies and increased risks for the industries. Furthermore, industries require initial studies to ensure that these benefits are actually practically viable. They first want to see it, before they can believe it.

4.2.2. Compatibility

The second attribute defined by Rogers touches upon the notion that a technology/system which is compatible with the circumstances into which it will be adopted. The industrial Microgrid's compatibility is established by the extent of discrepancy between the system and how the current industry prefers to arrange its energy system. The industrial Microgrid is based on the notion of a certain level of cooperation (ideally synergy) between elements and the actors behind these elements. They depend on each other.

The current energy system is configured as a system where industries are mainly autonomous and in rare occasions cooperate, as is discussed in the analysis of the current system and is well-grounded by the interviews. Cooperation currently is a big barrier for industries, since they lose their autonomy and increase risks. Furthermore it should be noted that only larger industries have their own DER in the form of a co-gen. Only co-gens are regarded since the industrial respondents indicated that installing PV or wind energy is not realistic in the near future. Thus implementing an industrial Microgrid will require much effort to put all the components in place.

Findings
When comparing the industrial Microgrid against how the Dutch industry is currently organized, it can be said that it is not completely compatible. This is well-grounded by the notion that the Microgrid is a radical innovation with radical system elements, e.g. social configuration, use of EMS, and incumbent system elements, e.g. generation of energy, energetic components, which means that adopting this new innovative technology would entail a completely different socio-technical environment in the energy system. Thus the industrial Microgrid is not perceived as compatible by the actors in the system.

4.2.3.Complexity

Complexity is the degree to which an innovation is perceived as difficult to understand and use. For the industrial Microgrid both the technical and the social system can be considered. With regard to technical complexity the functions of balancing and maintaining quality and reliability is an important aspect in the different modes. According to several non-industrial respondents however the technical issues are complex but solvable.

Furthermore, many R&D researches have been conducted internationally testing different Microgrid (control) designs, thereby increasing the knowledge regarding the technical system. Regardless, due to the fact that industries are unfamiliar with the system they perceive many technical complexities. Many reservations and questions arise regarding the insurance of the quality of the grid, the reliability of the grid due to complexity, the failures of ICT technology, retaining knowledge and operating and maintaining the complex flows of energy in such a system.

The technical complexity was mostly an issue for industrial respondents. Worries and challenges about social complexity however, was an aspect that all respondents, conveyed in the interviews. Social dependency, thus losing autonomy, risks of bankruptcy and considering other interests were issues brought up by almost all respondents. The social system is considered by all even more complex than the technical system.

Findings
Summarizing the industrial Microgrid is considered complex on two levels: the technical and most of all the social. This complexity is the main reason given by the industries to not consider adopting an industrial Microgrid. Inherent to complexity is increased risk of failures, according the respondents. A lot can be won to focus on flattening out this perception or find industries that have less to lose when failures

4.2.4.Trialability

The degree to which an innovation is experimented with on a limited basis is considered trialability. If it is easier to try out the industrial Microgrid, the uncertainties would become lower.

In the case of the interviewed industries it is impossible to try out the Microgrid. These industries (oil companies, chemical industries and metal industries) cannot try out the system since the consequences of something going wrong are too severe on an economic, technological and social level.

Findings
A distinction can be made between industries of whom the consequences of outages are not severe and industries of whom the consequences of outages are severe. In the case of the latter group, they may not test new energetic system. Regardless, it would be very difficult to try out the industrial Microgrid due to the fact that it is an extensive system innovation. It is not a system which is easily tried. Internationally the technical system already underwent several try outs. The main focus of trialability should be on the social aspects of the system.

4.2.5.Observability

The last attribute of Roger's prescribes that the more visible the results of the innovation are to others, the more likely it is for other industries to adopt the innovation.

During the interviews it became clear that industries are hesitant to exchange information. The results of an industrial Microgrid that can be visible to the outside is the improved image. Costs and revenues, an important criteria for any industry, is kept under wraps as to not expose a competitive advantage over others. Furthermore, it remains unknown whether or not the industries are really susceptible for the observability of the innovation. During the interviews it did not appear as if the industries would be interested in the processes of other industries. They focus mainly on their own processes. However this was not discussed explicitly.

Findings
The energy system is a non-core business activity; a process which is necessary and important, but still not a process to which they want to spend a lot of attention to. With regard to observability important conclusions cannot be drawn, since the interviews and desk research did not cover the actual observability and did not give insight to the importance of this attribute.

4.2.6.Synthesis 5 attributes of Rogers

The 5 attributes of Rogers give insight in the speed of an innovation and can provide a reason why adopters are reluctant or positive to adopt the innovation. After analyzing the attributes separately, the insights can be synthesized. The industrial Microgrid cannot be considered a successful innovation based on how it scores on the 5 attributes.

Trialability and observability are not considered attributes that weigh heavily on the decision why the industrial Microgrid could be a success. Since the industrial Microgrid is considered a radical innovation it was expected that it would not be fully compatible with the current system. However through pilots and projects the compatibility can be increased and the different parties can get used to the innovation. The perceptions regarding complexity and relative (dis) advantage it can de commented that the statements were mostly based on little knowledge and are shaped by the conservatism of the large industries. All of them would change if more was known of the innovation. However, it should be remembered that at this point two advantages are considered positive for the industrial Microgrid: allaying and the potential economic benefits.

4.3. The environmental factors

As a last element of development the environmental factors can be considered. According to the theory these are factors that are happening on three levels: 1) other TIS hindering or supporting the development, 2) the socio-technical regime and 3) landscape.

Analyzing these factors gives insight in factors or events that either serve as a barrier, driver or both for the development of an industrial Microgrid. It can thus influence the industrial Microgrids' innovation system and the circumstances around the perceptions. At each level a set of environmental variables can be identified and therefore each level is analyzed separately. First the variables have been identified based on the interviews and desk research, next their influence is analyzed.

4.3.1. Other TIS

In the environment of the TIS, other innovation systems can be present that either complement or compete with the TIS. In the case of the industrial Microgrid several other TIS exist: different DER, the Virtual Power Plant (VPP), storage and most importantly the Smart Grid.

DER

Since the development of the DER is still ongoing, they can also be considered TIS. The adoption of many DER sources, which is likely to happen according to the respondents, does not fit well in the current electricity system. This development will naturally lead to the development of intelligent grids, Smart Grids. One way to control these DER in a Smart Grid is through the Microgrid. The development of DER is thus complementary to the industrial Microgrid IS.

VPP

The second TIS is the VPP. This innovative technology is similar to the Microgrid in the sense that they both connect loads and DER and can be seen as a controllable entity. The only difference is that the VPP is software based and is not geographically limited. Furthermore it cannot go into island mode as the Microgrid does. An important VPP project has started in Texel by TexelEnergie (TexelEnergie, 2013). This TIS can be considered both complementary and competitive. Since the VPP is similar to the Microgrid they can be considered competitive as they fight for the same resources, however they can also be implemented complementary to each other. Furthermore, the introduction of the VPP is also beneficial to the Microgrid. Since the same obstacles can be applied to the VPP, solutions are more easily found if both TIS work on removing existing barriers.

Storage

The third TIS, which should also be taken into account, is storage. Although storage is not an absolute requirement of the industrial Microgrid, it can be an important driver for the adoption of Microgrid. Some sort of storage would be necessary if intermittent sources are incorporated in the Microgrid, however there is still substantial economical and technical uncertainty regarding these technologies. The development of the storage IS is complementary to the industrial Microgrid IS.

Smart Grid

The last TIS, and the most influential, is the Smart Grid. In the interviews it became apparent that both the industrial respondents and the non-industrial respondents have great skepticism towards the Microgrid. These respondents acknowledge most of the theoretical value propositions as discussed in the previous section, but they seem to have doubts about their validity applied in the Netherlands. Also in the analysis of the innovation system, it became apparent that there is little activity in the area of Microgrids going on. This is partly due to the fact that many of them are working on the development of the Smart Grid first. The difference between the industrial Microgrid and the classic grid is bigger than that of the Smart Grid and the classical grid. At this moment the Smart Grid is thus in competition with the industrial Microgrid. However, with the development of the Smart Grid the gap between the new system and the industrial Microgrid becomes smaller. Thereby eventually supporting the development of this innovative system.

Findings
Currently there are several technological innovations, which are also fighting for mainstream diffusion. These are all, in some level, in line with the concepts behind the industrial Microgrid, e.g. sustainability, efficiency. They can be considered competitive since the resources of the involved actors are not unlimited. However, every new positive development within these competitive TIS also help the development of the industrial Microgrid. Thus no real barriers can be identified on this level of the environment.

4.3.2. Socio-technical regimes

The relevant socio-technical regimes for the industrial Microgrid innovation system have a decisive impact on the innovation. Depending on the energy flows incorporated, the industrial Microgrid is interrelated with the electricity, gas and/or heat sector. The socio-technical regimes that influence the production, consumption and technology developments of the industrial Microgrid are mainly the centralized electricity regime and the decentralized heat production regime. The centralized gas regime is not taken into account since its system is not impacted at all by this innovation, as it is the case with electricity and heat. The latter two regimes are considered henceforth.

