Boundary conditions for an inclusive local Peer-to-Peer energy trading market

Case studies of the Smart City demonstration projects: The Next Generation Prinsenland and Het Lage Land in Rotterdam

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Preface

Before you lies the MSc thesis "Boundary conditions for an inclusive local Peer-to-Peer energy trading market". The research presented in this thesis is a product of extensive reading, interviewing, and interpreting for about seven months, a research based on embedded case studies into the Smart City and Smart Energy domain of the city of Rotterdam. The thesis results from a graduation project, which was carried out in cooperation between the Delft University of Technology and the Municipality of Rotterdam. The thesis was written and conducted in fulfilment of the Management of Technology program at TU Delft and offered recommendations on how to facilitate an inclusive local P2P energy trading market in Rotterdam in order to become an inclusive Smart City Rotterdam.

After writing the last lines in this thesis, it is an honour and a pleasure to express my gratitude and thanks to all those who helped and supported me. I would not have been able to complete this without their help and support. First of all, I thank my committee members, each of whom has provided their guidance, advice, expertise and flexibility throughout my research process. I would like to thank my first supervisor, Dr. Thomas Hoppe, for his advice, expertise, guidance and support throughout my research process and the numerous Teams meetings. I would also like to thank my second supervisor Prof.dr.ir. M.F.W.H.A. Janssen and my advisor Negar Noori for their expert advice and support during my thesis. A special thanks go out to MSc K. van den Berge, my external supervisor from the municipality of Rotterdam, for supporting me and ensuring that I possessed the means to get the work done. Furthermore, I would like thank the fourteen experts whom I interviewed for this research for their time, enthusiasm and expertise. Last but not least, I would like to thank my family and friends who always provided me with unconditional support, helped me, motivated me and always provided positive distraction during my most stressful moments. An additional special thanks and appreciation for their proofreading services!

With this thesis, I end a long study career. A study career that started at VMBO TL, and end at the TU Delft. Therefore, I shortly want to reflect on the last years as a student at the Master Management of Technology at TU Delft. This Master program fit perfectly me, and I learned a lot. Academically as well as personally, it gave me a lot of new insights into what really excites me, where my interest lies. Specifically, during the second year of this Master, where I could choose my specialization, electives, and of course, the topic of this graduation project. The Master Management of Technology and this graduation project were instrumental in determining the direction I would like to pursue after graduation.

I hope you will enjoy reading this thesis.

E.A. Afriyie

Delft, October 2021

Executive summary

Rapid urbanisation of the world's population confronts cities with new challenges and obstacles, related to organisational, social and technical aspects of a city. The Smart City concept incorporates information and communication technologies (ICTs) to develop a smarter infrastructure that enables data collection. Therefore, the Smart City concept has emerged as an effective solution, whereby cities can effectively collect and use the data generated from the ICTs to alleviate themselves from the challenges of rapid urbanisation. The Smart City concept aims to increase citizens' quality of life and provide economic opportunities, but it could also create barriers and negative externalities. The Smart City development based on a profit-driven approach contributes to creating negative externalities, especially for vulnerable and disadvantaged groups, and thus create more barriers. Conversely, a citizen-focused approach aims to manage the challenges of urbanisation and simultaneously ensure that the benefits of urbanisation are shared and adverse impacts of urbanisation are minimised. These approaches also highlight the importance of inclusion within the Smart City concept and should therefore be considered during the development of the concept.

A city struggling with the challenges of urbanisation is the city of Rotterdam. For Rotterdam, urbanisation creates problems relates to the city's energy consumption. To turn the tide, the city of Rotterdam aims to implement the concept of a Smart City and subsequently focus on a Smart Energy solution for two new residential areas, Prinsenland and Het Lage Land. Thereby focusing on the concept of inclusion and implementing a citizen-focused approach within the Smart City concept. Whereby the goal is to create an energy market that facilitates the participation of citizens. This can enable efficient management of Rotterdam's energy resources and enable the citizens of Rotterdam to trade their self-generated green energy, also known as Peer-to-Peer energy trading. However, the literature study revealed a lack of knowledge on the social implications, the concept of inclusion within P2P energy trading. Also, the literature study revealed a lack of knowledge exists on the market and regulation aspects of P2P energy trading. Accordingly, a lack of knowledge exists on the governance requirements and the boundary conditions of an inclusive P2P energy trading market. Therefore, this thesis will investigate the boundary conditions that need to be satisfied to create a market that facilitates energy trading. This enables the municipality to effectively manage to facilitate inclusive P2P energy trading. Therefore, the main research question of the thesis is: "How and under what conditions can the city of Rotterdam govern and facilitates P2P energy trading within the inclusive Smart City concept?".

