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Smart grid technology and the energy transition

EXPLORING THE DRIVERS AND BARRIERS OF A TRANSITIONAL TECHNOLOGY

Master Thesis

Strategic Management

Name: Thom Roelen

Student number: S4481550

Supervisor: I. Beenakker

Second examiner: P. M. M. Vaessen

‘Change is the law of life and those who look only to the past or present are certain to miss the future.’

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John F. Kennedy, 1963

Preface

Dear reader,

This master thesis marks the completion of my Master's in Strategic Management at the Nijmegen School of Management. Thereby, this thesis also marks the end of a challenging period in which I immerged myself in the changing energy world. The novelty of smart grid technologies and the fact that I had no prior knowledge on the ins and outs of the changing energy system made this master thesis both instructive and exciting.

Unfortunately, as a result of the corona crisis, adjustments had to be made to the initial research plan. At the outset, a comparative multi-case study would be conducted. However, since most of the potential respondents were occupied with other activities in order to cope with this corona crisis, I had to change my methodological approach. Due to time constraints, I chose to conduct an explorative case study. This methodological approach made it easier to find suited respondents, so that I could go on with my research.

Over the last few months, I worked in close collaboration with Ivo Beenakker as my supervisor. I would like to thank him sincerely for the pleasant collaboration and for the fact that he always kept a close eye on the quality of the thesis. Furthermore, I would like to thank Peter Vaessen for his efforts as the second examiner. Moreover, I would like to thank all the people that volunteered and provided their insights for this thesis.

Since this master thesis marks the end of my student days as well, I would like to sincerely thank my parents for their unconditional support during these years.

I hope you will enjoy reading my master thesis.

Thom Roelen

June 2020, Nijmegen

Abstract

Together with the increasing energy demand, the irregularity of renewable energy sources makes it challenging to align the demand- and supply-side of the energy market. However, smart grid technologies might help to align the demand- and supply-side of the energy market. The purpose of this research is to identify how drivers and barriers of smart grid implementation in the Dutch context influence the development of smart grid technologies in the Netherlands and to elaborate on the potential of smart grid technologies as a catalysator of the energy transition. The research question to be answered is: *How do the drivers and barriers of smart grid implementation in the Dutch context contribute to or hinder the development of smart grid technologies in the Netherlands and how can smart grid technologies support the energy transition?* To answer this question, an explorative case study has been conducted. The studied case is the Dutch Innovation Program Intelligent Nets (IPIN). The data is gathered via expert interviews and through document analysis. Concerning the driver dimensions of smart grid implementation, five different driver dimensions are distinguished: 1) the economic dimension, 2) the organisational dimension, 3) the technological dimension, 4) the regulatory dimension and 5) the societal dimension. Regarding the barrier dimensions of smart grid implementation, six different dimensions are distinguished: 1) the economic dimension, 2) the organisational dimension, 3) the technological dimension, 4) the regulatory dimension, 5) the societal dimension and 6) the political dimension. This research shows that the societal and the technological are the most important driver dimensions, while the economic and the societal are the most important barrier dimensions. With regards to the potential of smart grid technologies, smart grid technologies are facilitating the energy transition by offering a platform via which the demand- and supply-side of the energy market can be better aligned. Further research (e.g. comparative multi-case study) would be helpful to get an even more thorough understanding on the drivers and barriers of smart grid implementation and the potential of smart grid technologies.

Keywords: smart grid, drivers, barriers, energy transition, socio-technical transition

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1. Introduction

§ 1.1. Energy transition

Since the invention of electricity, fossil fuels have been used as the main sources of power. However, over the last decades, the use of fossil fuels as energy sources has been recognized as the largest contributor to global CO_2/greenhouse gas emissions, which is one of the main drivers of climate change (IPCC, 2018; Pfeiffer et al., 2016; IRENA, 2018).

The human influence on climate change is not new in the public debate. Since the anthropogenic climate change debate first emerged on the public agenda, it turned out it was there to stay (Moser, 2010). After all, it is well documented and beyond doubt that the rising concentration of CO_2 in the atmosphere and climate change are interrelated (IPCC, 2018; Rockström, 2015; Steffen et al., 2011). Recently, in 2015 a new global climate agreement was met during the Paris Climate Conference (UNFCCC, 2015). The Paris Climate Agreement aims at holding the global warming to well below two degrees Celsius, while “pursuing efforts” to limit it to 1.5 degrees Celsius above pre-industrial levels by reducing the humanity’s contribution to the greenhouse gas/CO_2 emissions (UNFCCC, 2015; Howell et al., 2017; Rogelj et al., 2016).

As a national reaction to the Paris Agreement, in the Netherlands the Klimaatakkoord was presented mid-2019 (Klimaatakkoord, 2019). Since February 2018, more than 100 parties were involved in the development phase of the Klimaatakkoord, in which a plan is presented with the goal of reducing the greenhouse gas emissions with 49% relative to the emissions in 1990 (Klimaatakkoord, 2019). Furthermore, on the provincial level (e.g. Gelders Energieakkoord, 2015) and the regional level (e.g. Warmtevisie Nijmegen, 2018) climate agreements are developed as well.

Using fossil fuels in the energy mix is one of the largest contributors to global CO_2/greenhouse gas emissions (IPCC, 2018; Pfeiffer et al., 2016; IRENA, 2018). Therefore, effective actions in the energy sector are needed in order to tackle the climate change problems (IEA, 2015). In order to decarbonize the energy system, the energy sector needs to shift from a polluting fossil fuels-based system towards a clean renewables-based system (Quaschning, 2019; Hentschel et al., 2018; Lund et al., 2017; Ketter et al., 2016). The renewables-based energy system is based on generating power from mostly solar and wind sources. However, geothermal, biomass and hydro sources are expected to gain importance as renewable energy sources in the near future (Rifkin, 2015). Using renewable energy sources instead of fossil fuels sources reduces the CO_2 emissions on a large scale (Ahl et al., 2020; Burke & Stephens, 2018).

Although, the global CO_2 emissions from the power sector reached a record high in 2018, the electricity market is at the vanguard of efforts to combat climate change and pollutions, thanks to the commercial availability of a diverse suite of low emission generation technologies (IEA, 2019). As a result, EU's coal generation decreased by 24% in 2019 and the CO_2 emissions fell by a record 12%. Meanwhile, the renewables rose to a new record, supplying 35% of EU's electricity (Sandbag & Agora, 2020). In other words, these promising numbers show that we are already in the middle of the transition in the energy sector from a fossil fuels-based to a renewables-based energy system (Sandbag & Agora, 2020).

§ 1.2. Drivers and barriers of the energy transition

Although the energy transition from a fossil fuels-based system to a renewables-based system is already taking place, the transition is not going as fast as desired (IEA, 2019). The speed of the energy transition is influenced by a variety of drivers and barriers. Drivers are factors that accelerate the energy transition, while barriers are factors that impede the energy transition (Fleiter et al., 2011; Arens et al., 2017). Within academic literature, the following four dimensions of drivers and barriers of the energy transition are distinguished: 1) the economic, 2) organisational, 3) technological and 4) regulatory dimension. Economic drivers and barriers are factors regarding the required costs and financial risks of the energy transition (Trianni et al., 2016; Cagno et al., 2015). Low required costs and high potential benefits make organisations more inclined to shift towards a renewables-based energy model (Cagno et al., 2015; Trianni et al., 2016), while high required investment costs and high financial risks prevent organisations from making this shift (Cagno et al., 2015). The organisational drivers and barriers involve the competences of an organisation regarding the energy transition (Cagno & Trianni, 2013). After all, it is easier to shift towards a renewables-based energy model if a company possesses the required competences in order to make that shift (e.g. technological skills in order to integrate renewables into the traditional energy system) (Cagno & Trianni, 2013), while the lack of those factors prevents an organisation from making the shift (Cagno et al., 2013). Technological drivers and barriers are the factors regarding the adequacy and availability of specific transitional technologies (Cagno et al., 2015). Decidedly, the presence of a variety of adequate technologies encourages organisations to make the shift towards a renewables-based energy model (Cagno et al., 2015; Lee, 2015). However, if those technologies are flawed or unavailable, this discourages organisations from making this shift (Cagno et al., 2015; Lee, 2015). Regulatory drivers and barriers involve all governmental norms, standards and facilities (de)stimulating the energy transition (Trianni et al., 2016). If these norms, standards and facilities encourage the shift towards a renewables-based business model (e.g. subsidies), organisations tend to shift towards a renewables-based energy model (Trianni et al., 2016). However, if those incentives lack, organisations are discouraged to make that shift (Trianni et al., 2016; O'Malley et al., 2003). Literature research showed that some drivers (e.g. technological) and barriers (e.g. regulatory) are quite overlooked in the academic debate, while other drivers (e.g. economic and regulatory) and barriers (e.g. economic and organisational) are discussed extensively. All in all, in academic literature, a lot of effort has been put into the identification of specific economic drivers (e.g. Trianni et al., 2016; Abmouleh et al., 2017; Lee, 2015), regulatory drivers (e.g. Trianni et al., 2016; Cagno et al., 2015), economic barriers (e.g. Cagno et al., 2015; Kiefer et al., 2019) and organisational barriers (e.g. Cagno et al., 2015; O'Malley et al., 2003; Rohdin & Thollander, 2006). However, academic research concerning the identification of specific technological drivers and regulatory barriers is scarce.

§ 1.3. Problem statement

As explained before, the energy transition is taking place slowly. The speed of the energy transition is influenced by a variety of drivers and barriers. Since academic research into the identification of some specific drivers (e.g. technological) and barriers (e.g. regulatory) is scarce, a comprehensive overview of the drivers and barriers of the energy transition in the Dutch context helps to get a better understanding of the current slowness of the energy transition. After identifying the drivers and barriers of the energy transition, the academic debate can focus on how to accelerate the energy transition in order to meet the climate goals as soon as possible.

§ 1.4. Research objective and research question

The main objective of this research is to identify how the drivers and barriers of the energy transition in the Dutch context influence transitional technologies development in the Netherlands. A research focused on the Dutch context is important, because in the Netherlands different actors in the energy system are already experimenting with transitional technologies (Rotmans, 2011; RLI, 2017). However, a comprehensive research regarding the drivers and barriers of the energy transition in the Dutch context lacks in academic literature. Moreover, research results from other contexts (e.g. India (Nagesha & Balachandra, 2006), Sweden (Rohdin & Thollander, 2006; Thollander & Dotzauer, 2010), China (Wang et al., 2008) and the African context (Ouedraogo, 2019)) are not directly applicable to the Dutch context, because some drivers and barriers are country-specific (e.g. regulatory (Ranta et al., 2018)) and the energy system differs from country to country (Tricoire, 2015).

The drivers and barriers of the energy transition are analysed based on a Dutch smart grid program. A smart grid is an electrical network that incorporates both the consumers and the producers, in which the electricity/power is being conveyed effectively via smart grid features and loads (Adefarati & Bansal, 2019). Thereby, the smart grid is regarded as an application with the potential to support the energy transition, because smart grids help to integrate renewables into an extremely flexible and effective grid (Zhou et al., 2016; Saad et al., 2019; Mylrea, 2017; Kabalci et al., 2019). However, smart grid technologies are not implemented on a massive scale yet due to the high required investment costs and the technological uncertainty regarding the smart grid technology (Tricoire, 2015). Therefore, smart grids are an interesting case to analyse the drivers and barriers of the energy transition.

Hence, the main goal of this research is to present how the drivers and barriers of smart grid implementation in the Dutch context influence the development of smart grid technologies in the Netherlands and to analyse how smart grid technologies can support the energy transition towards a decarbonized, more decentralized and sustainable energy industry. Therefore, the central research question of this thesis is:

How do the drivers and barriers of smart grid implementation in the Dutch context contribute to or hinder the development of smart grid technologies in the Netherlands and how can smart grid technologies support the energy transition?

In order to answer this research question, the following sub-questions are constructed:

- *How do the drivers of smart grid implementation in the Dutch context contribute to the development of smart grid technologies in the Netherlands?*
- *How do the barriers of smart grid implementation in the Dutch context contribute to the development of smart grid technologies in the Netherlands?*
- *How can smart grid technologies support the energy transition?*

In order to take the complexity and multifaceted nature of the energy transition into account, which is not only about the emergence and the development of new technologies (and their applications), but about the rethinking of the current configuration of the energy sector as well, this thesis builds on academic literature on the drivers and barriers of the energy transition. The drivers and barriers-perspective is an appropriate theoretical lens for this thesis, because this perspective helps to get a better understanding on the diffusion of innovations (i.e. smart grids), because the underlying factors of the choice whether or not to implement an innovative technology can be understood (Arens, et al., 2017). After all, the drivers and barriers are the relevant factors during the decision-making process regarding whether or not to implement smart grid technologies (Fleiter et al., 2011). Thereby, studying the drivers and barriers of smart grid implementation helps to understand not only whether a smart grid technology is implemented, but understanding the factors underlying the specific choice (not) to implement smart grid technologies as well (Arens et al., 2017).

§ 1.5. Practical relevance

A comprehensive overview of the drivers and barriers of smart grids has practical relevance, because after identifying the main issues, innovative approaches to laws and regulatory measures can be developed in order to offer appropriate solutions to possible regulatory barriers of smart grid implementation (and the energy transition in general) (Leal-Arcas et al., 2017). Furthermore, this research into the drivers and barriers of smart grids and its potential is helpful in order to scale up the use of the smart grid technology in the Netherlands. After all, a comprehensive overview of drivers and barriers in the Dutch context decreases the ambiguity concerning smart grid technologies and may act as a guideline for organisations when they are assessing the situation-specific drivers and barriers of possible smart grid implementation or upscaling. Subsequently, after analysing the assessment of the situation-specific drivers and barriers organisations are able to make a deliberate choice whether to implement smart grid technologies or not.

§ 1.6. Research outline

The outline of this master thesis is as follows. Chapter 2 of this thesis presents the theoretical framework for this research. This chapter discusses the energy transition and smart grids, but mainly focuses on the specific theoretical lens used in this research (i.e. the drivers and barriers-perspective). Chapter 3 explains and discusses the methodology used in this research and the studied case. Afterwards, Chapter 4 presents the research analysis and results of the used research method based on the drivers and barriers-perspective. This thesis ends with a conclusion and discussion in Chapter 5 in which the research question is answered. Furthermore, this chapter discusses the theoretical implications, the practical recommendations, methodological limitations and suggestions for further research.

2. Theoretical framework

This chapter provides the theoretical background for this research. At first, this chapter explores the energy transition in general. Moreover, this chapter elaborates on the theoretical perspective used in this thesis: the drivers and barriers of the energy transition. Finally, the chapter elaborates on the smart grid concept, after which the chapter ends with the introduction of the conceptual model of this thesis.

§ 2.1. The energy transition

The specific transition this research focuses on is the energy transition. The energy transition describes the shift from a fossil fuels-based energy system towards a decarbonized renewables-based energy system (Naus et al., 2015; Leach, 1992; Wolsink, 2018; Schubert, 2017; Hauff et al., 2014). The renewables-based energy system is based on generating power from mostly solar and wind sources. However, geothermal, biomass and hydro sources are expected to gain importance as renewable energy sources in the near future (Rifkin, 2015).

In order to thoroughly understand the energy transition, it is important to realize that the energy transition is a socio-technical transition. The concept socio-technical system is used to emphasize that a variety of social and technical elements are interrelated and dependent on each other (Markard et al., 2016). Thereby, change in one driver or barrier may entail the change of other drivers and barriers due to their interconnectedness (Markard et al., 2016; Ahlborg & Hammar, 2014; Arens et al., 2017). Socio-technical systems consist of different actors (e.g. the consumers, energy companies, norms, energy regulations), (political) institutions and the infrastructure (Geels, 2012; Markard et al., 2016; Bolton & Foxon, 2015). Its multifaceted, interrelated and interdependent character makes that a socio-technical change is hard to put through, since it requires interlinked changes in many elements of the system in order to establish a fundamental shift or structural change (Geels & Schot, 2010; Van den Bergh et al., 2011). Therefore, it is hard to transform original barriers (e.g. technological and regulatory) into drivers of the energy transition (Bell et al., 2014; Heyen & Wolff, 2019; Zhao et al., 2016). After all, influential stakeholders in the energy industry may be part of, and locked into, the socio-technical energy system, whereby they are not in a position to effect change in order to stimulate the energy transition (Bell et al., 2014).

Furthermore, the socio-technical landscape, consisting of macro-economics, deep cultural patterns, macro-political developments etc. is a key source of the transformation dynamics (Smith & Stirling, 2010; Geels, 2004; Geels & Schot, 2010; Geels, 2005; Geels et al., 2017). Changes at the landscape level usually take place slowly over multi-decade timescales (Grubler et al., 2016) and are often driven by politics and the power gradients between key stakeholders supporting different infrastructures or technologies (Li & Strachan, 2017; Fouquet & Pearson, 2006, Sovacool, 2009; Fouquet, 2010; Wilson & Grubler, 2011). The socio-technical landscape may therefore act as a rigid barrier of the energy transition, because changes in the socio-technical landscape do not happen overnight (Zhao et al., 2016). Briefly stated, socio-technical transitions indicate that technological innovation and social change are inseparably linked through a process of co-evolution (Naus, 2017).