Centralized electricity regime
As is explained in the section about the playing field both the social and technical supply chain of the electricity system are divided into smaller parts due to the liberalization. While singular DEG do not fit well into the existing technological infrastructure (Markard, 2008), they can more easily be implemented in the Microgrid due to the fact that electrically everything is controlled behind the PCC. Different research projects, both internationally as nationally have proven that a Microgrid can be successfully connected to the Macrogrid.

Technically almost everything is possible (Bongaerts, 2013; Wijgerse, 2013). The crux is however integrating the organizational structures of the Microgrid in the Macrogrid. The institutional arrangements and regulations on the interface between the Micro- and Macrogrid currently are important barriers for the adoption of the Microgrid. The most important are:

- Third party access makes it difficult to provide services;
- Administrative hassles (EAN codes and Responsibles/shippers) discourage change;
- Regulations are more lenient for industries, thus keeping energy prices relatively low;
- The energy market, other than the balance market, lacks compensation for flexibility.

Problems related to the introduction of DERs and infrastructure have already risen in the past. While Currently institutional structures are already becoming weaker, there is still a long way to go. A good initiative is the previously described innovation program of the Dutch government Intelligent Grids, which exempts the program of regulations from the current institutions in order to be executed freely and without barriers.

Decentralized heat production regime
For heat there is no centralized system, since the economical feasibility of transporting heat has only a limited radius. Heat is thus produced locally through CHP or steam production units. In the industry either gas or waste gas flows are used to produce the steam. The industrial Microgrid reinforces this regime. In this system, when heat is incorporated and extensive synergy is pursued, heat is

decentralized produced and interchanged between the different industries. Different technologies are developed, e.g. heat pumps (G. Walker & Cass, 2007) that fit in this regime, thereby thus positively influencing the development of the Microgrid. Thus while the central electricity socio-technical regime mostly creates barriers, the local heat generation regime can be considered a driver.

Findings

There are many institutional barriers to be identified on the socio-technical regime, related to the centralized electricity regime. This however is not peculiar: with (radical) innovations in general incumbent institutions and technologies often resist or are not adapting to the new development. Once the industrial Microgrid spreads around, institutions could be expected to change for the better and become drivers rather than barriers. However, this assumes there will be promotional activities from change agents working on thinking and acting by existing institutions.

4.3.3. Landscape

The landscape, the set of deep structural trends in which the industrial Microgrid is embedded, also influences its adoption and innovation. Based on the interviews and the understanding of the system, two trends are identified: price of energy and the trend towards sustainability.

Price of energy

One of the most important landscape factors is the price of energy. The (global) dynamics related to fossil fuel energy prices influence not only electricity price but also the desirability of CHP technology. Other important energy prices are those for CO_2, oil and coal. Depending on the relative price levels, the energy prices can be considered a driver or a barrier for the system. Therefore it is foremost an important uncertainty. At the moment the gas price is relatively high thanks to low pricing of US coal following the shale gas revolution and the low impact of the ETS prices. Thereby the cheap coal is converted into relatively cheap electricity. This makes CHP, the natural DER for the industrial Microgrid, less attractive.

The opinions on where the energy price will go, differ between all respondents. Some argue that the electricity prices will not rise, due to renewable energy. Others argue that all prices will rise due to the fact that fossil fuel prices will keep increasing. However, all agree that competition of other parts in the world forces cooperation as to reduce costs. The opinions on the development of the gas price, an important fuel for transitioning to a more sustainable industry according the respondents, also vary. Most have no idea when the gas prices will start coming down, while a small set of non- and industrial respondents state that the high prices of gas will stay this way for much more years. The price can thus change over the years, but it is uncertain when the current barrier for the diffusion of the industrial Microgrid will cease to exist.

Trend to sustainability

Another factor in the landscape is the global focus on the environment and the continuity of supply of energy. National and international regulations and agreements are made towards energy efficiency, emission reduction, development and introduction of DER. Especially since the industry consumes a lot of energy, this should act as a driver for the transition to the industrial Microgrid. However, as became apparent in the interviews, these regulations and agreements did not yet have an impact in the industry since reforms in their energy systems are not yet happening. Only if the costs are significant enough will the industries see energy not as an unavoidable cost item, but as something to improve.

Findings

The most important landscape level factor is the price of energy, which can be a driver or a barrier depending on the relative energy prices. It largely depends on the business case behind the industrial

Microgrid. The difficulty is that the prices cannot be predicted thus there will always be uncertainties regarding the economic advantages of the industrial Microgrid.

4.3.4. Synthesis industrial Microgrids' environment

The environment of the industrial Microgrid creates a large barrier for the development. Energy prices are a big pre-condition to materialize or not the potential economic advantages of the system and the current energy system is so robust that reliability is a non-issue with industries. The Smart Grid development is an important TIS, which currently hinders the development of the industrial Microgrid, but over time could reverse into supporting it.

4.4. The current development stage

Before the development paths can be created, the insights of the three analyses are put together to create a complete overview of the development of the Dutch industrial Microgrid.

The development of the Dutch industrial Microgrid is not forthcoming. Within the innovation process very few activities are noticeable that induce diffusion. This entails that there is no driver. The analyses show that this is partly due to the fact that the Dutch industries are not yet involved in the innovation system. The reason for this can be found in the 5 attributes of Rogers. There can be a lot of smaller disadvantages and advantages to this innovative system. The main reason why it does not come off the ground is the fact that the two most important advantages of the Microgrid do not really apply. The reliability of the classical grid is too good, and the economic advantages are for a large part influenced by the environmental factors, energy prices and Dutch policies regarding costs of emissions and energy taxes. Next there are still several roadblocks in the institutional possibility of implementation. To name a few larger ones: the European infrastructural laws make it difficult for service providers on an industrial Microgrid to force commitment on the demand side, because regulations require a permanent freedom of choice. Furthermore the cooperation is out of line with the current, more autonomous way of organizing the energy dimension in the industrial production processes. The industrial Microgrid is perceived as highly complex, mainly on the social level, making it an undesirable system for industries.

4.5. The development paths

In the previous section the innovation system of the Dutch industrial Microgrid is analyzed, next to its perceived characteristics and the environmental factors influencing its development. Every element presents unique insights in the development and inputs for the development path. However, these three elements are intertwined, because they can explain and improve each other. As is explained in Chapter 2, the development path is configured by combining barriers and drivers of the development.

During the analysis of the three elements that are of relevance when regarding the development of the Dutch industrial Microgrid, many different insights have been created. To configure a development path the barriers, drivers and actions are considered. In the analyses conducted, a list of barriers and drivers was identified, each derived from one or different factors. Since this list consists of over 10 barriers or drivers, they cannot easily be transformed into development paths. Thus four overarching clusters have been identified that embody the barriers and drivers that determine the development of the Dutch industrial Microgrid.

Table 5 Four main factors in development Dutch industrial Microgrid

Clusters	Description
Price & regulations	The price and regulations are environmental factors that have a great impact on the (perceived) advantages/disadvantages.
Grid intelligence & DER	Grid intelligence & DER contain the barriers and drivers related to the Smart Grids and DER development.
Knowledge & perceptions	This embodies the barriers and drivers with regard to knowledge and perceptions of the Dutch industrial Microgrid.
Complexity & allaying	Complexity & allaying cover the barriers and drivers that relate to the technical and social complexity of the system.

In the description (Table 5) one can see that the first two clusters are of an environmental nature. These cannot be directly shaped by the business ecosystem active in the Dutch industrial Microgrid. The latter two clusters can be influenced by the business ecosystem, and are filled in according to the scenario they are in.

Based on the two environmental clusters four types of scenarios are made (Figure 17). When both environmental factors evolve negatively, a "Stagnation" scenario for the development of the Dutch industrial Microgrid will be observed. When both evolve positively, a "Pervasive" scenario can be witnessed. In between the extremes two other scenarios may come up: 1) the "Exception" scenario and the 2) "Common" scenario. Whether the in-between scenarios become Exception or Common, will depend on the balance (negative/positive) in each of the two underlying clusters.

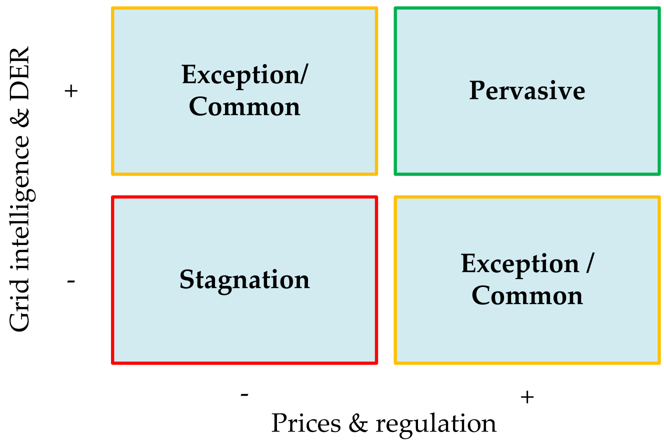


Figure 17 The development paths

4.5.1.Stagnation

In this Stagnation scenario the relative price of electricity generated with gas is not cheaper than the price of other forms of electricity in the Macrogrid. Furthermore regulations are not in place to create an incentive for industries to become more energy efficient, cleaner or more cooperative. The electricity is still generated centrally, and regardless of the share of renewable energy in the centralized grid, maintaining and operating the grid is organized well. Balancing due to intermittency is supported by some kind of flexible back up, or non-intermittent clean energy technology (nuclear) is available.

The industrial Microgrid does not have a lot of room to develop. The current barriers stay in place and no new drivers or changes come up to support the development of the innovative system. It is an extrapolation of the status quo. Changes in the knowledge & perceptions and the complexity & allaying factor are to no avail. A window of opportunity cannot be created in such an environment.

4.5.2. Exception

The "Exception" scenario is somewhat more positive than the previous scenario. Changes arise in the prices & regulations and/or the grid intelligence & DER cluster, however they are not strong and are rather indecisive and a clear picture cannot be drawn. The prices and regulations in combination with smart grid intelligence & DER do not immediately result in the development of the industrial Microgrid in the Netherlands.

Actions to improve knowledge & perceptions and to solve complexities will promote diffusion. Still, regardless of the effort, the diffusion of the industrial Microgrid will take place only at a niche level. There will not be many industrial adopters, and service concepts to counteract the complexity and enhance the allaying are not manifold. A window of opportunity is difficult to create in such an environment.

4.5.3. Common

As is the case with the previous scenario, changes arise in the two environmental factors which result in the development of the Dutch industrial Microgrid. Also in this case, it is difficult to map the environment since it does not really matter which factors changed. The result, which is of interest, is that these changes in the environment give a good pull for the knowledge & perception and the complexity & allaying factors.

In this development path it is assumed that the industrial Microgrid is common practice in the Dutch industry. Actions with regard to knowledge development & perception and service concepts are easier due to the fact that the environmental factors aligned. A window of opportunity thus arises.

4.5.4. Pervasive

In this scenario the environmental factors align so that the industrial Microgrid has room to boom. The economic advantages of the industrial Microgrid are more sure due to the fact that gas prices are lower. Furthermore regulations are in place to create an incentive for industries to become more energy efficient, cleaner or more cooperative. Renewable energy is installed in the centralized grid, and to a large extent DERs have been developed and implemented in the Netherlands and the Dutch industry. The current market model is improved and Smart Grids are implemented overall. However, due to the integration of DER and decreased reliability in the grid, Microgrids are considered the solution.

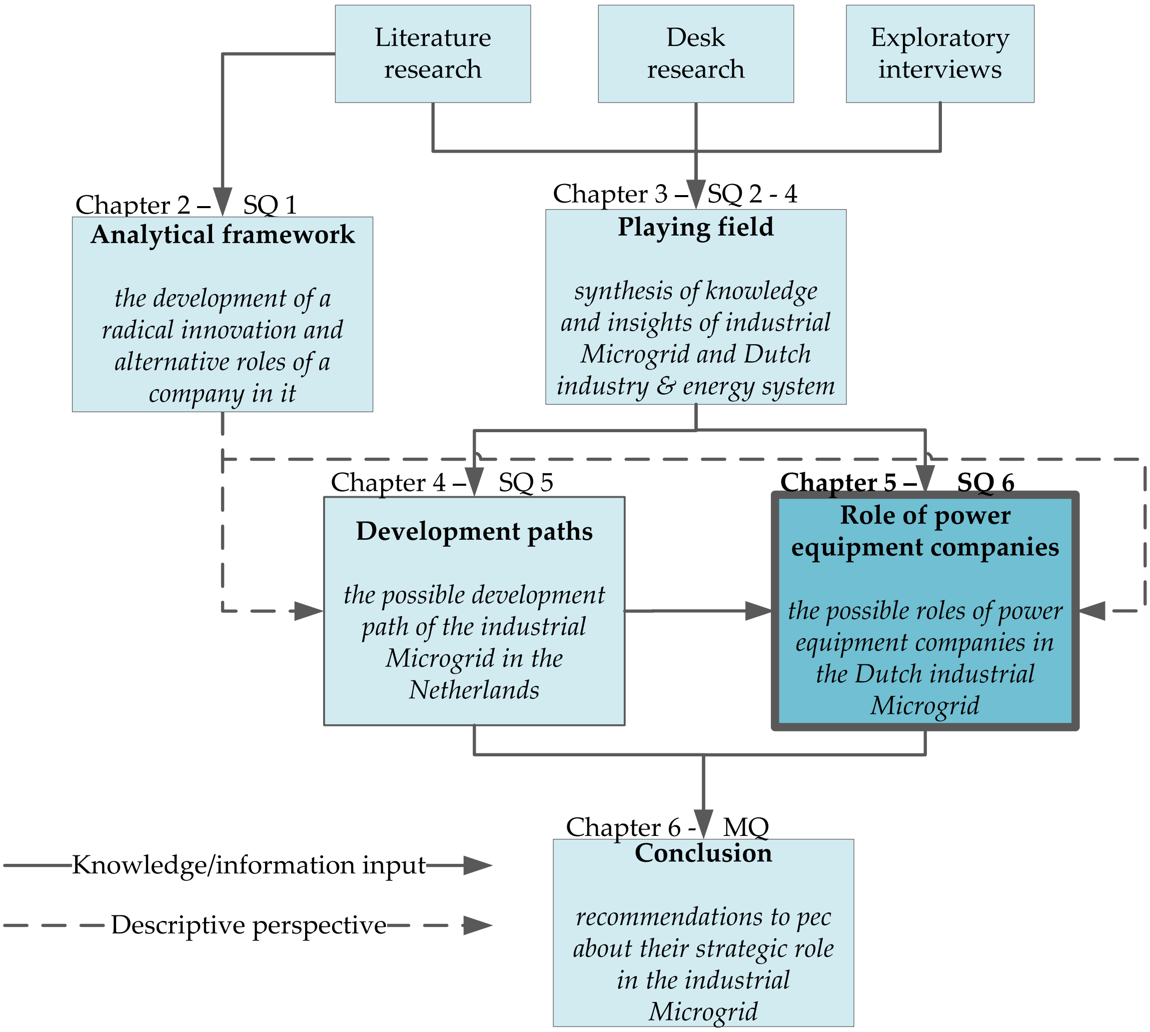
In this optimistic scenario there is tail wind: knowledge is diffused easily, perceptions are positive and proven service concepts are introduced. A strong window of opportunity is created in such an environment.

4.6. Conclusion

In this chapter an answer is formulated to sub-question 5 "*How might the industrial Microgrid develop in the Dutch industry?*". The answer is formulated through four different clusters, two of them so called environmental clusters, two of them internal ones. The first category is not shapeable by the actors, contrary to the latter. The environmental clusters will create the scenarios, while the two other clusters will influence the scenarios and might create the difference between Exception and Common or the speed of diffusion. In these scenarios the industrial Microgrid does not develop at all in the Netherlands, or only creates a niche market, or becomes a common practice, or becomes pervasive.

The clusters behind the scenarios embody the drivers and barriers that have been identified through the analyses of the innovation system, the 5 attributes of Rogers and the environment of the Dutch industrial Microgrid. These paths are more elaborately discussed in the next chapter, so that a strategic role can be determined for power equipment companies.

CHAPTER 5: THE ROLE OF POWER EQUIPMENT COMPANIES



In this chapter sub-question 6 is answered:
What roles could power equipment companies play in the development of the Dutch industrial Microgrids?

5. The role of power equipment companies

Business ecosystems are networks of large coalitions of companies around a common technological platform as discussed in Chapter 2. A first purpose of this chapter is to figure out how the business ecosystem around the industrial Microgrid is shaping up. That starts with identifying the actors involved in this radical innovation and charting their relations, strategies and behavior. Applying the methodology provided in the second chapter, these roles are positioned against the development paths configured in the previous chapter.

This chapter is composed as follows. In the first section (5.1) the industrial Microgrid ecosystem is described. The second section (5.2) provides a zoom on the power equipment companies themselves. The third section (5.3) applies the four strategic roles described in the theory of business ecosystems to the Microgrid context. The fourth section (5.4) relates the roles to the development paths described in the previous chapter. The fifth section (5.5) discusses alternative strategies the power equipment companies could opt for. The sixth section (5.6) contains the conclusions.

5.1. The Business Ecosystem of the Dutch industrial Microgrid

5.1.1. Identification of actors

To identify the actors of the business ecosystem insights gathered from the previous analyses is used. The functions within the industrial Microgrid, identified in the analyses of the playing field, combined with the actors active in the innovations system (TIS) create an overview of the active actors in the business ecosystem. It should be noted that actors not yet active in the innovation but are required in the system, are not yet taken into account. Due to the abstraction level of the research no individual companies are identified; instead classes of actors are analyzed:

- Project managers/engineering consultancy providers;
- DSO's;
- Suppliers of control functions (power equipment companies);
- Suppliers of hardware (power equipment companies);
- Ministery of Economic Affairs;
- European Union.

The business ecosystem is small scaled. This is due to the fact that the Dutch industrial Microgrid is still in its early developments. As can be seen in the analyses of the innovation system only a few actors are active in the inducement of the system. Actors indirectly involved, completing the extended enterprise, are not taken into account since their influence in this stage is still limited.

5.1.2. Key stakeholders & vision

After identifying the actors, the positions of key stakeholders within the development of the Dutch industrial Microgrid are discussed.

Project managers/engineering consultancy providers

Project managers and consultancy providers on engineering problems/issues are considered the companies that are already in regular contact with industries. They can be an important player in knowledge diffusion and in knowledge development, by participating in pilots and projects. Their power with regards to the business ecosystem can be regarded as high, since they have easy access. Their attitude is positive because the industrial Microgrid is also a new business opportunity for them. Though their interest is positive, they still require resources and cooperation of industries before committing to the development of the industrial Microgrid in the Netherlands.