§ 2.2. The drivers and barriers-perspective

The definitions of the drivers and barriers are as follows: drivers are the factors accelerating the use of transition-applications, while barriers are the factors impeding the use of those applications (Fleiter et al., 2011). Transition applications are applications or technologies that support the energy transition (Fleiter et al., 2011). Ahlborg and Hammar (2014) define the concepts of drivers and barriers as factors that enhance or hinder the wished-for development. This thesis uses the definition by Fleiter et al. (2011), because this research focuses on the factors enhancing and hindering a (possible) transitional technology (i.e. smart grids).

Within academic literature different taxonomies of drivers and barriers have been developed. In the following paragraphs, these taxonomies are presented and afterwards the definitions used in this thesis are introduced.

§ 2.2.1. Drivers

§ 2.2.1.1. Economic drivers

Economic drivers involve the monetary aspects of the energy transition (Trianni et al., 2016). The first important economic driver of the energy transition is the cost reduction which results from more efficient/lower energy use (Abdmouleh et al., 2017; Lee, 2015; Sorrell et al., 2004). After all, using energy more efficiently results in less energy used, which results in lower energy costs (Thollander & Ottosson, 2008; Lee, 2015). Since organisations tend to strive for low energy costs, the energy cost reduction is an economic driver of the energy transition (Thollander & Ottosson, 2008; Lee, 2015). For the energy producers, energy efficiency is wished-for as well, since less transport costs for example lead to higher margins for the producing parties (Lee, 2015; Thollander & Ottosson, 2010). This economic driver applies to smart grids as well. By interconnecting (locally) generated energy, a smart grid helps to increase the stability and resilience of the entire electrical power system, while the conversion and transport losses are minimized (TU Delft, n.d.). Furthermore, the decentralization of the energy system and the corresponding decreased dependency on centralized power plants is an economic driver of the energy transition (TU Delft, n.d.; IEA, 2019; Engelken et al., 2016; Peças Lopes et al., 2007). This decentralization is an economic driver, since hereby, for instance, the economic losses in case of contingencies at the centralized power plants are restrained (Peças Lopes et al., 2007). Moreover, the fact that consumers become involved in the production of energy by (partly) generating their own energy decreases their dependency on the big energy companies concerning fluctuating energy prices (Engelken et al., 2016). This economic driver applies to smart grids as well, because smart grids help to decentralize the energy system by facilitating a platform via which energy from different kinds of sources (e.g. centralized power plants, electricity generated by consumers etc.) is integrated into one grid (Wurtz & Delinchant, 2017). In this way, smart grid technologies help to decrease the dependency on centralized power plants by supporting the decentralisation of the energy system (Phuangpornpitak & Tia, 2013). In view of the above, this thesis uses the following definition of the economic drivers of the energy transition: Economic drivers are all of the drivers concerning monetary and efficiency aspects regarding the energy transition.

§ 2.2.1.2. Organisational drivers

The awareness regarding the energy transition within an organisation may act as an important organisational driver of the energy transition (Cagno et al., 2013). Awareness represents the status that decision-makers feel the urge of the energy transition and are aware of the (monetary) benefits coming from shifting towards a renewables-based energy model (Cagno et al., 2013; De Almeida et al., 2003). After all, if the decision-makers of an organisation feel the urge and are aware of the benefits, organisations are more likely to invest in transitional technologies, because decision-makers prefer to invest in technologies which they deem necessary and beneficial (Cagno et al., 2013). This (possible) organisational driver applies to smart grids as well. Awareness regarding the urge and the possible benefits of smart grid implementation stimulates organisations to implement smart grid technologies, since the tendency to implement smart grid technologies increases as the decision-makers feel the urge of smart grid deployment and are aware of its benefits (Luthra et al., 2014). Moreover, the competences and skills of the personnel and the managers of an organisation are organisational drivers of the energy transition as well (Cagno et al., 2013; Cainelli et al., 2015). The presence of the appropriate skills, competences and knowledge in order to exploit a transitional technology makes its implementation less complex (Cagno et al., 2013). As a result, organisations are more inclined to implement such technologies (Cagno et al., 2013). Regarding smart grid implementation, the presence of appropriate skills and competences among the personnel (e.g. technological skills and knowledge to integrate the renewables into the grid) is a (possible) organisational driver. After all, having an appropriately skilled workforce encourages organisations to implement smart grid technologies, since its implementation becomes less complex (Luthra et al., 2014). However, if an organisation lacks those skills, competences and knowledge, vocational training helps to develop them (Trianni et al., 2016). Vocational training is distinguished in 1) programs of education and training for the personnel of an organisation and 2) the technical support offered by an external party (Trianni et al., 2016). Using vocational training, the personnel of the company obtain the required skills, competences and knowledge in order to exploit the latest transitional technologies, so that the skills, competences and knowledge of an organisation become an organisational driver of smart grid implementation (Trianni et al., 2016). Once the personnel are more skilled and competent, the implementation of transitional technologies becomes less complex, making organisations more inclined to implement smart grid technologies (Luthra et al., 2014; Trianni et al., 2016). In view of the foregoing, this thesis uses the following definition of organisational drivers: Organisational drivers are the drivers related to the behaviour, competences, skills and knowledge of a specific organisation regarding the energy transition.

§ 2.2.1.3. Technological drivers

The availability of adequate transitional technologies qualifies as a technological driver of the energy transition (Cagno et al., 2015). If a transitional technology has no significant drawbacks and offers significant benefits, organisations are more likely to implement that specific technology (Lee, 2015; Cagno et al., 2015). Meanwhile, if the technologies are still in the development phase and not perfectly adequate, the ambiguity regarding the technology might stop an organisation from implementing it (see § 2.2.2.3. for further explanation) (Cagno et al., 2015; Lee, 2015). Furthermore, the fact that a transitional technology is available and suitable to the organisational context is essential for the successful implementation of the technology (Cagno et al., 2015; Lee, 2015). After all, the availability and suitability of a transitional technology makes it easier to implement a technology in the organisational context, because the technology can be implemented without the need of a radical change in the technological infrastructure of an organisation (Cagno et al., 2015). Therefore, organisations are more inclined to implement such technologies. Hence, the availability and suitability of a transitional technology are a technological driver of the energy transition (Lee, 2015; Cagno et al., 2015). Smart grid technologies provide a platform/technological environment which allows connecting and using smartly intermittent renewables thanks to an energy network in which the fluxes of energy are multidirectional and massively orchestrated by information and communication technologies (Wurtz & Delinchant, 2017). The technological environment of the smart grid thereby supports an energy system in which the (former) consumer can become producer and consumer (i.e. prosumer) simultaneously (Lösch & Schneider, 2016; Mah et al., 2012; Wurtz & Delinchant, 2017). In this way, the development of smart grid technologies leads to the realization of the full potential of individual technologies (e.g. renewables) supporting non-conventional power generation. Therefore, the potential of smart grid technologies is a technological driver of the energy transition (Luthra et al., 2014; Popovic-Gerber et al., 2012; Brown & Zhou, 2013). In view of the above, the following definition for technological drivers is used in this thesis: Technological drivers are the factors related to the availability, adequacy and characteristics of specific transitional technologies, which are drivers of the energy transition.

§ 2.2.1.4. Regulatory drivers

Regulatory drivers involve all norms, standards and governmental facilities aimed at stimulating enterprises towards the use of renewables-based energy, such as legal restrictions concerning the use of fossil fuels-based energy, taxes for emissions of greenhouse gas, possible subsidies for energy efficient projects, special purpose loans and guarantees for specific risks regarding transitional technologies (Trianni et al., 2016; Cagno et al., 2015; Reina & Kontokosta, 2017; Johansson & Thollander, 2018; Sudhakara Reddy, 2013). Those types of regulation are encouraging the use of transitional technologies in two different ways. First of all, some norms and standards discourage or prohibit the use of fossil fuels-based energy use and the related greenhouse gas emissions (e.g. legal constrictions, taxes) with the imposition of monetary sanctions (e.g. taxes, fines) for fossil fuels-based energy use (Trianni et al., 2016; Sudhakara Reddy, 2013). However, since organisations try to avoid monetary sanctions, these sanctions also encourage using renewables-based energy instead of fossil fuels-based energy (Sudhakara Reddy, 2013; Trianni et al., 2006). Secondly, some regulations are actively promoting the use of transitional technologies by offering the opportunity for financial support (e.g. subsidies, loans, guarantees) if organisations implement such transitional technologies (Reina & Kontokosta, 2017; Johansson & Thollander, 2018; Sudhakara Reddy, 2013). Thereby, the effects of the economic barriers of transitional technologies (e.g. the required costs) are restrained (Friedman & Sreedharan, 2010), so that organisations are more inclined to implement transitional technologies (Johansson & Thollander, 2018; Sudhakara Reddy, 2013). These regulatory drivers apply to smart grids as well. Especially in Europe, where the effects of climate change and the need for the energy transition are promoted extensively (Abdmouleh et al., 2017). This has resulted into the implementation of incentive regulation concerning the development of the distributed network especially for renewable energy sources (Cossent et al., 2009). Furthermore, on the national scale the Klimaatakkoord (Klimaatakkoord, 2019) is a regulatory driver of the application of transitional technologies (e.g. smart grids). After all, the greenhouse gas emissions have to be reduced and smart grid technologies might help doing so (Zhou et al., 2016; Saad et al., 2019; Mylrea, 2017). Moreover, the Dutch government subsidizes smart grid projects in order to guide and encourage the development of the smart grid technology (e.g. Energieplus.nl, 2014). Finally, regulation considering data protection (e.g. EU General Data Protection Regulation) is a regulatory driver of smart grids as well, since this regulation helps to restrain the privacy and security issues related barriers of smart grid implementation (see § 2.2.2.3. for further explanation of the privacy and security issues). In view of the above, this thesis uses the following definition of regulatory drivers: Regulatory drivers involve all norms, standards and (financial) facilities imposed by governmental authorities which are drivers of the energy transition.

§ 2.2.2. Barriers

§ 2.2.2.1. Economic barriers

The high required investment costs for transitional technologies are an economic barrier of the energy transition (Cagno et al., 2013; Cagno et al., 2015). High required investment costs deter organisations from investing in transitional technologies (Cagno et al., 2013; Fleiter et al., 2011). Due to its complexity (Good et al., 2017), smart grid implementation requires high investments in order to develop the smart grid technology transfer, provision of adequate infrastructure, communication systems, hiring of skilled professionals (e.g. engineers and other professionals), R&D work and the integration of renewable energy sources within the smart grid network appropriately (Luthra et al., 2014). Since smart grids require a lot of investments, the lack of capital available, is a barrier of its implementation (Cagno et al., 2013). If organisations are not able to find a budget in order to develop and implement smart grid technologies, they are logically not inclined to do so (Luthra et al., 2014). Furthermore, the hidden costs are an economic barrier of (the implementation of) transitional technologies (O'Malley et al., 2003; Sorrell et al., 2000). Hidden costs are costs such as staff retraining, potential loss of reliability and other costs that may not be considered in assessing the costs of implementing a particular technology (O'Malley et al., 2003; Sorrell et al., 2000). However, if those costs are considered, they may make the adoption of a particular transitional technology economically unfeasible (O'Malley et al., 2003; Sorrell et al., 2000). The hidden costs for the development and implementation of smart grid technologies are high as well due to the fact that a smart grid is changing the energy infrastructure radically, which requires an organisation to invest in staff retraining (Luthra et al., 2014). Moreover, the inherent riskiness of the pay-offs is an economic barrier of transitional technologies as well (O'Malley et al., 2003; Harris, 2000; Fleiter et al., 2011). After all, even if a transitional technology is thought to be cost effective, an organisation may not take on the project because the return is considered too low given the business risk. The business risk covers the sectoral economic trends, individual business economic trends and the financing risk (O'Malley et al., 2003). As the smart grid technology is still emerging and standards are not in place, its features are not proved yet (Kaushal, 2011) and the technology needs to validate estimates of customer load with customer data (Woychik & Martinez, 2012). Hence, the financial risks of smart grid implementation are deemed considerable (EPRI, 2011; Tricoire, 2015). In sum, the uncertainty about the returns on capital investments is an economic barrier of smart grid implementation (Luthra et al., 2014). Moreover, a long payback period of the high required investments in transitional technologies is an economic barrier of the energy transition as well (Lee, 2015; Harris, 2000). The long payback period indicates that it takes a long time for organisations to earn back their initial investments, while the returns on investments are insecure as well (Fleiter et al., 2011). A long payback period stimulates organisations to invest in projects with a shorter payback period in order to make short-term profits (Fleiter et al., 2011; Harris, 2000). The payback period of smart grid implementation is relatively long compared to the high initial required investment (EPRI, 2011). Thereby, the long payback period is an economic barrier of smart grid implementation as well (Luthra et al., 2014). In view of the above, this thesis uses the following definition of the economic barriers: Economic barriers are all the barriers concerning the monetary aspects of the energy transition.

§ 2.2.2.2. Organisational barriers

The conservative corporate culture of an organisation may act as an organisational barrier of the energy transition (Kiefer et al., 2019; Hillary, 2004; Rohdin & Thollander, 2006; Sorrell et al., 2000), since transitional technologies are innovative technologies and their implementation requires an innovation-orientated approach of the organisation. Therefore, a conservative corporate culture (i.e. aversion towards innovation) may act as an organisational barrier of (the implementation of) transitional technologies, because organisations with a conservative corporate culture are not inclined to invest in innovative technologies (Hillary, 2004). The innovative or conservative corporate culture may be related to the incomplete information regarding costs and benefits, unclear information by technology providers, trustworthiness of the information source and information issues on energy contracts which organisations have to work with (Cagno et al., 2013; De Almeida, 2003). After all, if an organisation does not have complete information (i.e. knowledge) regarding the necessity and the business opportunities of the energy transition, a sub-optimal level of transitional investment could result (O’Malley et al., 2003). The quality of energy information available to an institution might influence its approach regarding the energy transition. The lack of proper information leads to the status that the decision-makers simply ignore the necessity of and the possible benefits from the implementation of transitional technologies (i.e. lack of awareness). As a result, the energy transition is given a lower priority by the management team of an organisation (Trianni & Cagno, 2012). Additionally, this leads to lack of awareness among the personnel of the organisation (Cagno et al., 2015; Rohdin & Thollander, 2006). The lack of personnel awareness refers to the change-resisting attitude of personnel, whereby it is difficult to re-modify their established routines (Cagno et al., 2015). All in all, energy organisations provided with (quite) complete information are likely to have a more pro-active transitional approach, while organisations with less precise information tend to have a less pro-active transitional approach, since they are less aware of the urge for and the potential (monetary) benefits of the implementation of transitional technologies (O’Malley et al., 2003; Sorrell et al., 2000). Hence, imperfect information and the related lack of awareness within an organisation is an organisational barrier of the energy transition (Cagno et al., 2015). This barrier applies to the implementation of smart grids as well, since the lack of innovativeness and awareness in the energy industry is a main organisational barrier of smart grid implementation (Luthra et al., 2014). Instead of looking for innovative solutions to the problems of societal benefits, traditional energy companies prefer to work with traditional methods for safe and guaranteed returns on investments (Luthra et al., 2014; Good et al., 2017). Energy companies are afraid that the implementation of smart energy solutions in a previously well-functioning environment reduces its reliability and evokes worries about possibly losing their tradition customers (HAW Hamburg, 2013). The fear of innovating (i.e. conservative corporate culture) thereby acts as an organisational barrier of smart grid implementation, since the conservative corporate culture hampers the required innovation in technologies and systems like smart meters, energy controllers and communication technologies in order to improve the efficiency and profitability of a smart grid (Siano, 2014). Moreover, the lack of the required skills, competences and knowledge in order to implement a transitional technology is an organisational barrier as well (Kangas et al., 2018; Brunke et al., 2014; Johansson & Thollander, 2018). After all, if the personnel of an organisation lack the competences, skills and knowledge to work with innovative transitional technologies (e.g. technological skills to implement the technologies), organisations are discouraged to implement such technologies, since implementing such technologies is deemed too complex (Kangas et al., 2018; Brunke et al., 2014; Johansson & Thollander, 2018). This organisational barrier applies to smart grids as well, since smart grid implementation requires continuous demand for trained engineers and managers guiding the (radical) change and developing new skills in analytics, decision support and data management (Luthra et al., 2014; Kaushal, 2011). Even if organisations tend to implement smart grid technologies, the lack of the required skills, competences and knowledge might stop them from actually implementing smart grid technologies (Dedrick & Zheng, 2011). However, as stated before, vocational training may help to turn this organisational barrier into an organisational driver of the energy transition (Trianni et al., 2016). In view of the above, this thesis uses the following definition of organisational barriers: Organisational barriers are the barriers related to the awareness, priorities, competences, skills, knowledge and culture of an organisation regarding the energy transition.