DSO

The DSOs are, as explained in Chapter 3, the system operator of the grid on a local level. They are regulated by the government as to ensure that quality is achieved and that the DSOs do not take advantage of their monopoly position. The DSO can play an important part in the development of the industrial Microgrid, since they can provide services for the industrial Microgrid. Their power to influence the development is considered very high. Since they can influence the grid intelligence & DER cluster or the knowledge & perceptions cluster. However, as the interviews show, their interest in the Microgrid is low because they are still in mid-development of the Smart Grid and they are not convinced of the increased reliability, a value proposition of these new types of grids.

Power equipment companies

Power equipment companies are the companies that supply a large part of the technical elements in the industrial Microgrid system. They have many capabilities, but are centered on the technical system rather than on the social system. Their attitude and interest is considered high, since this is a new business opportunity for them. However, their influence is not considered high in comparison to the other actors.

EU/Dutch Ministery of Economic Affairs

The European Union and the Dutch Ministry of Economic Affairs are the governmental bodies that shape the activities of the industry through laws and regulations. However they are also the official bodies to incentivize the development of more sustainable technologies. As is discussed in the analyses of the innovation process and the contextual factors, both are active in supporting the development of Microgrids in general. The Dutch Ministery of Economic Affairs to a lesser degree since their focus is on intelligent grids rather than on Microgrids. The EU however supports the Microgrid through its projects More Microgrids. The power of the governmental bodies is substantial. As indicated in the interviews, the policies and regulations of the government helps prioritize investment decisions. However the probability that the government exercises its power to actually catalyze industrial Microgrids is low.

At this moment the various categories of respondents have differing opinions on who should take the initiative in the generation and diffusion of the industrial Microgrid. Several non-industrial respondents find that the industries themselves should take the initiative, since it is a innovation which should be applied in their system and of which they will benefit. Other non-industrial respondents see a potential role for themselves, since they could have the knowledge and expertise to implement such a system. The only drawback is that there should be some sort of commitment of industries to the industrial Microgrid, since the non-industrial parties do not have the (financial) resources to research the possibilities without clients. The industrial respondents believe that since they don’t feel the urgency to transition to this new technology, other parties should take the initiative.

5.2. Profile of a Power equipment companies

Power equipment companies vary widely in size, product portfolio and (global) market reach. The only ones that have a chance to shape the development of this radical innovation which requires a wide arrange of components and heavy financial muscle, are the handful of global players such as Siemens. The company is part of a powerful and rich conglomerate that covers everything relevant in a Smart Grid from infrastructure equipment to a wide range of generation equipment to digital services. The mother company is experienced in B:B activities and has the financial and market power to co-shape a market in the global economy. However, even for this global powerhouse the deep uncertainties surrounding important parameters such as pricing, government policy and industry adoption, make the business case incalculable and therefore impose the need to define an entry strategy that is proportional.

To better understand the company profile and the asset base it has to prepare it for a role as leading Industrial Micro Grid player, ten questions should be answered in a basic sense:

1. What is the the power equipment company current offering in the Energy market and the Smart Grid and Industrial Smart Grid;
2. How relevant is the power equipment company positioning in this market and how determined is the power equipment company to expand in this market;
3. Has the power equipment company specific experience and advantages to deal with the technology requirements in this field;
4. Has the power equipment company specific experience and advantages to deal with marketing, sales and implementation requirements in this field;
5. How does the power equipment company relate to competitive players in this field and how does the power equipment company relate to potential partners in this field;
6. To what extend could development of a position in this field contribute or benefit to other strategic developments and markets the power equipment company plays in;
7. Does the power equipment company have the financial muscles to deal with a prolonged entry journey and does the power equipment company easily handle the type of risks related to the journey;
8. Would a heavy strategy change the current profile of the power equipment company in the market and would such a change be in line with the future positioning it has published;
9. Would a light strategy offer a reasonable probability that the power equipment company stays in the market if things evolve at moderate pace;
10. Could the power equipment company survive if a light strategy would have missed an accelerated market development up to the point that the power equipment company would not become a dominant player?

Answering these questions, a classical Strength/Weakness/Opportunity/Threat analysis (SWOT) was made for Siemens, a leading power equipment company:

a. Strengths: end-to-end value chain; powerful mother company; infra and services tradition.
b. Weaknesses: lacking operational generation and grid experience, a complex company which will have difficulties organizing a new bundle of equipment and services;
c. Opportunities: with its strong reputation and full portfolio the power equipment company might establish an early lead; the power equipment company might be a credible partner in a JV with distribution leaders;
d. Threats: if players with a sharper strategy combine with distribution leaders, the power equipment company will face a difficult market.

5.3. Roles in the Microgrid ecosystem

Of the four roles only the ones in the upper part of the matrix in the figure below, are relevant, given the low level of innovative movement on Microgrids in the Netherlands momentarily.

The niche role could be played by a variety of stakeholders, but the role of value dominator could only be played by either the DSO's, the power equipment companies or by the global energy players if they would decide to enter this game.

An example is the niche role that could be played by construction companies, for a boom in industrial Microgrids would require lots of construction work on industrial sites. Also the energy retailers could opt for a mere niche role in supplying the Microgrids with gas and additional electricity. No doubt an easy role for the power equipment companies would be to just play a niche role and act as supplier for the many components that together make up the industrial Microgrid.

The real question is whether power equipment companies should go for the keystone role. For example by organizing the energy sourcing and construction activities as main service orchestrator and funding the investment in a specific industrial site, counting on a pay per use business model to get return on investment. While this would already be a large step away from their actual "build to order" mission towards a "service to demand" mission, the next challenge that would be raised is even larger. Could a power equipment company chose to also take the long term energy price risk (within a certain bandwidth) in order to make the business case calculable for the industries. It is hard to imagine that this is realistic, since power equipment companies are today no players in this part of the value chain. However, one could imagine that a consortium between a power equipment company and a global energy provider or national retail champion, could actually adopt the keystone role.

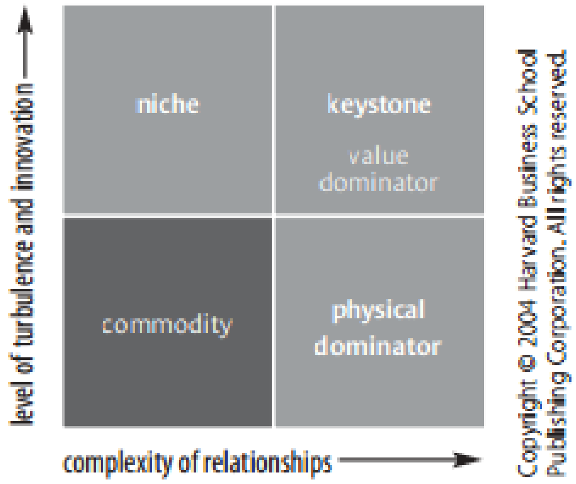


Figure 18 The strategic roles in a business ecosystem

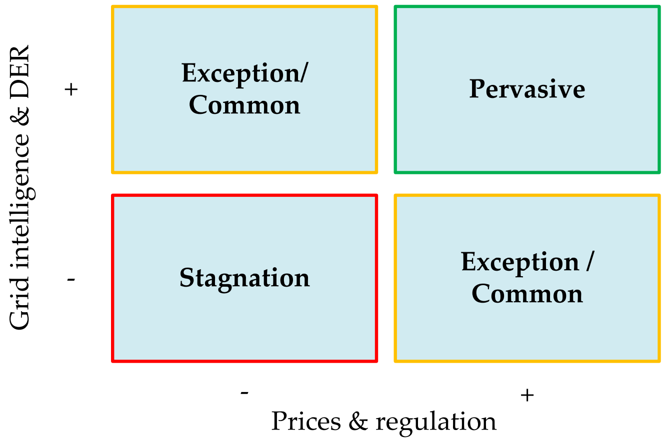
5.4. Scenarios and influence

As discussed in the previous chapter, it is essential to differentiate in the four clusters that contain all the drivers and barriers, the first set of two that are external and the second set of two that are internal, in the sense that actors can influence them.

Table 6 Clusters

Factor	Nature
Price & regulations	External
Grid intelligence & DER	External
Knowledge & perceptions	Internal
Complexity & allaying	Internal

The external clusters cannot be shaped directly by the business ecosystem active in the Dutch industrial Microgrid. As analyzed in the previous chapter various configurations of the external clusters lead to the four scenarios below.



The strategic choices that a power equipment company can make are threefold:

1. which scenario to bet on –shaped by a combination of the two external clusters, which in themselves are not under control of the company;
2. how to influence the scenario –contributing, amplifying or mitigating the drivers and barriers that together make up the internal clusters;
3. what role to play within the anticipated scenario, as already addressed in the previous section.

For a power equipment company acting in the Dutch context, probably the best option in this phase is to bet on the two in-between scenario's and contribute -within the limits of a moderate business case- to knowledge diffusion and build up an early reputation as a provider of industrial Microgrids.

5.5. Alternative Strategies

Most characteristic for a radical innovation in incubation stage from the point of view of a company trying to build a strategy around it, is the unpredictability.

It is worthwhile looking at various types of strategic uncertainties related to not yet adopted innovations and have a quick look at famous cases where companies dealt with those. From there we try to categorize which type of strategic uncertainty we have at hands in the case of the Industrial Micro Grid and what behavior could deal with the uncertainty at hand.

Categories of uncertain innovations:

1. Conceptual breakthroughs that have no applied solutions yet:
   - Example: light-based chips replacing semiconductors, cancer medicine
   - Approach: continued basic research in labs
2. Breakthrough technologies in a "wapen wedloop" with competing alternative technologies:
   - Example: new video, DVD or mobile communication standards
   - Approach: mobilization of ecosystem
3. High potential innovations which require mass adaption and massive infrastructure investment:
   - Example: Google maps
   - Approach: huge investment on single bet
4. Potential winning technology that requires social substitution of dominant technology:
   - Example: Electric Cars
   - Approach: consortiums, institutional lobby, entry offers

The Industrial Microgrid should be considered to be part of category 4 and therefore a consortium approach is to be considered.

Considering consortium shaping, a power equipment has three scenarios it could play on:

1. Go alone, playing on easier, but less powerful, electricity-based industrial Microgrids, and not over-invest by staying close to a general Smart Grid portfolio and marketing;
2. Combine with national distribution leaders or a global energy leader in early pilots to provide rich industrial Microgrid solutions, with a kind of future pricing commitment for the energy provision;
3. Go alone, pioneering rich industrial Microgrid solutions, probably piloting a few specially designed green field parks across Europe.

The "Easy" scenario has as its main advantage that the cost is not prohibiting and that it is a less risky strategy since all investments are made for Smart Grid in general; what pleads against it is that if a more determined market player enters with more focus and succeeds, the power equipment company would have lost the market opportunity.

The "Combine" scenario could deliver a decisive leadership position in a crucial market in the future; what pleads against it is that this is still a very early phase with high investments and high risks, even shared.

The "Pioneer" scenario could shape an unbeatable market position in which Siemens could cover the full value chain for industrial Microgrids, including operations; what pleads against it is that the challenge is steep, even for a powerhouse like Siemens.

The "Combine" scenario looks most interesting, but has to be validated on several aspects: is a credible partner interested; does this fit in the regulatory framework; what are the investments required; can a reasonable business case be designed for all stakeholders with the current market prices; is a global approach feasible with current regulatory differences?

5.6. Conclusion

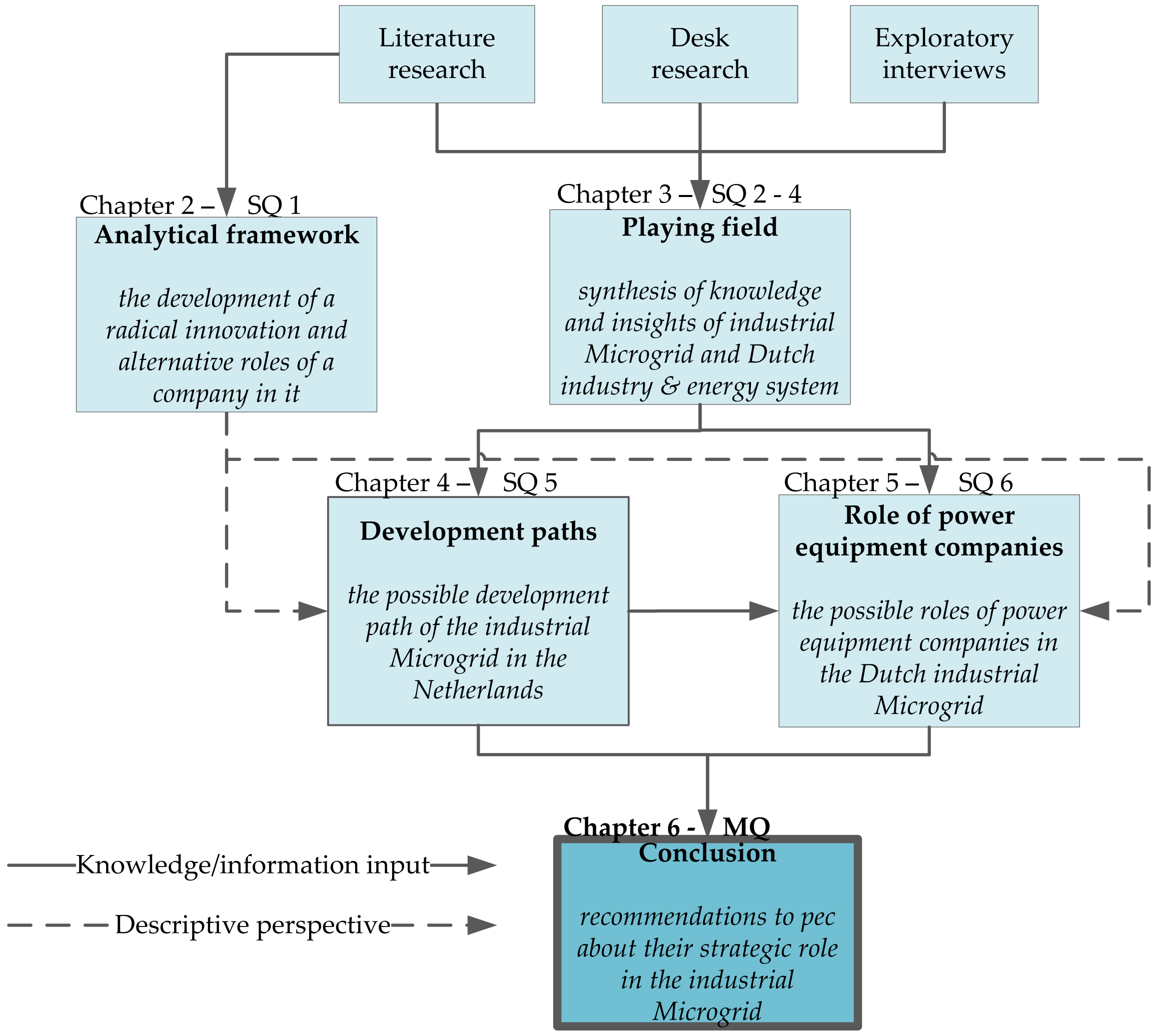
Power equipment companies must clarify the following questions to define a successful strategy:

- How to mobilize synergies between its overall Smart Grid positioning to its Industrial Smart Grid?
- How to organize an end to end Microgrid positioning in the current organizational silo structure?
- How to develop a Microgrid on a global and local market level?
- Which are its partner options?
- Which level of investment and risk is acceptable given the ambition?

The most obvious strategy to play is that of niche player, providing configured Microgrids with most of the physical components and the ICT, subcontracting the physical installation to construction companies.

The most inspiring strategy would be to enter in a consortium with either a global energy provider or a national retail champion and take on the keystone role, acting as a service provider that offers a calculable business case to industries. In this phase it is too early for such a decision.

CHAPTER 6: CONCLUSIONS & RECOMMENDATIONS



In this chapter the main research question is answered:
How might the industrial Microgrid develop in the Dutch industry?

6. Conclusions and recommendations

This research confirms the notion that the industrial Microgrid is a promising radical innovation that in the next decade might change the face of the energy provision worldwide and also in the Netherlands. At the same time the research finds that this innovation is experiencing "low energy" incubation in the Netherlands. If this would only have pointed to a slow start, one might have ushered thoughts about the time it takes before a flywheel really gathers momentum. In fact the theoretical framework borrowed from literature, based on socio-technological notions to explain incubation and adoption, following an S-curve, might have served us well. However, the research more firmly suggests that the window of opportunity has not yet opened itself and will not, unless the price of gas fuelling the midsize power plant at the heart of the Microgrid and/or the stability of the classical Macrogrid or the upcoming Smart Grid will be sufficiently undermined for industries to be willing to pay a premium for predictable energy provision. Neither of these developments can be scientifically or practically predicted for the near future. Not easy thus to answer the first main question of this research: predict the development of the industrial Microgrid in the Netherlands.

As if the original intention of the research was not ambitious enough. Even with a smooth incubation it would have been hard to answer the second part of the research question: counsel power equipment companies like Siemens how to position strategically for the new innovation. While there is a vast body of literature on strategy and also on how to be innovative, there is not much guidance on how to position strategically for a radical innovation that is incubating in the wider ecosystem. The paradox is there: if the industrial Microgrid becomes pervasive, there is no doubt that power equipment companies will find a huge new market to serve. And it is clear that the early players that have developed the right components and especially the right ICT solutions and service concepts, will benefit greatly. For this, even more than in the classical Grid, is a market that will allow repetition in solutions, sales and service, and therefore will offer economies of scale to those that started before others. So you better don't be late if you want to lead a future market of such magnitude. However, there is the other side of the paradox. If a company positions early and there is no takeoff, the losses can be staggering.

While literature didn't support this research with a ready-meal, there was a lot of inspiration from several theories related to incubation and adoption for the first part of the research question (plot the development of the Microgrid from innovation to applied technology), while for the second part of the research question (counsel power equipment companies how to position strategically for the Microgrid development) , support came from the paradigm of business ecosystems.

As often, it is easy to look back and wonder if the right tools for the job at hand were chosen. In Chapter 7, Reflections, the methodological choices will be scrutinized in order to understand better the strength and weaknesses behind this research and to make recommendations for future research.