§ 2.2.2.3. Technological barriers

The lack of adequate or available transitional technologies may act as a technological barrier of the energy transition (Cagno et al., 2015; Lee, 2015). If a transitional technology has significant weaknesses, organisations are discouraged to implement that specific technology (Lee, 2015; Cagno et al., 2015). This inadequacy of technology applies to smart grids as well, because the smart grid technology has some issues regarding security and privacy (Weck et al., 2017; Leal-Arcas et al., 2017). The security and privacy issues are qualified as technological barriers, since the sharing of personal data from end users via the internet is a part/a side-effect of smart grid technologies. After all, smart grids may be subjected to hacker-attacks because many of the technologies being implemented to support smart grids projects, like smart meters, sensors and advanced communication technologies are interoperable and open (Weck et al., 2017; Leal-Arcas et al., 2017). Frequent smart metering data collection and analysis helps improving energy efficiency and framing future policy. However, this comes at the cost of user privacy, because cyber systems are particularly vulnerable to worms, viruses, denial-of-service attacks, malware, phishing, and user errors that compromise the integrity and the availability of the smart grid network (Luthra et al., 2014; Ling & Masao, 2011; Fan et al., 2013). Therefore, developing and implementing smart grid security is a challenging task, considering the scale of the potential damage that could be caused by cyber-attacks (Luthra et al., 2014; Strüker & Kerschbaum, 2012). In the Netherlands the national regulatory authorities for the energy sector are already working jointly together with the Data Protection Authority on solving the data security and privacy issues of smart grids (Van Asselt, 2014; Elliott, 2013; UNFCC, 2017; Leal Arcas et al., 2017). However, since no real solution has been developed yet, the data security and privacy issues are a technological barrier of smart grid implementation (Allhoff & Henschke, 2018; AboBakr & Azer, 2017). Furthermore, the lack of an adequate technological infrastructure is a technological barrier of smart grid implementation. An important feature of smart grid technologies is the interconnection between a large number of energy distribution networks, power generating sources and consumers (Fan et al., 2013; USAID, 2010). However, the relative novel nature of the emerging smart grid technology causes that the ancillary technological facility cannot cop up with the (technological) requirements of smart grids yet (Yu et al., 2012). Thereby, the lack of an appropriate technological infrastructure discourages organisations from implementing smart grid technologies and is a technological barrier of smart grid implementation (Yu et al., 2012). In view of the above, this thesis uses the following definition of technological barriers: Technological barriers are the barriers related to the availability, adequacy and the characteristics (e.g. privacy and security issues) of specific transitional technologies.

§ 2.2.2.4. Regulatory barriers

The lack of regulatory incentives (e.g. subsidies) from governmental authorities regarding the energy transition are a regulatory barrier of the energy transition (O'Malley et al., 2003; Hirst & Brown, 1990). Transitional technologies require high investment costs (Cagno et al., 2013; Fleiter et al., 2011). Therefore, the "punishment" for using fossil fuels-based energy (e.g. high taxes and legal restrictions regarding greenhouse gas emissions) or the (monetary) governmental support for renewables-based energy use (e.g. subsidies, guarantees) might be necessary in order to ensure that organisations implement transitional technologies, while the lack of such may act as a regulatory barrier of the energy transition (Trianni et al., 2016; Cagno et al., 2015; Reina & Kontokosta, 2017; Johansson & Thollander, 2018; Sudhakara Reddy, 2013). In addition, the lack of a clear legal framework regarding the energy transition is a regulatory barrier of the energy transition, because without a clear and comprehensive regulatory and legal framework renewables-based energy cannot be used to its full potential (Painuly, 2001; Karatayev et al., 2016; Castagneto Gissey et al., 2018). After all, the lack of a comprehensive regulatory and legal framework leads to ambiguity regarding the legal restrictions and regulations regarding energy use (Painuly, 2001; Karatayev et al., 2016). This ambiguity deters organisations from implementing transitional technologies and is therefore a regulatory barrier of (the implementation of) transitional technologies (Painuly, 2001; Karatayev et al., 2016; Rosso-Cerón & Kafarov, 2015). Although the Paris Agreement (UNFCCC, 2015) and the Klimaatakkoord (Klimaatakkoord, 2019) emphasize the importance of the energy transition, a clear and comprehensive framework regarding smart grids has not been laid down in law yet. However, in the Netherlands the Omgevingswet is under development and is expected to come into effect in 2021. With this, a step is taken towards a clear regulatory framework regarding the energy transition (Rijksoverheid, n.d.). The current lack of a clear and comprehensive regulatory and legal framework regarding smart grids and the corresponding privacy and security issues nevertheless deters organisations from implementing smart grid technologies and is thereby a regulatory barrier of smart grid implementation (Muench et al., 2014; May et al., 2015; Römer et al., 2012). In view of the above, this thesis uses the following definition of regulatory barriers: Regulatory barriers involve the (lack of) norms, standards and facilities as imposed by governmental authorities which are barriers of the energy transition.

However, it is important to realize that drivers and barriers of the energy transition are interrelated (Ahlborg & Hammar, 2014). After all, original drivers can become barriers and vice versa (Arens et al., 2017). For instance, the technological skills of an organisation may be insufficient and thereby form an organisational barrier. However, after training the employees in order to exploit the latest transitional technologies, this organisational barrier may become a driver.

§ 2.3. Smart grids

The smartening of the grid has been taking the world by storm over the last decade (Papadimitriou et al., 2019). Smart grids are defined as '*electrical networks that enable two-way communication and power exchange between electricity consumers and producers, utilizing information and communication technology (ICT) to manage demand, and ensure safe and secure electricity distribution'* (Eid et al., 2017, p. 329; Hall & Foxon, 2014). Data is being exchanged between all of the players in the smart grid network, through which all the parts of the smart grid become interconnected. This makes it easier to integrate renewables-based energy sources and to use the traditional power plants as efficient as possible, since the supply- and demand-side can be balanced across the entire grid (see *Figure 1* for a visual representation of the smart grid structure) (Zhou et al., 2016; Saad et al., 2019; Mylrea, 2017). Moreover, smart grid technologies increase grid efficiency, sustainability, self-healing, safety, reliability and help developing new models for hybrid energy sources and thereby support the energy transition (Adefarati & Bansal, 2019; Wang et al., 2017; Kabalci et al., 2019; Solomon & Krishna, 2011; IRENA, 2019; Lösch & Schneider, 2016; Ghasempour, 2019). All in all, smart grids are changing the energy system from a 'dumb' to a 'smart system' (Blumsack & Fernandez, 2012; Hall & Foxon, 2014).

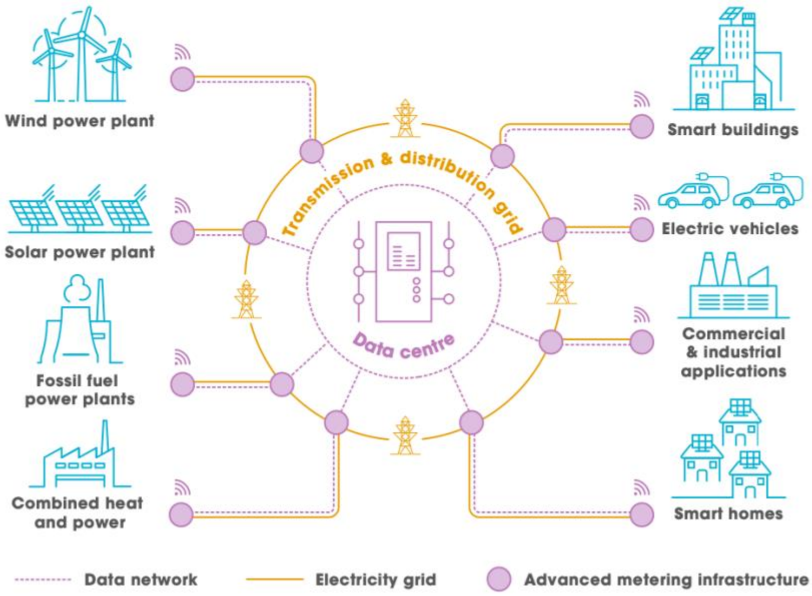

Figure 1. Smart grid structure (adopted from IRENA (2019) based on Höfling and Koschel (2019))

Furthermore, smart grids might be important, considering that a renewables-based energy system cannot replace the traditional fossil fuels-based energy system overnight (Höfling & Koschel, 2019). After all, the most important renewable energy sources (i.e. solar and wind energy) are subject to significant fluctuations and since all households depend on energy supply, an immediate switch to a renewables-based energy system ultimately leads to an energy deficit (Höfling & Koschel, 2019). During the transition period, the traditional energy system (i.e. fossil fuel power plants) therefore (for now) needs to be used in order to prevent the emergence of deficits (Höfling & Koschel, 2019; Lilis et al., 2017). During this period, smart grids can help to use the fossil fuel power plants as efficient as possible, by only using them to the extent to which the renewables-based energy falls short (Islam et al., 2014).

§ 2.4. Conceptual model

Based on the theoretical drivers and barriers-perspective and the discussed concepts, the following conceptual model is developed for this research (see *Figure 2*). We are in the middle of an energy transition from a fossil fuels-based energy system towards a renewables-based energy system (Sandbag & Agora, 2020). In academic literature, the potential of the implementation of smart grid technologies to support the energy transition is discussed extensively (e.g. Papadimitriou et al., 2019; Adefarati & Bansal, 2019; Höfling & Koschel, 2019). However, smart grid technologies are not implemented on a massive scale yet due to the technological uncertainty regarding smart grid technologies (Tricoire, 2015). Drivers encourage the implementation of smart grid technologies, while barriers obstruct the implementation of smart grid technologies (Fleiter et al., 2011). Moreover, drivers and barriers of the energy transition are interrelated (Ahlborg & Hammar, 2014), since original drivers can become barriers and vice versa (Arens et al., 2017). Furthermore, based on the theoretical framework, four different driver dimensions could be distinguished: 1) the economic dimension, 2) the organisational dimension, 3) the technological dimensions and 4) the regulatory dimension. However, no order of importance among the different driver and barrier dimensions could be distinguished (see *Figure 3*).

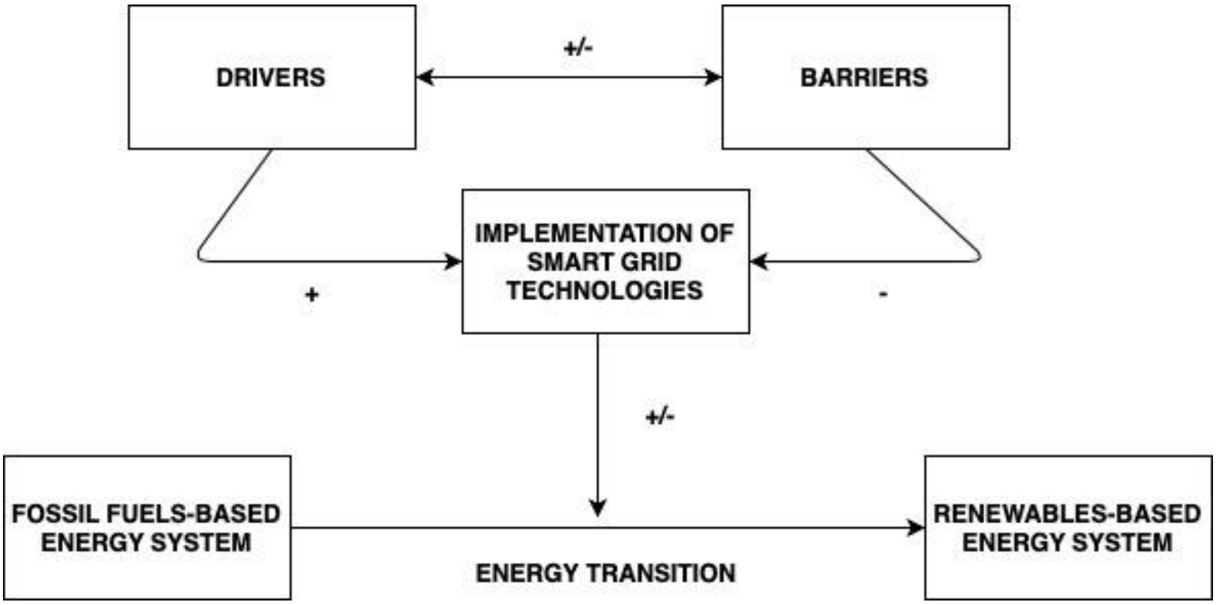

Figure 2. Proposed conceptual model of the drivers and barriers of smart grid implementation

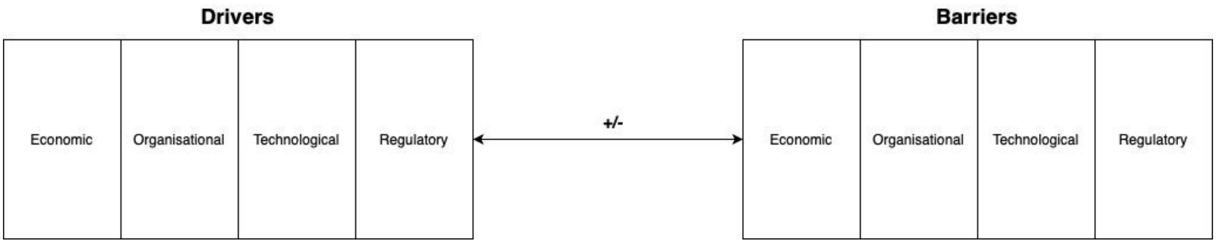

Figure 3. Proposed conceptual model of the drivers and barriers of smart grid implementation – zoomed into the driver and barrier dimensions

3. Methodology

This chapter describes the methodological approach of this thesis. First of all, the general approach of this research is discussed, whereby the studied case is introduced and the qualitative approach is discussed. Next, the specific methodological instruments (i.e. semi-structured expert interviews and document analysis) are discussed. Finally, this chapter describes the procedure of data collection and analysis.

§ 3.1. Research approach

Explorative case study

An explorative case study is conducted. This method has been chosen, because it suits explorative research questions and research which arises out of the desire to understand complex contemporary social phenomena (i.e. the energy transition) (Yin, 2018). Moreover, an exploratory case study not only makes the identification of the actions of an actor (*what*) possible, but also helps to understand the underlying ideas of his actions (*why*). This is crucial in a study on the drivers and barriers of certain behaviour (Yin, 2018). Understanding both the *what* and the *why* is important in order to identify the drivers and barriers of smart grid implementation (*what*) and to understand how those drivers and barriers contribute to or hinder smart grid development (*why*).

Semi-structured expert interviews

The primary data is obtained by conducting semi-structured interviews. A semi-structured interview has a sequence of themes to be covered, as well as suggested questions (i.e. the interview protocol (see *Appendix 3* for the interview protocol) (Bernard, 2011)). The sequence of themes which have to be covered in all of the interviews are the four dimensions of drivers and barriers as presented in Chapter 2. However, a semi-structured interview also offers the opportunity to change the sequence of questions and to divert from the suggested questions, as a result of the answers given by the interviewees (Kvale, 1996; Bernard, 2011; Yin, 2018; Mason, 2002). The latter is essential in order to gather knowledge on a complex and novel research phenomenon such as the drivers and barriers of smart grid implementation in the Dutch context (Yin, 2018; Gordon, 1992). Briefly stated, semi-structured interviews enable an in-depth understanding of the drivers and barriers of smart grid implementation and its potential as a supporting factor of the energy transition (Eisenhardt & Graebner, 2007; Yin, 2018). In this thesis, insights of experts within the energy sector are analysed (Przyborski & Wohlrab-Sahr, 2008). Expert interviews offer an effective means of quickly obtaining good results (Bogner et al., 2009). After all, experts are familiar with being in the public eye, curious about the topic and the field of research, silently aware of the scientific and/or political relevance of their field of activity or personal achievements and want to "make a difference" which makes it easy to encourage and motivate them to participate in scientific research in their field of expertise (Bogner et al., 2009).

The IPIN-case

The case studied in this thesis is the Innovation Program Intelligent Nets (IPIN), subsidized by the Dutch government (RVO, 2013). In this program, different actors in the energy sector worked together in order to explore on smart grid technologies. The IPIN-program formed the basis for further research into the potential of smart grids which is undertaken by IPIN in association with TKI Urban Energy (RVO, n.d.). The IPIN-program was selected for this thesis, because this program provides a good representation of smart grid use in the Dutch context due to the fact that the program covered twelve different testing grounds throughout the Netherlands in the period 2011-2016 (RVO, n.d.). Although the IPIN-program is a few years old, it can still be analysed, since events in the past can be analysed thoroughly via interviews with the representatives from the involved actors having (personal) experience with the specific cases (i.e. oral history) (Janesick, 2010; UC Santa Cruz, n.d.).

In this thesis, the following specific testing grounds within the overarching IPIN-program were studied:

1) Energy Neutral Heijplaat (Heijplaat);
2) The Couperus Smart Grid (Couperus);
3) Intelligent Network Zeewolde (Zeewolde), and
4) Proeftuinen Smart Energy Collective & Co (ProSECco).