This chapter is constructed as follows. In the first section (6.1) the conclusion of the research is presented, simply following the sub-questions, which should have lead to the answers that all together offer the pieces to solve the overall puzzle. The second section (6.2) discusses recommendations to the government and to power equipment corporations.

6.1. Conclusions

Following the problem statement (1.4), the main research question was formulated: "*What should the role of power equipment companies be in the development of the Dutch industrial Microgrid?*".

To answer this overall question, a series of six research questions will be answered.

6.1.1. What determines the development of an innovation and the role of a company within this process?

This question is in fact a replay of the main research question, be it in a generic sense. And again the question is split in two: what determines the development of an innovation, what role can one company play in this process.

By nature the first part of the question builds more on a socio-technological macro analysis. Borrowing from theories on technology transition and technology adoption, the answers gear around a set of factors, drivers and barriers in fact, that helps to incubate and help to diffuse and adopt. The context in which this takes place is that of an S-curve which follows various stages, each with its own dynamics. While the factors mentioned in the literature are granular and speak for themselves, the magic moment in which life really takes off, moving from "organic to inorganic", remains elusive.

For the second part of the question, the research builds on the theory on business ecosystems: figuring out which actors take on what roles. Again a somewhat socio-technological approach with clear insights on ideal typical roles a company could choose. Elaboration of these roles would quickly lead to the larger literature body on company strategies in general. The real problem to tackle however, in this case is that it is very difficult to calculate your moves in an unpredictable situation. Later on in the analysis a choice was made to launch a more intuitive scenario analysis. What if event A or B would happen, how would the world look like and how would you position?

6.1.2. What is the current state-of-the-art research regarding industrial Microgrids?

The current state of affairs in the industrial Microgrid world was gathered in a mix of literature, desktop research and interviews. Most sources focus on the technological development, which is still relevant, but definitively not the only dimension, since it became clear that the industrial Microgrid is as much an innovation in interaction between industries themselves and will require different behaviors and institutions then the ones we are familiar with in the world of the classical Macrogrid.
This is not to say that the technological dimension is mature and completely understood. Yes, the technical components are mostly known from the current world, but some of those are still under development. For sure there is still to gain from the development of more efficient midsize co-generation plants. The real challenge is to define the configurations that will allow synergies in usage of electricity and heat that offer decisive synergies compared to each of the industries on that site just hooking up individually to the Macrogrid. In general it is clear that a large part of the development will be in the ICT area, for a Microgrid is just another Smart Grid and the "Net of Things" is still under development.

Then there is the cooperation dimension. Companies that all depend on their energy inflow and are suddenly confronted with more interdependencies than they experience or perceive in their "anonymous play" on the classical Macrogrid. Not only is that a matter of organization in the "local commune", but also is there the institutional side: which service contracts are offered, how is the risk on the investment on the co-generation plant socialized, and how is the long term price development of the energy it consumes hedged? It is obvious that over a century of institutional savvy cumulated in the classical Macrogrid is not just equalized in a few years of pilot projects.

6.1.3. How are the Dutch industry and energy system organized?

The Dutch industry, like all industries, has a very heterogeneous energy profile. In essence that is one important reason behind one of the value propositions of the industrial Microgrid: combining and rebalancing the flows of energy (both electricity and heat) across the day between the neighbors, will lead to a lower collective intake of energy. The point is that one would want to redesign the legacy of industrial parks to create optimal combinations, and of course those "brown fields" will anyhow need a different infrastructure to cater for the internal flows.

Typical for the Dutch energy system is that it is very reliable. Which undermines another main driver of the industrial Microgrid: offer its own stability to the neighbors on site. The Dutch policy is not yet friendly to the industrial Microgrid. It tends to favor the public infrastructure and the private infrastructure of the few large players like Shell, but not offer protection for what is called the closed network, the one cross-neighbors that is necessary for the industrial Microgrid.

Most important is that the Dutch policy doesn't protect the relative pricing of natural gas, as a combustible for energy plants, be it the mega ones or the midsize ones that are relevant for the industrial Microgrid. Such protection could have been chosen to favor the lower emissions resulting from gas and to avoid renewed dependency on coal due to a temporal development on the global energy market. During this study it became more and more clear that this is the real barrier in the Netherlands.

6.1.4. What are the opinions and perceptions on the industrial Microgrid in the Netherlands?

The interviews of 19 Dutch operational energy managers proved great clarity on the criteria with which they measure their operational performance and new investment projects. At the same time the interviews showed that the knowledge of Microgrids is simply lacking in the Netherlands. The technology is not on the radar screen and the rather skeptical opinions are not taken to seriously yet. The window of opportunity has not arrived and meanwhile there is no fertile ground for knowledge diffusion. Most of the granular concepts in the theories about incubation and adoption lead up to one simple conclusion: the "soup of Microgrid life" is not brewing yet in the Netherlands. There is no doubt that in the current scenario, the Netherlands will be a laggard in this energy innovation.

6.1.5. How might the industrial Microgrid develop in the Dutch industry?

It is still very early days for the industrial Microgrid in the Netherlands and this research makes it abundantly clear that it is not likely that this innovation will takeoff soon:

4. The Dutch grid is very stable, which will only be threatened in a further future by the advent of more and more DER generation;
5. The cost advantage is not there, due to the high gas price which makes electricity generated locally in the Microgrid simply more expensive then the coal-generated central grid supply;
6. Cleaner energy is a good driver, but unfortunately not decisive if the price is prohibitive.

A useful step made in the final round of the research, was the identification of a few driving categories in which the rather granular and often non-decisive drivers and barriers derived from our theoretical framework could be clustered: knowledge & perceptions, complexity & allayment; grid coöpetition; prices & regulation.

Knowledge & perceptions as a cluster entails most of the detailed factors pointed at by the technology innovation literature. These are factors that help to understand how in an ecosystem around the innovation researchers and entrepreneurs make the first steps and get traction in a larger community, with knowledge diffusing and perceptions changing positively. In fact this process is already in full motion globally, but in the Netherlands there is little movement because some major drivers in the other categories are missing.

Complexity & allayment zooms in on a series of topics that clearly stood out in the interviews: energy managers are looking for service providers to take care of more of the energy processes in their production process, regarded as vital but secondary. While the Microgrid has the potential of more allayment once new service concepts to be developed in the future, at first sight it is perceived to lead to more hassle, by creating the need for cooperation between neighbors in the grid. Only in case of full-scale diffusion of this innovation, the needle in this cluster will move from red to green.

Grid coöpetition is the cluster that identifies the larger technological context for the Microgrid to develop in. At first there is the classical one-directional, passive, Macrogrid with an established ecosystem that is cautious about shaking up things by moving to a Smart Grid that in essence opens up the game to lots of new competitors. Then there is the bi-directional, open Smart Grid, which will facilitate the Microgrid but also competes with it. If the Smart Grid is able to handle the destabilization coming from DER's it will not . If not, one could see an ideal set of drivers coming out of this cluster: first Smart Grid diffusion opens the door for the Microgrid and if DER instability is insuffiently manageable (still not clear) Microgrid will be pulled in massively.

However, the Price & regulation cluster, could still block this, since the industrial Microgrid in essence gears around electricity and heat generation from a local natural gas-fuelled midsize energy plant. If only the price of the gas would be low enough to generate electricity at rates that could compete with the one generated from the classical grid, mostly coal-fuelled in the Netherlands. However, this is precisely the opposite today after coal prices have collapsed thanks to the US shale gas revolution. Without the government compensating with energy tax policy, gas centrals, be it the giant national drivers in the classic Macrogrid or the midsize ones driving the Microgrids will be out of business.

Reasoning from these categories four scenarios or development paths, which the industrial Microgrid innovation might follow in the Netherlands, were identified. The first is a Stagnation path in which the current no-growth continuous. The driver of Stagnation is a fatal combination of high gas prices and continued high stability in which the Smart Grid succeeds in handling the instability of increased DER production. The second scenario will lead to the Pervasive path. In this scenario a low gas price combines with the need to divide the Smart Grid in a set of smaller Grids in order to avoid killing instability coming from increased DER production. In this scenario the Smart Grid will connect a series of Microgrids, especially industrial Microgrids. In this scenario knowledge diffusion from universities & labs and the proliferation of easy service concepts coming from big energy & equipment providers will be pulled by the huge opportunity.

Less extreme and less easy to predict are two middle scenarios: Exception and Common. Behind both scenarios will be a non-decisive combination of gas price and grid stability development. Effectiveness of the knowledge process and a proactive attitude of the providers will determine whether the balance goes in the direction of Exception or Niche.

6.1.6. What roles could power equipment companies play in the development of the Dutch industrial Microgrids?

Power equipment companies can play a crucial role in the value chain since their products, e.g. electrical equipment, generators, control systems, directly support the functioning of the system. However, power equipment companies are almost by definition not the most appropriate ones to deal with the social dimension of the innovation due to their technological cultures. Also the fact that they have more of a project than a service culture doesn't make them natural operators. While they have a natural contribution to make in knowledge development and distribution, they should probably play on other partners such as the large energy retailers or oil companies to initiate operational pilots and develop the sophisticated service concepts that will allay the industries in the more sophisticated energy play of the Microgrid.