The first project is the Heijplaat-project (RVO, 2013a; Topsector Energie, n.d.). The goal of the Heijplaat-project was to renovate a neighbourhood in Rotterdam into a sustainable and energy neutral neighbourhood (RVO, 2013a; Topsector Energie, n.d.). Another goal of this project was to gain insight in the possibilities and the feasibility to lower the energy consumption and integrate renewables, using smart grid technologies (RVO, 2013a; Topsector

Energie, n.d.). The second project studied is the Couperus-project (RVO, n.d.(a); Topsector Energie, n.d.(a)). Couperus is a residential complex with around 300 residences in Den Haag (RVO, n.d.(a)). The main goal of the project was to gain insight into how the energy infrastructure needs to be set up so that all parties involved in the energy system – including the consumer – benefit maximally from smart grid deployment. The third project is the Zeewolde-project (RVO, n.d.(b); Topsector Energie, n.d.(b)). In Zeewolde, the involved actors took the initiative to develop an intelligent network for the electricity supply (RVO, n.d.(b); Topsector Energie, n.d.(b)). The main goal was the full local use of locally generated sustainable energy (RVO, n.d.(b); Topsector Energie, n.d.(c)). The fourth project is the ProSECco-project (Topsector Energie, n.d.(c); RVO, n.d.(c)). In the ProSECco-project intelligent nets were studied and demonstrated in practice, whereby combinations of services and techniques were developed (Topsector Energie, n.d.(c); RVO, n.d.(c)). The main goal of the ProSECco-project was to determine the economic feasibility and the social acceptance of smart grid technologies (Topsector Energie, n.d.(c); RVO, n.d.(c)).

§ 3.2. Data collection procedure

The key selection criterion is that the interviewees have experience with smart grid technologies and with the decision-making process prior to the implementation of smart grids. The first criterion is important to get a proper understanding on the potential of smart grid technologies to support the energy transition. The second criterion is important to identify how the drivers and barriers of smart grid implementation in the Dutch context influence smart grid development in the Netherlands.

Next to the primary data, secondary data is analysed in this research as well. The secondary data analysed in this thesis are, publicly available, case-specific governmental reports. Analysing multiple types of data (i.e. data triangulation (Golafshani, 2003)) is beneficial, because it helps to get multiple perceptions about a single reality. In this way, a more truthful image of an event is obtained (Healy & Perry, 2000; Scott, 2007; Cohen & Manion, 1994). Data triangulation thus helps to increase the reliability of this research, because it increases the probability that repeating the research procedure would produce identical or similar research results (Bush, 2012; Aspinwall et al., 1994). Furthermore, data triangulation improves the (construct) validity of the research. Different sources are likely to yield different kinds of insights into the drivers and barriers of smart grids, whereby the data is better able to actually represent the phenomenon under investigation (Mishra & Rasundram, 2017; Bush, 2012).

The research subjects (i.e. interviewees) are assembled using the snowball sampling-method. The IPIN-program has a few spokespersons who were approached for questions regarding the project. In this research, these initial experts were used to recruit additional interviewees with expertise regarding the specific smart grid cases (Etikan et al., 2015; Heckathorn, 2015; Bogner et al., 2009).

In order to conduct a valid and comprehensive explorative research, ten interviews are taken and four case-specific governmental reports are analysed. The ten interviewees consist of employees of energy companies, grid operators, consultancy companies and independent research organisations. The diversity of interviewees increases the reliability and the validity of the obtained data and the explanatory power of the results (Bush, 2012). One of the respondents was not involved in the IPIN-program. However, the organisation he works for was involved in the IPIN-program and the respondent had experience with smart grid implementation. For this reason, his input is considered valuable and is therefore used.

§ 3.3. Data analysis procedure

In order to transform the collected data into clear and explicit research results, the coding-method is used. Coding is a key step in qualitative data and involves the categorization of the data obtained, being the semi-structured expert interviews and the case-specific governmental reports (Yin, 2018; Stuckey, 2015; Evers, 2016; Henning et al., 2004). In order to get to the coding stage, first the interviews have to be transcribed from an audio-file into a written format. Afterwards, the interview transcripts (and the additional observational notes) are read attentively. Doing so, a general idea of the collected data and its main themes is obtained (O'Connor & Gibson, 2003).

After this step of getting to know the data, the actual coding begins. The coding phase is supported by the chosen theoretical frame of this research (i.e. the drivers and barriers-perspective). This theoretical frame provides the required guidelines and handles in order to delineate important variables, suggest inter-variables relationships and give direction to the interpretation of the actual findings (Bryman, 1995). In order to do so, the data is divided into several separate code groups, using the technology of MAXQDA 2020. In this thesis, thematic codes are used to structure the data (Evers, 2016). The initial thematic codes are deducted from the dimensions presented in the literature review as discussed in Chapter 2 (Evers, 2016; Crabtree & Miller, 1999). Thus, the specific thematic codes used are economic, organisational, technological, and regulatory drivers/barriers. However, due to the exploratory and inductive nature of this study, other thematic codes/dimensions may arise during the analysis of the data. Thematic codes are used, because they help to reach at the dimensions underlying the text and thereby help to structure the specific drivers and barriers of smart grid implementation (Evers, 2016).

In order to identify which drivers and barriers are the most important, a quantitative content analysis is conducted, which means that the code frequencies are the starting point for the analysis (Hou, 2010; Krippendorff, 2018). The codes that are assigned to a lot of text segments are classified as more important than codes assigned to a few segments. Moreover, it is important to note that multiple codes can be assigned to one text segment, because one text segment can reflect multiple codes. The analysis of the data is divided into two different levels. The first level is the dimension level. On this level, the different driver/barrier dimensions are distinguished and the relative importance is determined using visual representations of the data. Afterwards, the analysis zooms in to the factor level. On this level, the specific drivers and barriers per dimension are identified and the relative importance of those specific factors is determined using visual representations of the data.

§ 3.4. Research ethics

For this research, an informed consent form (see *Appendix 1*) is used. This informed consent guarantees that the given consent can be withdrawn, without reason, within fourteen days after the participation of a respondent. Furthermore, the respondent has the right to demand the destruction of the research data within fourteen days after participation. Moreover, the informed consent form guarantees that all of the data is treated in accordance with the applicable European and Dutch regulation. Besides, the respondents get the chance to indicate that they want to receive the research plan and the research results. Furthermore, all the interviews are anonymised before they are analysed using MAXQDA 2020, so that personal information is not exposed to the environment of MAXQDA 2020. The transparency of research goals is secured by sending all interviewees an information document (see *Appendix 2*), at least three days prior to the interview. In this information document, the research aims are described, so that the interviewees get a better understanding on the goal of this research.

4. Research analysis

§ 4.1. Research analysis on the dimension level

§ 4.1.1. Drivers

Based on the quantitative code frequency (see *Figure 4*), the societal dimension turns out to be the most important driver dimension of smart grid implementation. The importance of this dimension is illustrated by the fact that a good coupling between technologies and the demands of the end user is essential in order to develop and exploit smart grid technologies: *'In order to develop services and products in cooperation with residents and make them succeed at neighbourhood level, it is crucial to respond to the local needs of the residents. This is one of the keys to success'* (Stedin et al., 2015, p. 18). It is interesting that the societal dimension is the most important driver dimension of smart grid implementation, since this dimension could not be derived from theoretical research. The societal dimension concerns the drivers and barriers from a broad societal context and the characteristics of the energy system as such. The fact that the societal dimension cannot be derived from theoretical research is explained by the fact that the current academic debate on the drivers and barriers of the energy transition particularly focuses on the industrial/organisational perspective regarding the energy transition (e.g. Cagno et al., 2013; Trianni et al., 2016). However, the energy transition and the smartening of the grid require a socio-technical change, which not only concerns the organisations in the energy system, but requires interlinked changes in many elements of the system in order to establish the fundamental shift (Geels & Schot, 2010; Van den Bergh et al., 2011). Technological innovation in the (socio-technical) energy system and social change are inseparably linked through a process of co-evolution (Naus, 2017). Therefore, it is important to analyse the drivers and barriers coming from the broader societal context and the characteristics of the energy system as such in order to get a more comprehensive understanding of the drivers and barriers of the energy transition.

The second most important driver dimension is the technological dimension. This is not surprising considering that the technological opportunities regarding smart grid technologies are an important rationale for organisations to use smart grid technologies: *'The coordination* [author: within a smart grid system] *guarantees a stable and constant supply of electricity. This compensates for a disadvantage of sustainable energy sources: it is difficult to predict how* *much energy they will supply at a certain time in the future, and it is also difficult to adjust the power they supply'* (Stedin et al., 2016, p. 10).

The third driver dimension in line of importance is the economic driver dimension due to the fact that deploying smart grid solutions leads to efficiency benefits: *'The economy of the smart grid is that you avoid the need to make your infrastructure more robust in a smart way… You still need a good physical grid, but by adding intelligence, you are trying to postpone investments in net reinforcements. This saves costs for the grid operator'* (Interview 1, Par. 57 and 185).

The next driver dimension in line of importance is the organisational dimension. This can partially be explained with the fact that appropriate communication skills are essential to achieve success with smart grid technologies: *'A situational approach is indispensable for achieving local sustainable success, as Heijplaat clearly shows. Every neighbourhood, and within that every street, every block, every resident is different'* (Stedin et al., 2015, p. 18).

As indicated in *Figure 4*, the least important driver dimension is the regulatory dimension. This is nicely illustrated by the following statement: *'Ultimately, of course, regulation must follow developments* [author: in the energy sector]. *You can't start with regulation and say: "This is what the development has to comply with."… You shouldn't regulate it too intensive… Above all, I think that the market should do its job and that regulation shouldn't bother too much'* (Interview 2, Par. 104 and 106).

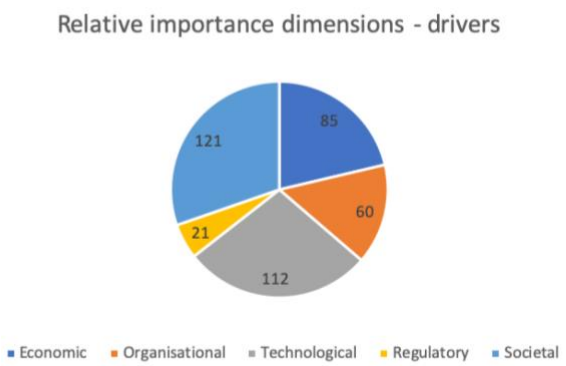

Figure 4. Visual representation of the relative importance of dimensions – drivers

§ 4.1.2. Barriers

Based on the quantitative code frequency (see *Figure 5*), the economic dimension is the most important barrier dimension of smart grid implementation. This is explained by the fact that it is hard to develop a positive business case for smart grid implementation: *'That one* [author: the business case] *is still tricky. At least, the business case is spread over several parties… Part of the value* [author: of the smart grid] *lies with the customer/end user, part with the energy supplier, part with the grid manager and part with the software party. Ultimately, it is a social business case, but it may well be that one party has to invest more than they receive in return, while it is good for the social business case, it is not good for the individual business case'* (Interview 2, Par. 42).

The second most important barrier dimension is the societal dimension. After all, in the Netherlands, the need for a smart grid is not felt throughout society yet. The end users are not (yet) interested in smart grid solutions: *'It is not yet well understood that energy is a scarce commodity that can run out and therefore needs to be managed smartly and actively, with demand-driven management as a possible control mechanism'* (Stedin et al., 2016, p. 31).

The third barrier dimension in line of importance is the technological dimension. The impact of this dimension is explained by the fact that smart grid technologies are not crystallized yet, which may lead to occasional malfunctioning: *'Analysis of the various graphs over one or more days has shown that the* [author: imbalance] *signal is not always reliable'* (Stedin et al., 2016, p. 20).

The next dimensions in line of importance are the organisational dimension, the regulatory dimension and the political dimension. The detection of a political dimension is interesting, since the political dimension could not be deducted from the literature research. The political dimension concerns the broader, overarching, political course and vision of a country regarding the energy transition. Although, the presence (Trianni et al., 2016; Cagno et al., 2015; Reina & Kontokosta, 2017; Johansson & Thollander, 2018; Sudhakara Reddy, 2013) and absence (O'Malley et al., 2003; Hirst & Brown, 1990) of adequate laws and regulations are topics which are often mentioned in the academic debate, the broader overarching political course and vision of a country regarding the energy transition is often ignored. The fact that this dimension is overlooked is explained by the tendency in academic literature to solely focus on existing laws and regulations when it comes to the governmental role (e.g. Trianni et al., 2016; Cagno et al., 2015; Reina & Kontokosta, 2017; Johansson & Thollander, 2018; Sudhakara Reddy, 2013). As a result, the more abstract overarching political vision is often overlooked. However, a country's overarching political vision directs the way a country is heading regarding the energy transition and thereby influences actors in the energy system and end users regarding their (smart) energy management. After all, changes in the socio-technical landscape (i.e. the energy system) are often driven by politics (Li & Strachan, 2017).

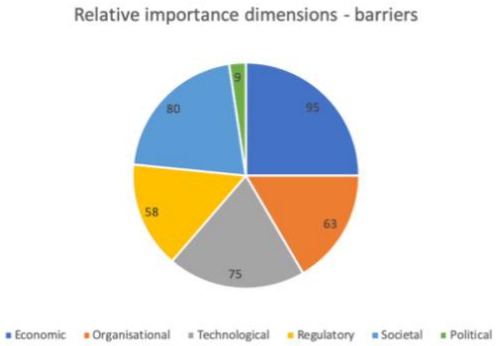

Figure 5. Visual representation of the relative importance of dimensions - barriers

§ 4.2. Research analysis on the factor level

§ 4.2.1. Drivers

§ 4.2.1.1. Economic drivers

As indicated in *Figure 6*, the most important economic driver of smart grid implementation is grid efficiency. This can be explained with the fact that by adding flexibility and monitoring capacity to the grid (smartening the grid) (see § 4.2.1.3. for further explanation), the current grid can be used more efficiently, whereby costly grid reinforcements are postponed or prevented: *'Then, based on the data you can say: "Okay, how warm is this cable? How much power is going through it right now? How warm is the outside temperature? Is it blowing as well?... So, you can load the cable much more heavily than what it was designed for. And you make a living organism out of that network…If you measure smart and if you combine data as well, you can use the grid much more efficient* [author: whereby costly grid reinforcements are prevented]*'* (Interview 6, Par. 58-60).

Another important economic driver of smart grid implementation is the presence of a clear customer proposition. If the end users are interested in buying products embedded in the smart grid, smart grid implementation will be accelerated, since cooperation from end users is essential in order to smarten the grid. This is nicely illustrated with the following example: *'In the end, if I think from the end user's perspective, somehow, he wants his own life to be easier or at least as pleasant as the solutions he has now… From the customer's point of view, it is* *smarter in terms of convenience, that it is financially interesting. Things like that'* (Interview 8, Par. 34).

The last important economic driver of smart grid implementation is the fact that a smart grid helps to control the energy costs. A smarter grid makes it possible to buy energy cheaper and thereby ultimately leads to decreasing energy costs. In regard to this driver, one of the interviewees pointed out: *'The electricity price, the energy price, naturally fluctuates sharply throughout the day, throughout the week, throughout the month, throughout the year. You can respond to that. You can shift sales from expensive to cheap moments'* (Interview 9, Par. 29). The efficiency of workforce is an economic driver of smart grid implementation as well. However, considering the quantitative code frequency (see *Figure 6*), the efficiency of workforce is not an important economic driver.

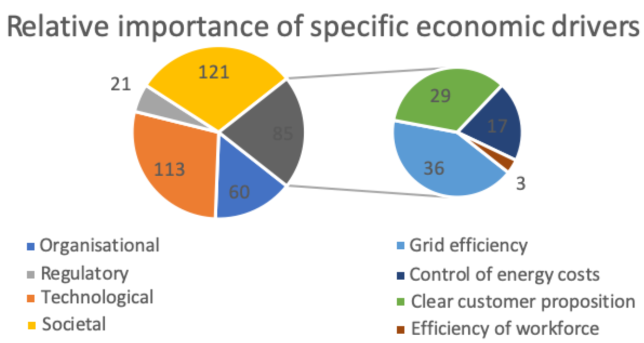

Figure 6. Visual representation of the relative importance of specific economic drivers

§ 4.2.1.2. Organisational drivers

Based on the quantitative code frequency (see *Figure 7*), the most important organisational driver is the presence of adequate communication skills among the employees/officials within organisations. After all, using appropriate communication skills helps to take away societal barriers of smart grid implementation such as privacy issues. However, it is important to adjust the communicational approach to the people you are dealing with: *'A situational approach is indispensable for achieving local sustainable success, as Heijplaat clearly shows. Every neighbourhood, and within that every street, every block, every resident is different'* (Stedin et al., 2015, p. 18). A good example of an appropriate way of communication towards the end user is illustrated by the following example: *'We set up a consultation hour, every two weeks there was an hour and a half. Then people with all kinds of energy questions could come by and I or someone else would sit there with a laptop to answer all kinds of questions'* (Interview 3, Par. 39).