With regards to pilots or initial project, it can be easier for the business ecosystem to focus on new industrial parks and sites rather than on existing, since it can actively steer towards gathering industries with energy flows that can be synergized.

The business ecosystem of the industrial Microgrid is still small, which is due to the fact that there are not many activities around the system. The actors that are currently active are suppliers, adopters and several supporting groups, e.g. research institutes and engineering companies. The innovative system can be regarded as a niche, where no actor yet has adopted a leading role in the business ecosystem. There is no commitment yet of any early adopter industries.

In many ways it is understandable that Dutch players are non-committal so far: the current development is very difficult to calculate and while the play is more doable for global players with larger economies of scale, most probably the Netherlands is not the right country to host strategic execution within these multinationals, but rather other geographies that experience a more dynamic industrial Microgrid development.

The best chance for a player such as Siemens to play a leading role in the development of the Dutch Microgrid, is to go in consortium with another global player with service experience and involved in the primary process of energy sourcing, rely on rich projects in more favorable markets and play on just a handful of pilots in the Netherlands to showcase and experience.

6.2. Recommendations

An answer is given to the main research question. Following the process and the results different recommendations can be formulated towards power equipment companies and government.

6.2.1. Recommendations to power equipment companies

Designing a business model is still way too early, thus the focus should really be on influencing the business ecosystem to start creating momentum and early positioning. However it is not recommended to aim for a fast introduction, generation and diffusion of the industrial Microgrid, since the transition towards this system is too far a stretch. As became clear in the analyses many developments around the Smart Grid are occurring. While this can seem as a competitive development, it should be seen as an opportunity. Making the step from a simple Smart Grid towards a Microgrid is less difficult to calculate.

If the power equipment companies do not want to take the driver's seat in this development, it should participate in some early pilots and projects to learn and profile.

The choice for power equipment companies for which role to play depends on three things:
- Their understanding of the scenarios and their courage to choose a scenario to bet on and help shape (knowing that the two main driving clusters are not really in their hands);
- Their choice for a specific role in the new ecosystem, positioning themselves between the utilities on the one hand and the consuming industries on the other hand;
- Their ability to play a global game in which their investments in the Netherlands can be lowered thanks to those in geographies that are more favorable to the Microgrid than the Netherlands.

The recommendation to power equipment companies is unequivocal:
- Bet heavy on this new innovation, because sooner or later a large part of the Smart Grid will be energized by a series of Microgrids;
- Anticipate on one of the two in-between scenario's, either "exception" or "common", but not on the most positive "pervasiveness" scenario;

- Play a global game and opt for the long run in geographies such as the Netherlands that have a reliable grid and relatively cheap electricity from the classical grid;
- Think hard about entering a consortium with either one of the large utilities with global aspirations or with one of the oil companies;
- Develop easy, no-hassle, service concepts with the partner, to allay the industries participating in Microgrids;
- Move from one-time power equipment construction to long term risk-taking pay-per-use service provisioning.

6.2.2.Recommendations to the government

Though the research has not explicitly focused on the role of the government, some recommendations follow naturally:

- Recognize that in all activity towards the Smart Grid, there should be a systematic stream, with participation of all stakeholders, especially the industry itself, that also explores the Microgrid potential in the Netherlands;
- Rethink how price policies could lead to less dependency on coal, obviously easy said, but at the same time difficult to proportion in order not to loose sight of the overall competitiveness of Dutch industry;
- At least create favorable conditions for a handful pilots on Greenfields and one or two o relevant Brownfields, eventually adapting regulations for the pilots and the taxation of natural gas, in order to create a specific business case for co-generation;
- Fund some research to keep track of developments in the most advanced countries and stimulate the energy sector to organize consortia to end the stagnation in the Netherlands.

CHAPTER 7: REFLECTION & DISCUSSION

7. Reflection & discussion

In the previous chapters the conducted research has been reported on. Thereby covering the choices made, the steps taken and the results of this research in a clear and structured manner. An important last step after conducting the research is to reflect on various aspects of the research. This ensures that the research is put into perspective and learning elements can be defined from the hind-sight analyses of the content and choices made. Four elements of the research are discussed: 1) its relevance on academic, practical and social level, 2) the methods and approach of the research, 3) the results of the research and 4) the process.

7.1. Relevance

The relevance of this research can be regarded on the scientific, practical and social level. In the first chapter of this research the potential relevance of this research based on the then gathered insights have been discussed. Here, looking back, the actual relevance is established.

7.1.1. Academic

The academic relevance is present in the (valuable) expansion of knowledge to the academic community. This research's additions can be found in the constructed analytical framework and the new knowledge on industrial Microgrids in the Netherlands.

The development of (radical) innovations is a widely discussed subject. The theories describe the process and the characteristics of the innovation. However valuable, they do not focus on actual strategic actions of specific companies or groups of companies to influence the development process towards successful diffusion. Neither do theories on possible strategies for companies. In this research an attempt is made to fill this identified gap, by constructing a new analytical framework that focuses on strategic roles of a company in the development a radical innovation. The premise is that based on the potential development paths of an innovation and the business ecosystem, a strategic role can be adopted and pursued as to influence the development through its network of actors. The framework builds on the theories of technological transition, technology adoption and business ecosystems. By combining elements of both the technology transition theory and technology adoption theory, a radical innovation's development is regarded from the structures in place to develop the innovation, the characteristics of the innovation and the environmental factors in play. The result is a richer understanding of the current development stage and the ability to identify and analyze factors in future development paths. Based on the different scenarios and the corresponding sequential path of possible actions, four possible roles within business ecosystems are analyzed. This analytical framework thus focuses mainly on strategic roles of companies that could influence the development of a radical innovation, thereby covering the previously discussed gap.

It should be noted that the analytical framework and its elements are not verified by experts. The framework should be tested and validated, to ensure that the relevance is indeed generally applicable and possibly be improved. It can also function as a starting point for a discussion or for the construction of a better framework in the academic society to formalize the influential role of companies in the development of a radical innovation.

The second academic contribution can be found in the subject discussed in this research. The Microgrid has been a new topic of research over the past decade, mostly covering the technical side. In the literature the social aspects of the Microgrid have been underdeveloped. In this research it is shown that the social aspects can be extremely complex. Especially when it comes to industrial Microgrids integrating different industrial companies and their varying interest. Then there is also the environmental and economic impact a possible failure might have. The insights gathered in this research into the industrial Microgrid adds to the existing research of Microgrids in general and industrial Microgrids in particular. It should be noted however that the research does focus on the Dutch industry, thereby limiting the applicability of this knowledge to other parts in the world. Because of the research's structure, the methods used and framework give insights in how and which knowledge has been generated. This will simplify the same kind of research in other parts in society or scientific community.

7.1.2.Practical

The practical relevance is vested in the (valuable) expansion of knowledge for real life applications and decisions. This research's added value can be found in the insights it gathered into the issues involved in the development of the industrial Microgrid and the advice formulated for power equipment companies, e.g. Siemens.

Derived from the constructed analytical framework, a systematic approach is used to analyze the development of the industrial Microgrid in the Netherlands. Through the systematic approach, insights have been gathered regarding the development characteristics of the industrial Microrgrid, the complexity of the system and its potential development paths. The exploration shows the issues that surround the development of the industrial Microgrid in the Netherlands, which are for a part similar to issues in the development of the Smart Grid, e.g. regulation, systematic willingness to adopt an innovative system. These insights can be used to reveal the important issues and can act as a starting point for discussion on how to tackle these issues within the industrial Microgrid system on different levels, e.g. consumers, service providers, governmental parties.

Next to that, practical relevance can be found in the advice formulated for power equipment companies, e.g. Siemens, on strategic roles and actions to influence the development of the industrial Microgrid in the Netherlands. The complexity of the system and the unknowns of this innovative system make it difficult to create a starting point for strategic actions to make something profitable of this innovation. The results of this research provides this starting point for Siemens and other power equipment companies. First of all objective insights have been created in the current state of affairs of the industries and the system, and the issues at hand. It gives them an overview of this new potential product and market and provides them with a suggestion for a possible action path. Based on these insights the companies may decide for themselves whether or not the industry and the industrial Microgrid lead to respectively a interesting new market or to adjustments and additions to their product portfolio.

7.1.3.Social

The social relevance can be found in the valuable expansion of knowledge the research achieves benefiting society. This research's added value can be found in the overall exploration of the industrial Microgrid in the Netherlands.

The Smart Grid is currently one of the most influential topics in the energy industry, since intelligent grids may make the energy system more efficient, more sustainable and more economical than the current grid. However, the discussion around intelligent grids in the Netherlands focuses mainly on household level. Not on industrial consumers or sites. With this research the focus is given to industries. Industries are large consumers of energy, therefor the impact of the benefits to society are greater in comparison to the household applications of intelligent grids. Increasing energy efficiencies and the cleaner production of electricity and steam will have a positive impact on sustainability issues (climate change, finite fossil fuels, dependency on providers of energy). Furthermore it also has a good impact on the economic side, making the industries increasingly cost-effective, thereby improving their competitive advantage (or disadvantage) of being stationed in the Netherlands. It also reduces costs for products. This research furthermore gives insight in the Microgrid, which can be applied to different environments and has several (theoretical) benefits. Currently there is no place for Microgrids; the institutional, social and technical environment of the Netherlands is not ready for it. However, there is large potential when the Netherlands is further down the road of DERs and high energy prices. Changes in the current technical system (e.g. decreased reliability due to DER) and the institutional system (e.g. changes in electricity market model) will support the development of intelligent grids and make Microgrids possibly the standard in the Netherlands.