Moreover, the organisational awareness regarding the need for a smart grid is an important organisational driver of smart grid implementation. The fact that organisations, especially grid operators, feel the need for a smart grid, makes them more inclined to invest in and to develop smart grid technologies: *'I think those grid operators are very aware that something has to be done, sometimes they even lag a bit behind the events'* (Interview 7, Par. 40). Image building is an organisational driver of smart grid implementation as well. However, considering the quantitative code frequency (see *Figure 7*), image building is not an important organisational driver.

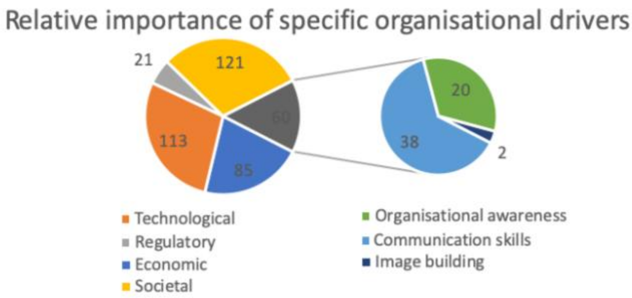

Figure 7. Visual representation of the relative importance of specific organisational drivers

§ 4.2.1.3. Technological drivers

As indicated by *Figure 8*, the fact that smart grid technologies help to decrease the energy misbalance belonging to an energy system which is increasingly dependent on irregular energy sources as wind and solar is the most important technological driver of smart grid implementation: *'The coordination* [author: within a smart grid system] *guarantees a stable and constant supply of electricity. This compensates for a disadvantage of sustainable energy sources: it is difficult to predict how much energy they will supply at a certain time in the future, and it is also difficult to adjust the power they supply'* (Stedin et al., 2016, p. 10).

Moreover, smart grid technologies help to decrease the energy misbalance by flexibilizing the demand-side of the energy system, so that the demand- and supply-side of the energy market are better aligned. This flexibilizing of the demand-side is nicely illustrated by the following example: *'Your freezer can get a signal from the energy management system, for example: "Cool a little deeper now. Then afterwards, you can shut down for a while"... You spread the load on the grid and ensure that you use energy when it is available. Certainly, for all those non-urgent processes, not time-critical processes, there is a lot to be gained* [author: by flexibilizing the demand-side]*'* (Interview 10, Par. 32).

Moreover, this flexibility of the demand-side helps to prevent congestion, which is an important technological driver of smart grid implementation as well. After all, a flexible demand-side helps to prevent excessive peaks on the grid, which otherwise lead to malfunctions: *'If you can determine sequences, or timing, or phasing or procrastination* [author: energy consumption]... *So that you do indeed not overload the net, or net boxes. Doing so, you keep the grid intact and used optimally'* (Interview 3, Par. 109).

Finally, the least important technological driver of smart grid implementation is the fact that smart grid technologies enable the grid operator to monitor the grid extensively. Thereby, weak spots of the grid can be discovered in an early stage, so that malfunctioning can be prevented and the negative effects of those weak spots are restrained. This is nicely illustrated by the following example: *'The grid operator is now very reactive. If there is a malfunction somewhere, he will go there, but he hardly sees the malfunction coming. By adding this kind of intelligence* [author: smart grid technologies], *a grid operator is much faster and more alert, which we all benefit from'* (Interview 1, Par. 185).

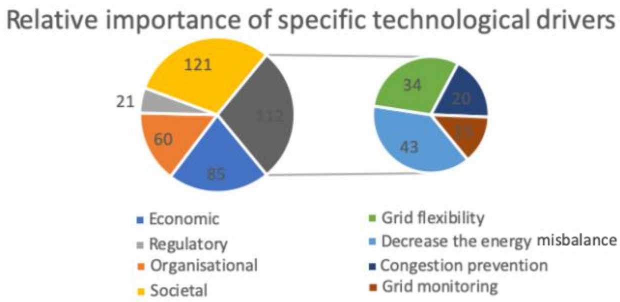

Figure 8. Visual representation of the relative importance of specific technological drivers

§ 4.2.1.4. Regulatory drivers

Based on the quantitative code frequency (see *Figure 4*), the regulatory dimension is the least important driver dimension of smart grid implementation. Based on the interviews, current laws and regulations in the Dutch context are not steering organisations and end users towards smarter energy use and a smart grid. Despite the fact that the regulatory dimension is the least important driver dimension, there are two regulatory drivers of smart grid implementation: subsidies and regulatory encouragement (see *Figure 9*). Subsidies are a regulatory driver of the implementation of smart grid technologies, because subsidies increase the financial attractiveness of smart solutions and thereby form an incentive for customers and organisations in the energy world to use smart grid technologies: *'And of course you have the governmental* *factors that come into play. They can stimulate you. How can you stimulate those techniques? By subsidizing them in different ways, giving incentives to entrepreneurs or residents'* (Interview 3, Par. 33).

Regulatory encouragement is a regulatory driver of smart grid implementation, since the (sparse) laws and regulations steering towards smarter energy management stimulate organisations and end users to use energy in a smarter way. The following example was mentioned by one respondent: *'The Clean Energy Packet… That is a package of laws, regulations and directives, which are now being implemented, were important* [author: regulatory] *drivers come from. For example, the requirements that demand-side flexibility must be able to participate in all electricity markets and products, such as balancing products, which was not the case until recently'* (Interview 9, Par. 45).

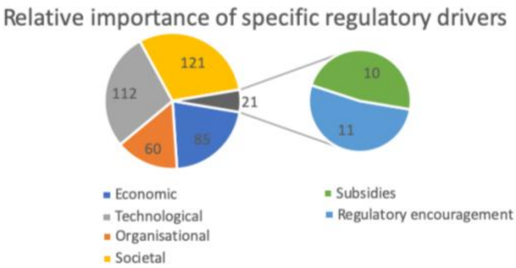

Figure 9. Visual representation of the relative importance of specific regulatory drivers

§ 4.2.1.5. Societal drivers

Based on the quantitative code frequency (see *Figure 10*), the most important societal driver of smart grid implementation is the involvement of the end user in the development and the implementation phase of smart solutions. After all, end user involvement in the development phase helps to discover end users' needs and thereby helps to develop a clear customer proposition in which the specific targeted end users are interested: *'In order to develop services and products in cooperation with residents and make them succeed at neighbourhood level, it is crucial to respond to the local needs of the residents. This is one of the keys to success'* (Stedin et al., 2015, p. 18). In fact, end user involvement is the most important factor among all specific drivers and barriers (for an overview of all factors in order of importance, see *Appendix 9*).

The next societal driver in line of importance is societal awareness. If end users understand the necessity of a smart grid and are open to make changes, so that the grid can be smartened, the deployment of a smart grid gets easier. This is nicely illustrated by the following example: *'The* [author: end users] *said: "That* [author: smart car charging] *is important, yes, because it makes sense indeed that we have to charge smartly, because if we all drive electric soon, we will have to do it in a smart way."…So you already felt that there with that group, that is the consumers, that there is awareness. Familiarity with the phenomenon'* (Interview 3, Par. 43). A high degree of societal awareness thus helps organisations to develop attractive customer propositions. After all, if consumers understand and feel the need for smart energy solutions, they are more interested in those propositions.

Although the cooperation between different actors in the energy system is the second least important societal driver based on the quantitative code frequency (see *Figure 10*), it is indeed a societal driver of smart grid implementation. Smart grid technologies are restructuring the energy system, whereby all of the actors in the energy chain are affected. Therefore, the involvement of and cooperation between different actors within the energy chain is essential to deploy smart grid technologies successfully: *'Ultimately cooperation* [author: between the different actors in the energy chain] *is also crucial. You just have so many factors that interlock… So, if you want to make such a neighbourhood energy neutral, then you actually need a kind of delta plan, where all major parties say: "We believe in this, we are going to do this. We will cut this in four or five pieces* [author: phases in the execution]*" Otherwise it will be difficult to get it going'* (Interview 3, Par. 33). Moreover, social cohesion is a societal driver of smart grid implementation as well. However, considering the quantitative code frequency (see *Figure 10*), social cohesion has little relevance as a societal driver of smart grid implementation.

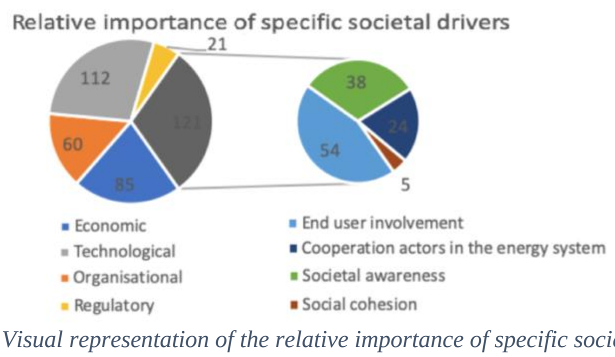

Figure 10. Visual representation of the relative importance of specific societal drivers

§ 4.2.2. Barriers

§ 4.2.2.1. Economic barriers

Based on the quantitative code frequency (see *Figure 11*), the lack of a clear business case is the most important economic barrier of smart grid implementation. This is because it is hard for organisations in the energy system to couple a profitable business case to smart grid technologies. Therefore, organisations in the energy world are less inclined to implement smart grid technologies. This becomes evident in the following example: *'That it* [author: smart grid technologies not] *has its own positive business case. And that phase was at the time, I'm talking about two/three years ago, but is still not reached. In the end, it only costs money'* (Interview 2, Par. 34).

The next economic barrier in line of importance is the lack of a clear customer proposition: *'The research shows that this* [author: customer proposition] *is a complex issue. Aspects such as money, time and the importance of autonomy and control make it difficult to quickly develop appropriate products and services* [author: for the end users]. *In short, it has proven difficult to translate the technical character of the* [author: smart grid-]*project to the end user'* (Stedin et al., 2016, p. 3). It is hard to propose a clear customer proposition, since most end users see energy just as a commodity and thereby only want to adjust their behaviour in return for substantial financial benefits relative to their current energy costs. However, it is not possible to generate the demanded decrease in energy costs using smart grid technologies. Consequently, it is hard to encourage end users to use smart energy solutions: *'The energy world thinks: "If the customer changes his behaviour a little, he might be able to earn 50/60 euros a year"… So, you see an enormous discrepancy between what the customer expects and what the pay-offs actually are… The customer thinks: "That's not much, I don't know if that is a big enough trigger for me"… That really is a discrepancy… That was the reason for us* [author: Couperus-project] *not to persevere. We couldn't promise what customers were hoping for'* (Interview 4, Par. 16). Moreover, end users have to invest heavily in order to use smart grid technologies, which makes the smart grid technologies even less attractive for the average end user: *'Everybody is looking at their own wallets. And energy is already, of course, after the mortgage, the second or third expense of households… And if you say: "You have to invest more, but it doesn't mean you're going to consume less." That's not such an attractive story, of course'* (Interview 2, Par. 88).

The least important economic barrier of smart grid implementation are the high required investment costs. The high required investment costs in order to implement smart grid technologies deter organisations from investing in smart grid implementation. Especially since the payback period of these required investments is very long. The fact that smart grid implementation is not profitable in the short-term and the returns on investments in the long-term are unclear, makes it an unattractive investment: *'The* [author: smart grid] *development requires an investment and you have to earn that investment back, and if that takes too long, it* [author: the investment] *won't happen'* (Interview 9, Par. 57).

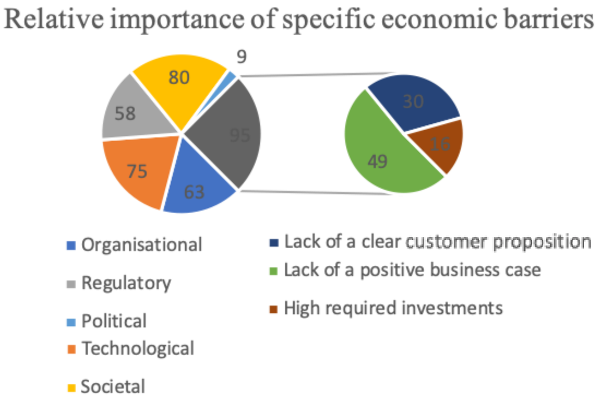

Figure 11. Visual representation of the relative importance of specific economic barriers

§ 4.2.2.2. Organisational barriers

Considering the quantitative code frequency (see *Figure 12*), the most important organisational barrier of smart grid implementation is the lack of organisational awareness. Not all the actors in the energy system feel the need of smartening the grid: *'In general, we note that the subject of demand-driven management is not (yet) alive in the majority of companies'* (Baken et al., 2015, p. 14**)**. This lack of organisational awareness is illustrated by the following example regarding energy companies: *'I think that awareness* [author: regarding the necessity of the smartening of the grid] *is low among the energy companies, because they do not have a problem yet. In the coming years they will still earn their money by selling kilowatt hours and cubic meters of gas. Naturally, they are discussing the customer base and the new entrants, but smart grids are not necessary for them to get out of the commodity crisis'* (Interview 4, Par. 48). Energy companies mainly adapt their products and services to the end users' demands. As long as the end users consider energy as a commodity, low costs are the most important trigger to satisfy end users. Energy companies thus not tend to invest in smart solutions, because investments in smart grid implementation lead to higher energy costs for the end users.

Furthermore, the smartening of the grid comes together with the need of an operational technology (‘OT’) and information technology (‘IT’) convergence. The difference between OT and IT is illustrated by one of the respondents: *‘OT stands for Operation Technology. That’s the guy with the blue overalls. That’s somebody who’s got a screwdriver on, whose overalls stink of grease, while the substation is ‘his house’. He knows every hole, every nook and cranny and if there’s anything wrong, he walks up to the box, kicks it once with his boot: “Well, it is working again”… Then you have IT. I always characterize that as the person with the Star Wars T-shirt, who only sees bits and bytes, that is someone who sees codes, zeros and ones, who thinks algorithms.’* (Interview 6, Par. 38 and 40). The lack of this IT OT convergence within organisations in the energy sector is an organisational barrier of smart grid implementation: *‘They* [author: OT and IT] *do not always know where to find each other and sometimes they do not want to find each other. After all, people who were into assets, like that and think: What should we do with software and IT? They actually speak a different language. So that’s really a barrier’* (Interview 2, Par. 58).

The lack of IT OT convergence is an almost equally important organisational barrier of smart grid implementation as the required time-consuming organisational transition towards an organisation in which OT and IT are converged. The fact that this IT OT convergence transition requires a time-consuming cultural change is an organisational barrier of smart grid implementation as well: *‘To change people and to change cultures, that is of course the hardest thing there is. So, from the strategy devised at the head office to the implementation at the substation or in the field, some time goes by’* (Interview 6, Par. 46). Moreover, the lack of adequate communication skills is an organisational barrier of smart grid implementation. However, the lack of communication skills is not an important organisational barrier.

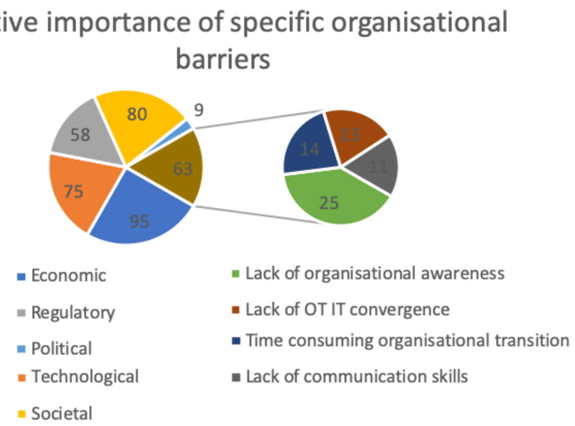

Figure 12. Visual representation of the relative importance of specific organisational barriers

§ 4.2.2.3. Technological barriers

As indicated by *Figure 13*, the most important technological barrier of smart grid implementation is the immaturity of smart grid technologies. In numerous smart grid pilots, it became apparent that the smart grid technologies showed some teething troubles, whereby the desired results could not be met. These teething troubles are illustrated by the following example: *'Analysis of the various graphs over one or more days has shown that the* [author: imbalance] *signal is not always reliable'* (Stedin et al., 2016, p. 20). However, those teething troubles are part of the immature phase which the smart grid technologies are in and are expected to decrease as the smart technologies develop.

The second most important technological driver are the privacy issues related to smart grid technologies. This barrier is qualified as a technological barrier, because the sharing of personal data from end users with different actors in the energy sector in order to balance the supply- and demand-side is a part/side-effect of smart grid technologies. For this reason, end users' aversion to this idea is a barrier of smart grid implementation. Those issues for instance emerged during the introduction of the smart meter: *'When one says that a smart meter comes into your house, 20% of the people say: "I don't want one of those things in my house. It sees when I am home or not, because that thing is smart. If that gets into the wrong people's hands, the burglars, for example, know when I am not at home." That was literally used as an argument to make the* [author: smart] *meter as stupid as possible.'* (Interview 1, Par. 173). However, according to other respondents those privacy issues are not that significant that they form a barrier of smart grid implementation. After all, appropriate communication skills may help to take away the scepticism of end users regarding the privacy issues: *'Beforehand, there was the fear that there would be resistance among participants due to personal privacy considerations. However, this turned out not to be the case. Perhaps this has to do with the degree of interaction with the user and the provision of feedback'* (Maandag & Wielaard, 2016, p. 7).

Another important technological barrier of smart grid implementation is the difficulty to scale up smart grid technologies into a bigger context. Specific (planning) contexts ask for tailor-made (smart grid) solutions. Therefore, smart grid technologies cannot be applied in a uniform way: *'I do think you could reuse the* [author: smart grid] *technology, but in one district it will be less applicable, because there is no generation at all or people mainly travel by bicycle, and in other districts it is mainly done by metro* [author: etc.]. *Basically, the principle of matching* *supply and demand will be the same and perhaps the technology as well, but you will need other assets, consumers and frequencies. Easy said, it could be the same technology, but it often isn't that easy'* (Interview 3, Par. 69). The lack of a uniform control platform is a technological barrier of smart grid implementation as well. However, considering the quantitative code frequency (see *Figure 13*), the lack of a uniform control platform is the least important technological barrier.

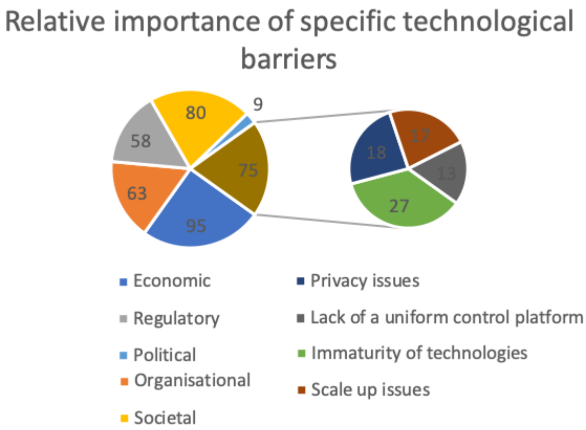

Figure 13. Visual representation of the relative importance of specific technological barriers

§ 4.2.2.4. Regulatory barriers

Considering the quantitative code frequency (see *Figure 14*), the lack of regulation through which flexibility can be rewarded by grid operators is an important regulatory barrier of smart grid implementation. Nowadays it is impossible for grid operators to reward the providers of flexibility due to legal restrictions: *'The current regulations hinder further developments as they* [author: the regulations] *make it difficult to unlock the value of flexibility'* (Maandag & Wielaard, 2016, p. 4). However, if the regulations would enable grid operators to reward flexibility, this would be helpful to stimulate actors to provide flexibility. A reward for flexibility would encourage end users and energy companies to flexibilize the demand-side of the energy market.

Moreover, the fact that the current regulation does not allow the grid operators to manage the grid actively is a regulatory barrier of smart grid implementation. After all, grid operators are not authorized to put battery capacity on the grid or to switch off an energy generator in order to prevent congestion on the grid: '*The special thing is, of course, that when the grid is overloaded, when there is too much supply of electricity, then electricity prices drop. However, a grid operator may not intervene in the* [author: energy] *market. The grid operator may therefore not offer services that disrupt the market. By introducing these kinds of instruments* [author: e.g. battery capacity]*, however, you are going to do so automatically'* (Interview 1, Par. 91). Enabling grid operators to manage the grid actively is essential to exploit smart grid opportunities to their full potential, because that way the grid can be used of as efficiently as possible.

Another important regulatory barrier is the current netting regulation in the Netherlands. Due to this regulation, the return of self-generated energy to the grid is rewarded with such high fees that end users are not inclined to storage their self-generated energy and to use it in a smart fashion. The problems regarding the netting regulation are illustrated by one respondent: *'If I use it* [author: energy from the energy supplier] *and it passes my meter, all costs are included. You have generation costs from the supplier, which are about 5/6 cents. Then all excise duties and taxes and you end up with 22/23 cents per kWh… The funny thing is: If I deliver that* [author: energy] *back… I get 23 cents as well… If I sell it, I'd only get 5 cents … If you compare that with whether you want to store it at home in a house battery… Then it is only worth 5 cents. So, it is much more interesting to return it, because then I get 23 cents in return'* (Interview 2, Par. 52). By adjusting this netting regulation properly, smart energy use by end users will be encouraged.

Another interesting regulatory barrier is the fact that the innovation costs cannot be discounted (properly) in the transport rate of grid operators: *'Based on the level of your regulatory asset base, RAB, you* [author: grid operators] *may charge your customers a transport fee… The regulator decides if you may allocate the investment costs you incur to the RAB. If you have an innovation project, which you may allocate to the RAB as investment costs, you may also ask for a higher transport fee and you will earn it* [author: the innovation costs] *back'* (Interview 6, Par. 68). If the regulator decides that grid operators can allocate innovation costs to the RAB, grid operators will be more encouraged to innovate, since they can earn the innovation costs back as they will receive a higher transport fee. Moreover, the current privacy regulation is a regulatory barrier as well. However, considering the quantitative code frequency (see *Figure 14*), the current privacy regulation lacks relevance, whereby it is not an important regulatory barrier.

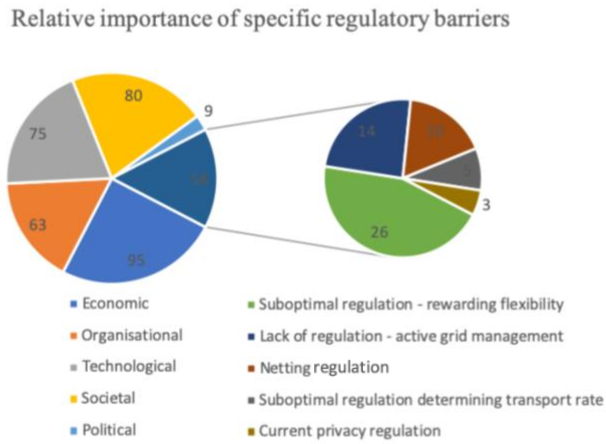

Figure 14. Visual representation of the relative importance of specific regulatory barriers

§ 4.2.2.5. Societal barriers

Based on the quantitative code frequency (see *Figure 15*), the fact that end users do not want too much hassle is the most important societal barrier of smart grid implementation. The necessity for end users to change their habits or to make big adjustments in their houses in order to be part of a smart grid network keeps them from using smart grid technologies: *'Participants* [author: of a smart grid project] *want to know where they stand. Furthermore, the participants attach great importance to ease of use and operation and effortless process… The testing grounds made it clear that consumers don't want complexity'* (Maandag & Wielaard, 2016, p. 10).

Moreover, the lack of societal awareness is a societal barrier of smart grid implementation. Due to the lack of societal awareness regarding the necessity of smart energy solutions to keep the energy market balanced, end users are not interested in investing in smart energy solutions: *'I think the* [author: lack of societal] *awareness is a barrier. In the end, the energy transition, sustainability, you hear it more and more, but a lot of people do not feel the urgency yet. The* [author: lack of] *societal awareness is one of the biggest barriers'* (Interview 2, Par. 48).

Another import societal barrier is the complexity of the Dutch energy system. A couple of decades ago the Dutch energy chain was cut up into different actors (e.g. grid operators, energy companies). Consequently, the shift towards a smart grid is more difficult, because it requires the cooperation between all actors. Cooperation between all the actors proves to be difficult, because it is hard to align the interests of all those actors: *'The energy sector is already quite complex. And smart grids don't make things much easier… It* [author: the energy sector] *is cut* *in quite a lot of players. Everyone has their own role and their own interests'* (Interview 5, Par. 102 and 104).

Finally, the lack of societal trust in the energy companies is a societal barrier of smart grid implementation. In the Netherlands, the trust in the energy companies is quite low. Because of this, the end users look with suspicion at all the proposals and actions of energy companies. This is illustrated by the following statement: *'You can see that* [author: lack of trust] *in everything an energy company does, people really dive into it. They're going to control everything, so you're in a less trusting position as an energy company'* (Interview 4, Par. 24).

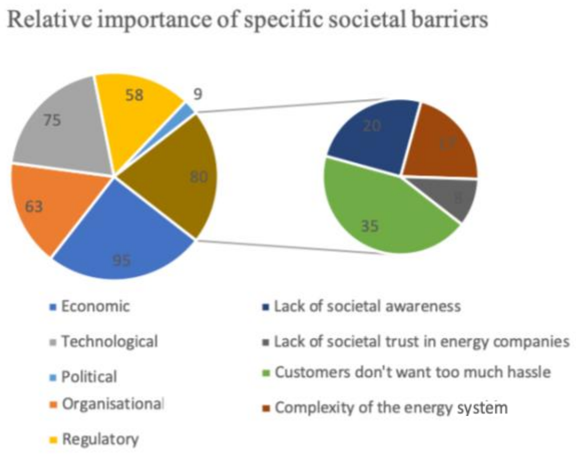

Figure 15. Visual representation of the relative importance of specific societal barriers

§ 4.2.2.6. Political barriers

The lack of a clear political course in the Netherlands concerning the energy transition is a political barrier of smart grid implementation in the Dutch context. Due to the lack of a clear political course, it is unclear which way the Dutch energy system is going. As a result of this uncertainty, not all actors in the energy sector are inclined to invest in transitional technologies, since they are not sure if those investments will pay off. However, a clear political vision and course regarding the energy transition encourages the actors in the energy sector to invest in transitional technologies. Thereby, the political course may set the flywheel in motion: *'An important thing for a country like the Netherlands is clarity in the political course concerning where you want to go as a country… A clear course for the Netherlands and not an election thing every four years, is very important. Then companies and investors know where they're going. They will then invest more in the technology and that can speed things up'* (Interview 7, Par. 68).

§ 4.3. Potential of the smart grid technology

Smart grid technology has the potential to be a facilitating technology of the energy transition, because the growing electricity demand together with the energy transition asks for smart energy solutions in order to meet the energy demands and to prevent congestion on the grid. With regard to this a respondent stated: *'I think it* [author: smart grid technologies] *certainly has that potential* [author: to accelerate the energy transition]. *Even if only because of the fact that because of this smart grid technology we can, certainly on a small scale, take better care of the demand for energy, adjust it to energy generation and thereby actually use the sustainable generation optimally, with which we can phase out fossil faster or at least less fossil* [author: generation]*'* (Interview 10, Par. 66), *'Smart grids are an essential link in the transition to a sustainable decentralised energy supply'* (Stedin et al., 2016, p. 7) and *'But the fact that you move towards decentralized* [author: generation], *that you go to difficult controllable sources, which you have to use as sun and wind, requires much more control and intelligence'* (Interview 7, Par. 16). However, before the smartening of the grid actually has a significant impact on the energy transition, it has to be applied on a bigger scale: *'It has to get critical mass first before it can really accelerate* [author: the energy transition]. *Now it's a lot of loose tufts everywhere. There isn't really a crystallized image yet'* (Interview 2, Par. 114).

§ 4.4. Conceptual model

In § 2.4., the initial conceptual model of this thesis was presented. However, based on the research findings, the following adjusted conceptual model is developed (see *Figure 16*). In this model, the links between all the analysed concepts are visualized. We are in the middle of an energy transition from a fossil fuels-based energy system towards a renewables-based energy system (Sandbag & Agora, 2020). The implementation of smart grid technologies has a positive effect on the energy transition. The smart grid technologies are facilitating the energy transition by helping to balance the demand- and supply-side of the energy market. Doing so, smart grid technologies help to overcome the difficulties regarding the fluctuations belonging to the renewables-based energy generation (i.e. solar and wind energy). Furthermore, drivers have a positive effect on the implementation of smart grid technologies, while barriers have a negative effect on the implementation of smart grid technologies. However, those drivers and barriers are interconnected. After all, drivers may become barriers and barriers may become drivers. Moreover, certain drivers help to restrain the obstructing effects of the barriers. For example, the communication skills of an organisation might help to decrease the worries about privacy issues on the end users' side. The research analysis indicates, in contrary to the initial conceptual model (see *Figure 3*), that there are five driver dimensions and six barrier dimensions to be distinguished (see *Figure 17*): 1) the economic driver/barrier dimension, 2) the organisational driver/barrier dimension, 3) the technological driver/barrier dimension, 4) the regulatory driver/barrier dimension, 5) the societal driver/barrier dimension and 6) the political barrier dimension. Moreover, in contrary to the initial conceptual model (see *Figure 3*), the research analysis indicates that the driver and barrier dimensions can be ranked in order of relative importance (see *Figure 17*). With regards to the drivers, the societal and technological are the most important driver dimensions, while the economic and the societal are the most important barrier dimensions.

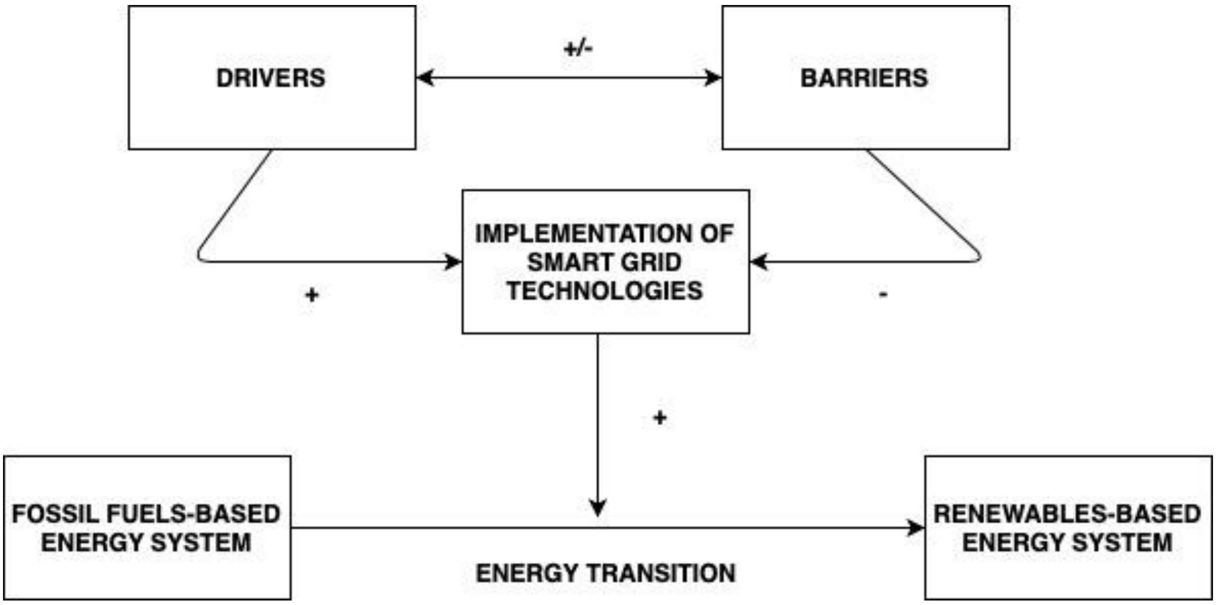

Figure 16. Adjusted conceptual model of the drivers and barriers of smart grid implementation

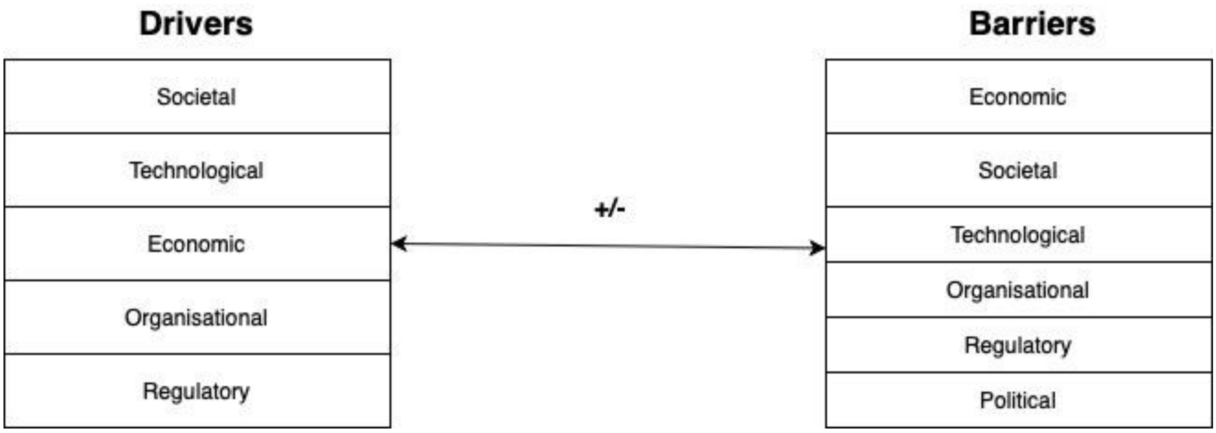

Figure 17. Adjusted conceptual model of the drivers and barriers of smart grid implementation – zoomed into the driver and barrier dimensions

5. Conclusion and discussion

In this final chapter, the main theoretical and practical contributions of this research are presented and the answer to the research question is proposed. First of all, the research results are summarized and used to answer the research question. Next, the main theoretical implications and practical recommendations are presented. Finally, the methodological limitations and the suggestions for further research are presented.