7.2. Methods and approach

In this section the used methods and taken approach are reflected upon. The approach has been centralized around the constructed analytical framework. The methods used to collect data consist of literature research, desk research and exploratory interviews.

Approach

With regards to the approach, the research started with the objective of developing a recommendation for power equipment companies on a strategic role as to influence the development of the industrial Microgrid in the Netherlands. After first creating an insight in what the Microgrid is, an attempt was made to construct the analytical framework. An extensive literature research was carried out in order to select theories and elements to incorporate in the analytical framework. Here the academic contribution partly took shape. The analytical framework provided a step by step approach for the research. In hind-sight, it was important to establish this framework, because there was no existing one yet. It would otherwise be difficult to maintain structure and logic throughout the research, making it unnecessarily difficult.

As said previously, literature research and desk research were conducted to gain knowledge of the industrial Microgrid in the Dutch context. However data on the industrial Microgrid were limited to the technical aspects of the Microgrid and matter-of-fact knowledge on the Dutch energy system. Knowledge was lacking on the social factors of cooperation in Microgrids and the opinions of the different actors relevant in the development of the system. Exploratory interviews thererfore formed the main source of data and insights in this research. By selecting the respondents and topics covered in the interviews the results of the research were shaped.

Respondents

With regard to the respondents, ten industrial respondents and nine non-industrial respondents have been interviewed. The ten industrial respondents were chosen from three large energy-intensive branches: the petroleum industry, the steel and chemical industry. These industries were chosen in the assumption that the impact, urgency and willingness of adopting an industrial Microgrid would be larger than smaller industries. However, during the research it became apparent that these largest industries are most likely not the focus industries. Interviewing possible target industries would probably lead to insights from a somewhat different perspective, which could then be added to the gathered conclusions and recommendations. Regardless, the interviews were very valuable and several notions could be derived that are most likely applicable to all industries, e.g. trade-off reliability and costs. Furthermore, due to the systematic approach it is not likely that the results of the research would be radically different if the focus industries would have been interviewed. Additionally, the ten industrial individual respondents were all higher level management and all had positions on the technical operational side of the plants' processes. These respondents were able to imagine an implementation of the industrial Microgrid, mostly from a technical perspective. However the commercial and social perspective were therefore underexposed. The first perspective could have been covered by increasing the number of interviews to include the commercial counterparts of the current respondents. For the social perspective respondents higher in the management level should have been consulted. As a result the commercial and social aspects of the industrial Microgrid from the industrial perspective are not adequately covered in the data. Economic and social factors may therefore have slipped through. However, the nine non-industrial respondents were a diverse group, each covering various perspectives of the industrial energy system. The functions in these companies were often related to innovation or business development within the Smart Grid area. In this group the technical aspect were less relevant. Here the social aspects were mostly covered. By interviewing both groups, technical and social aspects of the industrial Microgrid have been covered. The commercial aspect has largely been overlooked. This is likely due to the fact that the development of the industrial Microgrid is still in its early phase and the economics are too uncertain at this stage

The topics which were discussed during the interviews did not correspond exactly to the factors identified in the analytical framework. . This is because the analytical framework took its final form only after the interviews were conducted. Regardless, the data and insights of the interviews did correspond well to most factors analyzed in the development and business ecosystem. However the impact can mainly be found in the lack of richness of the analyses covering the development of the industrial Microgrid. While most factors were covered superficially in the interviews, supplementary questions were required to go in depth of the motives and opinions to fully understand the importance and create richness of the analyzed factors. Thus, more time could have been spent on going into depth in the interviews. However, in the relatively short time of the research this would have been challenging, since there are many factors to cover in the analyses. Furthermore, the willingness of respondents might decrease if the interviews take longer. Thus with the amount of factors present in the analytical framework and the time available for collecting data, a trade-off must be made between spending time on the interviews and analyzing them and the depth and richness of the analyses.

7.3. The results

Three types of results are generated in this research: 1) the constructed analytical framework, 2) the development paths of the industrial Microgrid in the Netherlands and 3) the strategic role of power equipment companies.

7.3.1.The analytical framework

The analytical framework builds on theories of technology transition, technology adoption and business ecosystems. The analytical framework's premise is influencing the development of a radical innovation through taking on a strategic role in the business ecosystem. The premise of a radical innovation is taken because of the fact that the industrial Microgrids can be considered a radical innovative system, being very different from the technical and social system in place. Theories have therefore been used that deal with the development of a radical innovation. However, in hind-sight it can be concluded that the theories, and thus elements used in the analytical framework, do not make a distinction between incremental or radical innovations. Thus the premise of a radical innovation was not necessary, since there does not exist such a difference in the theory. The supossed applicability of the framework becomes greater.

A distinction which is not made in the premise of the framework and the theories used, but regardless important to consider, is the difference between stand-alone innovative technologies, e.g. batteries, innovative systems, e.g. Microgrid. The elements used in the framework derive from theories that focus on innovative (stand-alone) technologies. Since such theories could not be found that made this distinction, the latter theories were used regardless. However, it became clear that innovative system may require advanced concepts. The complexity of the innovation increases due to the fact that it is an entire system. The concepts and factors of the analytical framework did not give the opportunity to address this complexity and was kept in mind during the execution of the analyses. For future research a distinction should be made between innovative systems and innovative stand-alone technologies. The framework constructed here would be most suitable for stand-alone innovations.

Overall the framework is a good attempt to provide a theoretical base for tackling the issue in this research. However, this analytical framework is structured in such a way that it should be able to be applied to any innovation and any company (e.g. customer, supplier). Unfortunately, in this research the innovation at hand is more complex than any stand-alone technology. The framework is not well suited that handle the complexity of the industrial Microgrid. The richness and number of the different factors covering the complexity which are at play in the energy system are overwhelming. It thus seems that its potential is not achieved in this research.

7.3.2. The development path

Reflecting on the results of the development paths various aspects can be discussed. First of all the development path is constructed based on the analyses of the three elements (innovation system, 5 attributes of the innovation and environment). As is discussed earlier, taking into account these three elements ensures a rich view of the development. In hindsight it can be noted that due to the almost non-existence of the system, the analysis of the innovation system does not gather many insights other than that there is no inducement of the innovation yet. Thus again, the general applicability of the framework does not precisely correspond to the problem tackled in this research. However, it is expected that these factors will be relevant when the innovation is in a more developed stage.

Furthermore with regards to the development paths four clusters of factors identified. These should be reflected upon as well, since these mainly shape the four development paths. Two internal clusters have been identified, "knowledge & perceptions" and "complexity & allayment", which can be influenced by the actors in the business ecosystem. The external clusters of factors, "grid intelligence & DER" and "prices & regulations", define the possible paths. Due to the complexity and the manifold of factors that followed from the analyses, it would not have been possible to construct development paths without the overarching clusters. The clusters make it possible to structure and oversee the complexity.

7.3.3. The strategic role of power equipment companies

The strategic roles gives clear action points on what a power equipment should do based on the development, business ecosystem and the assumption that these companies want to actively influence the development. However a generalization is made of power equipment companies with based on their power and capabilities. It should be easier if a single strategy is formed for a specific company. However, it is still of practical use. The specific companies should only make a last translation step to make it applicable and concrete to their own company.

7.4. Research process

The research process focuses on how I, the author, look back on the research process, and the steps taken. This research has been proven to be quite challenging due to a number of reasons.

In the beginning of the research a lot of the subject was unknown. As a consequence the paths that one could have taken were manifold. While at first sight the industrial Microgrid is a demarcated system, it still has many perspectives and levels of detail to focus on. The results of this research have been the product of constant rethinking and reflecting the scope and details to take into account. This was enhanced by the fact that the analytical framework, the backbone of the research was only finalized in the last parts of the research. Especially in researches where the analytical framework is guiding the steps taken in the research it is of utmost importance to establish the framework, be comfortable with the entire process and only then follow the steps. The complexity of the framework, and it being at odds to the actual research, have proven to be the main challenge of this research.

In addition the research was quite challenging due to the level of ambition pursued. As is discussed several times, the research consists of two parts: 1) the development paths and 2) the strategic role of power equipment companies. However, actually three parts have been researched. The industrial Microgrid in the Netherlands has not yet been a subject of research. Thus researching the playing field, the actual socio-technical system, has been a large part of the research as well. These three aspects separately, the innovative system, the development of the system and the strategic roles could have been three separate, sequential, six months researches. This would have opened up the opportunity to go into more detail of each aspect separately.

As a final reflection, the industrial Microgrid is a challenging subject to explore and over the months conducting this research the complexity of the surroundings and factors that are of importance have been overwhelming. To explore such a new subject that has both social and practical value, to see its beginning, gave drive to complete the research and gave a sense of importance. Even though it may not seem interesting business concept at the moment, it has a good chance of being in the future when environmental factors change and the attitude of industries towards cooperation is more open. The challenge was found even more since it is a subject and approach new to everyone else. Finding a research subject that is as interesting as this one, has been a real drive to get the most out of the research time. A scientific research is very challenging and demanding, the extra energy given through the subject is very welcome at times.

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