The main objective of this research is to identify how the drivers and barriers of the energy transition in the Dutch context influence the development of smart grid technologies. The research question is: *How do the drivers and barriers of smart grid implementation in the Dutch context contribute to or hinder the development of smart grid technologies in the Netherlands and how can smart grid technologies support the energy transition?* To embody this research question, three sub-questions were formulated. The first sub-question focuses on the drivers of smart grid implementation in the Dutch context. The second sub-question covers the barriers of smart grid implementation in the Dutch context. The third and last sub-question refers to the potential of smart grid technologies in order to support the energy transition.

§ 5.1. Conclusion

In this paragraph, the three sub-questions are answered, whereby the main research question is answered as well.

The first sub-question is: *How do the drivers of smart grid implementation in the Dutch context contribute to the development of smart grid technologies in the Netherlands?* The drivers of smart grid implementation are divided into five different dimensions: 1) the economic dimension, 2) the organisational dimension, 3) the technological dimension, 4) the regulatory dimension and 5) the societal dimension. Of these different dimensions, the societal driver dimension is relatively the most important driver dimension. This dimension is so important, because a good coupling between smart technologies and the demands of the end users is essential in order to develop and exploit smart grid technologies (Stedin et al., 2015). The next most important driver dimension is the technological dimension, because smart grid technologies can help to decrease the (possible) energy misbalance caused by a renewables-based energy system by flexibilizing the demand-side of the energy market (Stedin et al., 2016;

Wurtz & Delinchant, 2017). Next in line of importance is the economic driver dimension, as deploying smart grid technologies leads to grid efficiency benefits (TU Delft, n.d.). The fourth most important driver dimension is the organisational dimension. The presence of adequate communication skills (Cagno et al., 2013; Cainelli et al., 2015; Stedin et al., 2015) and organisational awareness (Cagno et al., 2013; De Almeida et al., 2003) are namely drivers of smart grid implementation. The least important driver dimension is the regulatory dimension. Although the regulatory dimension is relatively speaking the least important driver dimension, subsidies and the (scarce) regulatory encouragement are nevertheless drivers of smart grid implementation (Reina & Kontokosta, 2017; Johansson & Thollander, 2018; Sudhakara Reddy, 2013).

The second sub-question is: *How do the barriers of smart grid implementation in the Dutch context contribute to the development of smart grid technologies in the Netherlands?* The barriers of smart grid implementation are divided into six different dimensions: 1) the economic dimension, 2) the organisational dimension, 3) the technological dimension, 4) the regulatory dimension, 5) the societal dimension and 6) the political dimension. Based on this research, it can be concluded that the economic barrier dimension is relatively the most important barrier dimension of smart grid implementation. This is explained by the fact that it is hard to develop a positive business case and customer proposition for smart grid solutions, while the required investment costs are high due to the complexity of smart grid implementation (Cagno et al., 2013; Fleiter et al., 2011; Good et al., 2017; Stedin et al., 2016). The next barrier dimension in line of importance is the societal dimension. In the Netherlands, the need for smart grid solutions is not felt throughout society yet, whereas end users do not want too much hassle regarding the implementation of smart grid solutions (Maandag & Wielaard, 2016). The third most important barrier dimension is the technological dimension. The immaturity of smart grid technologies may namely occasionally lead to malfunctions (Stedin et al., 2016). The organisational dimension is the fourth most important barrier dimension, which is caused by the lack of organisational awareness, the lack of OT IT convergence and the need for a (time-consuming) organisational transition in order to converge OT and IT properly (Baken et al., 2015; Cagno et al., 2015). The second least important barrier dimension is the regulatory dimension. The suboptimal regulation regarding active grid management and flexibility reward by grid operators makes that smart grid technologies cannot be used to their fullest potential (yet) (Maandag & Wielaard, 2016). The least important barrier dimension is the political dimension, since the lack of a clear overarching political course in the Netherlands regarding the energy transition causes ambiguity about the direction our energy system is going. Therefore, not all actors in the energy sector are inclined to invest in smart grid technologies.

The third sub-question is: *How can smart grid technologies support the energy transition?* Smart grid technologies have the potential to support the energy transition, since smart grid technologies help to facilitate the energy transition. The growing electricity demands together with the ongoing energy transition make that a smarter grid and the smarter use of the generators and the end users is essential in order to align the demand- and the supply-side of the energy market (e.g. Adefarati & Bansal, 2019; Wang et al., 2017; Kabalci et al., 2019).

§ 5.2. Discussion

§ 5.2.1. Theoretical implications

The findings of this thesis have multiple implications for theory. After all, in this research, two new driver/barrier dimensions are derived: the societal driver/barrier dimension and the political barrier dimension. These two dimensions could not be inferred from literature research on the drivers and barriers of the energy transition. The societal dimension concerns the drivers and barriers from a broad societal context and the characteristics of the energy system as such. The most important societal drivers of smart grid implementation are end user involvement, the cooperation between the different actors in the energy system and societal awareness. The fact that customers do not want too much hassle, the lack of societal awareness and the complexity of the Dutch energy system are the most important societal barriers of smart grid implementation. The fact that the societal dimension cannot be derived from theoretical research is explained by the tendency in the current academic debate to solely focus on the organisational perspective regarding the drivers and barriers of the energy transition. As a result, the drivers and barriers of the energy transition are analysed through the perspective of organisations in the energy world, whereby the drivers and barriers coming from a broader societal context are often ignored (e.g. Cagno et al., 2013; Trianni et al., 2016). However, since the energy transition requires a socio-technical change (Geels & Schot, 2010; Van den Bergh et al., 2011), it is important to include the drivers and barriers coming from a broader societal context (e.g. societal awareness and end user preferences) and the characteristics of the energy system (e.g. complexity) as such in the academic debate on the drivers and barriers of the energy transition.

The political barrier dimension is a new dimension derived from the data as well. The political dimension concerns the broader, overarching, political course and vision of a country regarding the energy transition. The presence and absence of stimulating laws and regulations are topics that are often mentioned in academic literature (e.g. Trianni et al., 2016; O'Malley et al., 2003). The presence of stimulating laws and regulations encourage actors in the energy sector and end users to use their energy smarter (Trianni et al., 2016; Cagno et al., 2015) and the absence of stimulating laws and regulations obstructs smarter energy use (O'Malley et al., 2003; Hirst & Brown, 1990). However, the (lack of an) overarching political course and vision of a country is often ignored in academic literature. The effects of a country's clear political course and vision regarding the energy transition are not researched extensively. This is explained by the tendency in academic literature to solely focus on existing laws and regulations when it comes to the governmental role (e.g. Trianni et al., 2016; Cagno et al., 2015; Reina & Kontokosta, 2017; Johansson & Thollander, 2018; Sudhakara Reddy, 2013). However, since a country's overarching political vision gives direction to a country's approach to the socio-technical energy transition (Li & Strachan, 2017), it is important to include the political barrier dimension in the academic debate on the drivers and barriers of the energy transition. On the one hand, a clear overarching political vision regarding the energy transition encourages the implementation of transitional technologies. On the other hand, the lack of an overarching political vision regarding the energy transition causes ambiguity about the future of the energy system, whereby actors in the energy system and end users are hesitant to invest in transitional technologies.

§ 5.2.2. Business relevance

Based on the findings in this thesis, multiple recommendations for practice can be made. The most important practical recommendation for organisations which tend to deploy smart grid technologies is to involve end users in both the development and the implementation phase of smart grid deployment, because end user involvement is an important (societal) driver of smart grid implementation in the Dutch context. End user involvement helps to discover end users' needs and thereby helps to develop a clear customer proposition, while it makes it easier to implement smart solutions. Moreover, it is important for organisations to adjust their communicational approach to the people they are dealing with. After all, appropriate communication skills are an important (organisational) driver of smart grid implementation, because they help to take away the societal barriers of smart grid implementation (e.g. privacy issues). The last important practical recommendation for organisations is to keep in mind that end users do not want too much hassle regarding the implementation of smart solutions. That is an important (societal) barrier of smart grid implementation. It is therefore important to make sure that the step towards smarter energy use is easy and profitable for the end users. A clear customer proposition is after all an important (economic) driver of smart grid implementation and therefore essential in order to implement smart grid technologies successfully.

Furthermore, there are some important practical recommendations regarding the regulator. The first recommendation is to adjust the legal task description of grid operators, so that grid operators get the opportunity to reward flexibility. This makes smart energy use more attractive for both end users and energy companies. Moreover, it will be helpful if grid operators are authorised to manage the grid more actively, so that grid operators, for instance, can add battery capacity to the grid or can switch off generators in order to prevent congestion. Enabling active grid management is essential to exploit smart grid opportunities to their full potential. Finally, it is recommended to adjust the current Dutch netting regulation. The current netting regulation makes that end users are not inclined to storage their self-generated energy and to use it in a smart fashion. However, adjusting this netting regulation properly helps to encourage smart energy use by end users.

§ 5.2.3. Methodological limitations

Unfortunately, but unforeseeable, the methods used in this research have their limits. Due to the corona crisis, it turned out that the initial research plan, conducting a comparative multi-case study, was impossible to execute due to difficulties in finding suitable respondents. For that reason, considering time constraints, instead of a comparative multi-case study, an exploratory case study was conducted, which enabled me to study the specific case very thoroughly.

Moreover, the use of expert interviews has its limitations and drawbacks. According to Hammersley and Gomm (2008), the information the respondents provide, is shaped, to some degree, by the questions they are asked, by what they think the researcher wants and by what they believe the researcher would approve or disapprove. Thereby, the results of the interviews might be biased by the tendency of respondents to give answers that they think the researcher approves (Alshenqeeti, 2014). However, by asking appropriate follow-up questions in order to thoroughly understand the respondents' motives, these effects are restrained. Therefore, expert interviews are an effective means to gather reliable information regarding the drivers and barriers of smart grid implementation in the Dutch context.

Furthermore, due to the qualitative nature of this research, the subjectivity of the researcher is intimately involved in the interpretation of the data. In order to reduce the risk of researcher subjectivity, the research analysis tried to stay as close as possible to the transcripts of the expert interviews and the case-specific reports, so that a more objective analytical process with limited bias in results could be ensured.

Besides, due to the limited number of expert interviews (i.e. ten), corresponding governmental reports (i.e. four) and the fact that only one case is studied, the issue of the generalizability of the findings of this research to the entire Dutch context arises (Shang & Lin, 2010). However, in order to improve the generalizability of this research, the IPIN-program was selected, since it represents research into the potential of and development of smart grid technologies in the Dutch context (RVO, n.d.(c)). Although, the research results are applicable to the Dutch context, they cannot directly be applied to foreign contexts, because this research is solely centred on the Dutch context and some of the drivers and barriers (e.g. regulatory) differ from country to country (Ranta et al., 2018; Nagesha & Balachandra, 2006).

Moreover, the drivers and barriers of smart grid technologies are dependent on the time boundary. Smart grid technologies continue to develop over time, while the research has come to an end, which means that the research conclusions are a result of the moment in time at which the study was conducted (Dubois & Gadde, 2002).

Finally, the research results regarding the impact of the smart grid as a catalysator of the energy transition are not quantifiable due to the nature of the research method of this thesis. However, the qualitative approach of this research was suited to get a better understanding on context factors such as the drivers and barriers of smart grid implementation in the Dutch context.

§ 5.2.4. Suggestions for further research

The first suggestion for further research is to conduct a comparative multi-case study into the drivers and barriers of smart grid implementation based on a socio-technical perspective

(Markard et al., 2016; Geels & Schot, 2010). A comparative multi-case study will help to distinguish the main and the case-specific drivers and barriers and the socio-technical perspective takes the multifaceted, interrelated and interdependent character of the socio-technical energy transition into account (Geels & Schot 2010; Van den Bergh et al., 2011). This way, the relative importance of the drivers and barriers of smart grid implementation can be understood more thoroughly. Another suggestion is to conduct a research into the contribution of smart grid technologies regarding the energy transition, using a strategic niche management perspective (Raven et al., 2010). Researching smart grid technologies using a strategic niche management perspective will provide a better understanding of how the experimental introduction of (radical) innovations (e.g. smart grid technologies) can benefit the wider energy transition process (Raven et al., 2010; Smith & Raven, 2012). Moreover, using a multi-level perspective to compare the drivers and barriers of smart grid implementation in different countries is an interesting direction for further research as well. Using a multi-level perspective, the (possible) differences in country-specific drivers and barriers can be identified and linked to differences in the interlinked levels of country-specific socio-technical systems (Foxon et al., 2010; Geels, 2010; Naus, 2017).

6. Literature

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7. Appendices

Appendix 1 – Informed consent form

Radboud Universiteit

Nijmegen School of Management

TOESTEMMINGSVERKLARING

Voor deelname aan:

Wetenschappelijk onderzoek naar de drivers en barriers van de smart grid en haar potentie in het kader van de energietransitie.

In te vullen door de DEELNEMER vóór aanvang van het onderzoek:

Ik bevestig:

- mondeling dan wel schriftelijk naar tevredenheid over het onderzoek te zijn geïnformeerd op basis van informatie door de betreffende onderzoeker.
- gelegenheid te hebben gehad om grondig over deelname aan het onderzoek na te denken.
- uit vrije wil deel te nemen.

Ik stem in dat:

- mijn gegevens voor wetenschappelijke doeleneinden worden verkregen.
- de volgende gegevens worden verzameld: geluidsopname.
- de gegevens worden gebruikt voor dataverzameling en -analyse.
- de onderzoeker bij presentaties kan refereren aan bevindingen uit dit onderzoek in pseudonieme vorm.
- data gebruikt kan worden voor vervolgonderzoek.

Ik begrijp dat:

- ik als respondent deelneem aan dit afstudeeronderzoek naar de drivers en barriers van smart grids en de potentie hiervan in het kader van de energietransitie.
- dit afstudeeronderzoek kennisvergaring en -vermeerdering beoogt.
- ik ervoor kan kiezen op de hoogte te worden gehouden van de onderzoeksresultaten.
- ik het recht heb om mijn toestemming op ieder moment weer in te trekken zonder dat ik daarvoor een reden hoef op te geven tot <u>14 dagen</u> na deelname.
- ik het recht heb op vernietiging van mijn onderzoeksgegevens tot <u>14 dagen</u> na deelname.
- mijn gegevens worden behandeld volgens de geldende Europese/Nederlandse regelgeving.
- ik bij elke nieuwe deelname opnieuw gevraagd zal worden om toestemming.

Ik ontvang graag het onderzoeksplan.
JA/NEE

Ik wil op de hoogte worden gehouden van de onderzoeksresultaten.
JA/NEE

Ik stem in dat ik benaderd kan worden voor een toekomstige studie.
JA/NEE

(omcirkel keuze)

Ik stem in met deelname aan het onderzoek:

Naam :
………………………………………………………………………………………………………

Datum :
………………………………………………………………………………………………………

Organisatie :
………………………………………………………………………………………………………

E-mail (indien interesse in resultaten en/of plan):

……………………………………………………………………………..

Handtekening :

………………………………………………………………………………..

Onderzoeker:

Naam : Thom Roelen

Organisatie : Radboud Universiteit Nijmegen, Nijmegen School of Management

Email : t.roelen@student.ru.nl

Telefoon : +31 (0)6 – 134 95472

Privacyverklaring Radboud Universiteit:

Website : https://www.ru.nl/vaste-onderdelen/privacyverklaring-radboud-universiteit/

Appendix 2 – Information document

Since the interviews will be held in Dutch, the information document is in Dutch as well. After all, the selected interviewees are Dutch.

Informatiedocument – Drivers en barriers van smart grid-implementatie

Inleiding

In het Nederlandse energiesysteem is momenteel de trend gaande richting een energiesysteem waarin het aandeel van hernieuwbare energie aan het groeien is. Deze trend wordt ook wel omschreven als de energietransitie. Aan de snelheid/traagheid van de energietransitie liggen diverse aanjagers ('drivers') en barrières ('barriers') ten grondslag. Drivers zijn factoren die de energietransitie versnellen, terwijl factoren die deze transitie vertragen worden aangemerkt als barriers. Zowel de drivers als barriers worden in de volgende vier categorieën onderverdeeld: 1) economisch, 2) organisatorisch, 3) technologisch en 4) regulerend. Onder economische drivers en barriers worden o.a. de (verborgen) kosten van de energietransitie, de risico's en de mogelijke verdienmodellen verstaan. Specifieke voorbeelden van organisatorische drivers en barriers zijn het gedrag, kennis, cultuur en competenties binnen een organisatie. Technologische drivers en barriers betreffen de beschikbaarheid, adequaatheid en karakteristieken van specifieke technologieën die de energietransitie kunnen versnellen, terwijl de regulerende drivers en barriers zien op de faciliteiten en wet- en regelgeving vanuit de overheid, die van invloed zijn op de energietransitie.

Het onderzoek

Tegen deze achtergrond doe ik in mijn thesis onderzoek naar de drivers en barriers en de potentie van de smart grid in de Nederlandse context. De smart grid kan een potentiële katalysator zijn voor de energietransitie, aangezien met een smart grid, onder meer, het aanbod van de verschillende energiebronnen kan worden afgestemd op de vraag, waardoor energie efficiënter wordt gebruikt. Uit academische literatuur blijkt echter dat er de nodige barriers bestaan voor smart grid-implementatie. In deze thesis doe ik derhalve onderzoek met als doel om een zo compleet mogelijk beeld van de drivers en barriers van smart grid-implementatie in de Nederlandse context te verkrijgen. Tevens onderzoek ik het potentieel van de smart grid als katalysator van de energietransitie. Ik onderzoek deze leerstukken aan de hand van interviews met ervaringsdeskundigen en zodoende ben ik bij u uitgekomen.

Bijdrage geïnterviewde

Hoe u aan dit onderzoek kunt bijdragen is door inzicht te bieden in uw ervaringen met de implementatie van een smart grid. Tijdens het (virtuele) interview beantwoordt u open vragen van de onderzoeker over besluitvorming aangaande energietransitie. Allereerst worden enkele vragen over uw precieze rol/de precieze rol van de organisatie waarin u werkzaam bent in het betreffende smart grid-project gesteld. Vervolgens wordt dieper ingegaan op de door u gepercipieerde drivers en barriers van smart grid-implementatie. Om hier alvast een idee bij te krijgen, is het goed om te weten dat de vier categorieën zoals hierboven benoemd de omkadering vormen van de vragen betreffende de drivers en barriers van de smart grid-implementatie. Daarnaast kunt u ook denken aan vragen over de potentie van de smart grid. Heeft de smart grid daadwerkelijk de potentie om de energietransitie te versnellen en zo ja, op welke wijze draagt een smart grid hieraan bij? Indien de smart grid deze potentie volgens u ontbeert, kunt u denken aan vervolgvragen over de (mogelijke) bredere rol van de smart grid in het energiesysteem. Bij aanvang van het interview vraagt de onderzoeker of het gesprek mag worden opgenomen voor analysedoeleinden. U wordt verzocht om uw wensen hieromtrent reeds voorafgaand aan het interview kenbaar te maken. Bij aanvang van het interview wordt u daarnaast gevraagd of u een interviewtranscript en/of een onderzoeksplan wenst te ontvangen. Ook betreffende deze punten wordt u verzocht uw wensen kenbaar te maken. Daarnaast zijn er voor de respondent geen risico's en ongemakken aan deelname verbonden. Verder kunt u via het informed consent-formulier aangeven of u de onderzoeksresultaten wenst te ontvangen. Daarnaast benadrukt de onderzoeker dat u op vrijwillige basis meedoet en zich zonder opgaaf van reden terug kan trekken uit het onderzoek binnen veertien dagen na afname van het interview.

Dataverwerking

Tijdens een interview maakt de onderzoeker notities en een geluidsopname. De tijdens dit onderzoek gebruikte gegevens zijn nodig om de onderzoeksvragen te beantwoorden en over de resultaten te publiceren. Voor het gebruik van deze data vragen wij u via het informed consent-formulier om toestemming. Vooraleer de verzamelde gegevens worden geanalyseerd, maakt de onderzoeker deze pseudo-anoniem. Er blijft echter altijd een bepaalde mate van contextinformatie aanwezig, gezien de aard van de kwalitatieve data. Vervolgens worden de pseudo-anonieme gegevens gebruikt voor het ontwikkelen van een kwalitatieve dataset, het schrijven van een scriptie en publicaties, alsmede bij presentaties. De thesis wordt voor een periode van minstens zeven jaar bewaard in de bibliotheek van de Radboud Universiteit. Geïnteresseerden binnen en buiten de universiteit hebben in die periode toegang tot de thesis. Hierbij is het belangrijk om te vermelden dat de gegevens worden bewaard op een beveiligde wijze volgens de richtlijnen van de Radboud Universiteit.[1]

[1] https://www.ru.nl/vaste-onderdelen/privacyverklaring-radboud-universiteit/

Appendix 3 – Interview protocol

Generally, the following structure will be followed during the interviews. However, since this thesis uses semi-structured interviews, there is always space for some flexibility. After all, after each interview, the questions will be adapted using the results of the other interviews, if necessary.

Since the interviews will be held in Dutch, the interview protocol is in Dutch as well. After all, all selected interviewees are Dutch.

1. Introductie

Informatie over de organisatie

1. Zou u kort het bedrijf waar u werkzaam bent kunnen omschrijven en kunnen omschrijven wat de precieze rol is van het bedrijf in het energiesysteem (consument, producent, grid operator etc.).

2. Kunt u omschrijven wat uw functie is binnen het bedrijf?

Informatie over rol organisatie binnen het smart grid-project

3. Kunt u omschrijven wat de precieze rol was van uw organisatie in het specifieke smart grid-project?

4. Kunt u omschrijven wat uw functie was binnen het specifieke smart grid-project?

2. Drivers en barriers

Drivers

5. Als u vanuit uw ervaringen met smart grids spreekt, welke factoren bespoedigen volgens u de implementatie van de smart grid technologie?

6. Gelet op uw eigen ervaringen met smart grids, welke economische drivers van smart grid-implementatie komen dan duidelijk naar voren? En heeft u hiervan enkele voorbeelden? En waarom bespoedigen deze factoren dan de implementatie van de smart grid technologie?

7. Gelet op uw eigen ervaringen met smart grids, welke organisatorische drivers van smart grid-implementatie komen dan duidelijk naar voren? En heeft u hiervan enkele voorbeelden? En waarom bespoedigen deze factoren dan de implementatie van de smart grid technologie?

8. Gelet op uw eigen ervaringen met smart grids, welke technologische drivers van smart grid-implementatie komen dan duidelijk naar voren? En heeft u hiervan enkele voorbeelden? En waarom bespoedigen deze factoren dan de implementatie van de smart grid technologie?

9. Gelet op uw uw eigen ervaringen met smart grids, welke regulerende drivers van smart grid-implementatie komen dan duidelijk naar voren? En heeft u hiervan enkele voorbeelden? En waarom bespoedigen deze factoren dan de implementatie van de smart grid technologie?

10. Welke factoren zijn belangrijke drivers en welke drivers acht u minder belangrijk? En waarom gelden deze factoren dan precies als drivers van de implementatie van smart grids?

11. Zijn er nog drivers die u als dusdanig niet heeft benoemd, maar die wel belangrijk zijn? Zo ja, wat zijn deze factoren en waarom fungeren deze factoren als drivers van de implementatie van de smart grid technologie?

Barriers

12. Als u vanuit uw ervaringen met smart grids spreekt, welke factoren staan volgens u in de weg aan de (verdere) implementatie van de smart grid technologie?

13. Gelet op uw eigen ervaringen met smart grids, welke economische barriers van smart grid-implementatie komen dan duidelijk naar voren? En heeft u hiervan enkele voorbeelden? En waarom staan deze factoren dan in de weg aan de implementatie van de smart grid technologie?

14. Gelet op uw eigen ervaringen met smart grids, welke organisatorische barriers van smart grid-implementatie komen dan duidelijk naar voren? En heeft u hiervan enkele voorbeelden? En waarom staan deze factoren dan in de weg aan de implementatie van de smart grid technologie?

15. Gelet op uw eigen ervaringen met smart grids, welke technologische barriers van smart grid-implementatie komen dan duidelijk naar voren? En heeft u hiervan enkele voorbeelden? En waarom staan deze factoren dan in de weg aan de implementatie van de smart grid technologie?

16. Gelet op uw uw eigen ervaringen met smart grids, welke regulerende barriers van smart grid-implementatie komen dan duidelijk naar voren? En heeft u hiervan enkele voorbeelden? En waarom staan deze factoren dan in de weg aan de implementatie van de smart grid technologie?

17. Welke factoren zijn belangrijke barriers en welke barriers acht u minder belangrijk? En waarom gelden deze factoren dan precies als barriers van de implementatie van smart grids?

18. Zijn er nog barriers die u als dusdanig niet heeft benoemd, maar die wel belangrijk zijn? Zo ja, wat zijn deze factoren en waarom fungeren deze factoren als barriers van de implementatie van de smart grid technologie?

.

3. Potentie van de smart grid

19. Heeft de smart grid-technologie de potentie om de energietransitie te versnellen? Zo ja, op welke wijze kan de smart grid-technologie de energietransitie dan versnellen? En waarom versnelt de smart grid op deze wijze de energietransitie?

20. Zo nee, welke rol kan de smart grid dan wel spelen in het energiesysteem? Op welke vlakken is haar toepassing van toegevoegde waarde? Of is de smart grid een technologie waar helemaal geen toekomst in zit? En waarom ontbeert het de smart grid technologie dan aan mogelijkheden in het energiesysteem?

4. Afsluiting

21. Als u het smart grid project waarbij u betrokken bent geweest opnieuw zou mogen doen, wat zou u anders hebben gedaan? En waarom zou u deze bepaalde dingen dan anders hebben ingevuld?

Appendix 4 – Overview interviewees

Interview #	Date	Smart grid project	Company/organisation	Job title
1	21-04-2020	Heijplaat	Energy company	Development Manager
2	29-04-2020	Couperus	Grid operator	Innovator/Business Developer
3	01-05-2020	Heijplaat	Energy company	Business Developer
4	11-05-2020	Couperus	Energy company	Manager Product House/Innovation
5	12-05-2020	Zeewolde	Grid operator	Consultant
6	15-05-2020	Overig	Energy solutions provider	Former Program Manager and current Manager of Customer Relations
7	19-05-2020	Zeewolde	Grid operator	Transition Manager
8	20-05-2020	Couperus	Independent Research Organisation	Consultant and Project Leader
9	25-05-2020	Smart Energy Collective & Co	Energy Consultancy	Business Manager Demand Side Flexibility
10	27-05-2020	Couperus	Independent Research Organisation	Business Line Manager

Appendix 5 – Frequency table regarding the relative importance of driver dimensions

Dimensions	Frequency	Illustrating quote
Economic	85	*'The economy of the smart grid is that you avoid the need to make your infrastructure more robust in a smart way… You still need a good physical grid, but by adding intelligence, you are trying to postpone investments in net reinforcements. This saves costs for the grid operator'* (Interview 1, Par. 57 and 185)
Organisational	60	*'You have to understand that there are different categories of people. All these categories therefore also require different approaches. And that is essential with smart grids, because you intend that everyone can join the basic structure'* (Interview 1, Par. 43)
Technological	112	*'The coordination* [author: within a smart grid system] *guarantees a stable and constant supply of electricity. This compensates for a disadvantage of sustainable energy sources: it is difficult to predict how much energy they will supply at a certain time in the future, and it is also difficult to adjust the power they supply'* (Stedin et al., 2016, p. 10)
Regulatory	21	*'There are obligations from the European Union. They say that generating installations greater than 3 KwH or 5 kWh, I do not know, at least not very big, that it should be possible for grid operators to control these'* (Interview 5, Par. 94)
Societal	121	*'In order to develop services and products in cooperation with residents and make them succeed at neighbourhood level, it is crucial to respond to the local needs of the residents. This is one of the keys to success'* (Stedin et al., 2015, p. 18)

Appendix 6 – Frequency table regarding the relative importance of barrier dimensions

Dimensions	Frequency	Illustrating quote
Economic	95	*'That one* [author: the business case] *is still tricky. At least, the business case is spread over several parties. We always all that a 'stacked business case'. Ultimately, the value does not lie with one party. Part of the value* [author: of the smart grid] *lies with the customer/end user, part with the energy supplier, part with the grid manager and part with the software party. Ultimately, it is a social business case, but it may well be that one party has to invest more than they receive in return, while it is good for the social business case, it is not good for the individual business case'* (Interview 2, Par. 42)
Organisational	63	*'In general, we note that the subject of demand-driven management is not (yet) alive in the majority of companies'* (Baken et al., 2015, p. 14)
Technological	75	*'The landscape hasn't crystallised yet. There is not really a clear final solution or status quo yet. All kinds of technologies and opportunities are emerging now… You can develop it* [author: smart grid technologies] *quickly, but before it really works and has any influence, that takes a while'* (Interview 2, Par. 62)
Regulatory	58	*'However, in the current tariff structure, the grid operator is not allowed to use cost savings to reward those providers of flexibility. This would require a fundamental change in the network tariff structure in order to unlock the value of flexibility for the network'* (Baken et al., 2015, p. 34)
Societal	80	*'It is not yet well understood that energy is a scarce commodity that can run out and therefore needs to be managed smartly and actively, with demand-driven management as a possible control mechanism'* (Stedin et al., 2016, p. 31)
Political	9	*'An important thing for a country like the Netherlands is clarity in the political course concerning where you want to go as a country… A clear course for the Netherlands and not an election thing every four years, is very important. Then companies and investors know where they're going. They will then invest more in the technology and that can speed things up'* (Interview 7, Par. 68)

Appendix 7 – Frequency table regarding the relative importance of specific drivers

Dimensions	Specific factors	Frequency
Economic	Grid efficiency	36
	Clear customer proposition	29
	Control of energy costs	17
	Efficiency of workforce	3
Organisational	Communication skills	38
	Organisational awareness	20
	Image building	2
Technological	Decrease the energy misbalance	43
	Grid flexibility	34
	Congestion prevention	20
	Grid monitoring	15
Regulatory	Regulatory encouragement	11
	Subsidies	10
Societal	End user involvement	54
	Societal awareness	38
	Cooperation actors in the energy system	24
	Social cohesion	5

Appendix 8 – Frequency table regarding the relative importance of specific barriers

Dimensions	Specific factors	Frequency
Economic	Lack of a positive business case	49
	Lack of a clear customer proposition	30
	High required investments	16
Organisational	Lack of organisational awareness	25
	Time consuming organisational transition	14
	Lack of OT IT convergence	13
	Lack of communication skills	11
Technological	Immaturity of technologies	27
	Privacy issues	18
	Scale up issues	17
	Lack of a uniform control platform	13
Regulatory	Suboptimal regulation – rewarding flexibility	26
	Lack of regulation – active grid management	14
	Netting regulation	10
	Suboptimal regulation determining transport rate	5
	Current privacy regulation	3
Societal	Customers don't want too much hassle	35
	Lack of societal awareness	20
	Complexity of the energy system	17
	Lack of societal trust in energy companies	8
Political	Lack of a clear political vision	9

Appendix 9 – Overview of all factors in order of importance

#	Driver/barrier	Dimensions	Specific factors	Frequency
1.	Driver	Societal	End user involvement	54
2.	Barrier	Economic	Lack of a positive business case	49
3.	Driver	Technological	Decrease the energy misbalance	43
4.	Driver	Organisational	Communication skills	38
4.	Driver	Societal	Societal awareness	38
6.	Driver	Economic	Grid efficiency	36
7.	Barrier	Societal	Customers don't want too much hassle	35
8.	Driver	Technological	Grid flexibility	34
9.	Barrier	Economic	Lack of a clear customer proposition	30
10.	Driver	Economic	Clear customer proposition	29
11.	Barrier	Technological	Immaturity of technologies	27
12.	Barrier	Regulatory	Suboptimal regulation – rewarding flexibility	26
13.	Barrier	Organisational	Lack of organisational awareness	25
14.	Driver	Societal	Cooperation of actors in the energy system	24
15.	Driver	Organisational	Organisational awareness	20
15.	Driver	Technological	Congestion prevention	20
15.	Barrier	Societal	Lack of societal awareness	20
18.	Barrier	Technological	Privacy issues	18
19.	Driver	Economic	Control of energy costs	17
19.	Barrier	Technological	Scale up issues	17
19.	Barrier	Societal	Complexity of the energy system	17
22.	Barrier	Economic	High required investments	16
23.	Driver	Technological	Grid monitoring	15
24.	Barrier	Organisational	Time consuming organisational transition	14
24.	Barrier	Regulatory	Lack of regulation – active grid management	14
26.	Barrier	Organisational	Lack of OT IT convergence	13
26.	Barrier	Technological	Lack of a uniform control platform	13
28.	Driver	Regulatory	Regulatory encouragement	11
28.	Barrier	Organisational	Lack of communication skills	11
30.	Driver	Regulatory	Subsidies	10
30.	Barrier	Regulatory	Netting regulation	10
32.	Barrier	Political	Lack of a clear political vision	9
33.	Barrier	Societal	Lack of societal trust in energy companies	8
34.	Driver	Societal	Social cohesion	5
34.	Barrier	Regulatory	Suboptimal regulation determining the transport rate	5
36.	Driver	Economic	Efficiency of workforce	3
36.	Barrier	Regulatory	Current privacy regulation	3
38.	Driver	Organisational	Image building	2