To effectively answer this research question, a theoretical framework is used to determine the governance requirements regarding capable agents and opportunity structures, instrumentation and legitimacy. The theoretical framework was modified and subsequently extended to analyse the governance requirements for the Dutch energy system and the concept of inclusion. The empirical part of this thesis encompasses The Netherlands as the main case and the municipality of Rotterdam as an embedded case study. Additionally, this case study has two sub-units of analysis: the residential areas Prinsenland and Het Lage land. The data for the embedded case study is collected through grey literature, documentation and interviews. The interviews are conducted in a semi-structured manner as part of qualitative research, and for the analysis, ATLAS.ti was used.

This research created a new energy trading design, referred to as Community-Market energy trading. Additionally, this study determined nine boundary conditions for the Community-Market energy trading market; 1) determine the goal and focus of energy trading, 2) create an Energy Community, 3) conceptualising inclusion and include it in the design, 4) integrate adequate smart metering devices, 5) integrate an aggregator with an ACM license, 6) create an energy community with different energy profiles, 7) integrate a forecaster, 8) integrate an actor for the financial risks, and lastly, 9) "shop" the technologies needed for well-defined energy trading system. Additionally, this research determined the capable agents, instrumentation and legitimacy for the governance

of an inclusive P2P energy trading market. Accordingly, this research provides knowledge on the interaction of the capable agents, instrumentation and legitimacy for the governance of an inclusive P2P energy trading market. Moreover, this study reveals that the interviewees did not fully understand inclusion in P2P energy trading. However, the interviewees acknowledged the relevance of inclusion and determined it to be an objective for energy trading.

This research determines that Community-Market energy trading can be an effective tool to combat the challenges related to rapid urbanisation and enable a climate-neutral city. To understand the social implication and value of Community-Market energy trading, the municipality should focus on determining the goal and conceptualising inclusion before developing it. Therefore, this study introduced the term conceptualise inclusion, which refers to linking the dimensions of inclusion to the values of community. Practically, the municipality of Rotterdam should identify the needs and challenges of citizens related to P2P energy trading to create a design that actively aims to combat the challenges and needs. Thus, linking the development of P2P energy trading to the citizens living in the city. Additionally, the municipality should assess the activities and instruments they currently use in terms of inclusion and adjust them if needed. Furthermore, the municipality should focus on instruments that aim to raise awareness about P2P energy trading among their citizens, focusing on environmental awareness and behaviour. Lastly, they should aim to empower their citizens to participate in the decision making processes. Therefore, the research provides several recommendations for the municipality:

- Assess the needs and challenges of their citizens related to energy trading and other Smart Energy solutions.
- Enable inclusive integration of DERs and smart metering devices.
- Focus on creating an energy community.
- Investigate energy trading by utilising own assets for trading, thus focus on Business-to-Business energy trading
- Determine the value and the goal of facilitating a Community-Market
- Investigate TROEF Sharing Energy consortium, that consist of multiple capable agents
- And therefore, open the dialogue for Community-Market energy trading for their citizens.
- Investigate batteries

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Glossary

Table 1 and 2 provide an overview of the abbreviations and concept used within this study. Accordingly, the table gives the definitions of the abbreviations and concepts.

Concept	**Abbreviation**	**Definition used within this study**
Information and communication technology	ICT	Various sets of technological tools and resources used to transmit, store, create, share or exchange information
Smart Energy solution	SEs	Innovative energy technologies and/or services where ICTs are integrated to measure, receive, transmit, store and communicate data to generate information for managing energy.
Distributed Energy Resources	DERs	Small-scale energy generation sources and units, and energy storage systems, that are integrated and operate locally.
Peer-to-Peer energy trading	P2P energy trading	A Smart Energy data-driven business model/solution that enables flexible energy trades between peers, where the excessive energy from the small-scale DERs is traded with and among the peers.
Governance	Not applicable	The mechanisms whereby societal actors and state actors interact and coordinate to regulate issues of societal (Borrás & Edler, 2014)
Governance requirements	Not applicable	The regularities associated with governance of change
Boundary conditions	Not applicable	The socio-technical constraints in order to facilitate a local P2P energy trading market (Behnke & Janssen, 2020)
Prosumers	Not applicable	Actors who produce and consume energy.
Peers	Not applicable	Energy consumers, all potential active agents in the energy market
Socio-technical system	STS	A system with a strong degree of complementarity enabled through physical and social network relationships. (Koirala & Hakvoort, 2017)
Energy poverty	Not applicable	Occurs when households spend approximately 10% of their income on their energy consumption

Table 1: Definition of abbreviations used within this study

Concept	**Abbreviation**	**Definition used within this study**
Socio-technical and innovation system	ST&I system	Articulated ensembles of social and technical elements which interact with each other in distinct ways, are distinguishable from their environment, have developed specific forms of collective knowledge production, knowledge utilisation and innovation, and which are oriented towards specific purposes in society and economy. (Borrás & Edler, 2014)
End-users	Not applicable	Energy consumers, prosumers and consumers
Governance of change	Not applicable	The way in which societal and state actors intentionally interact in order to induce change in the systems, by regulating issues of societal concern, defining the processes and direction of how technological artefacts and innovations are produced, and shaping how these are introduced,absorbed, diffused and used within society and economy. (Borrás & Edler, 2014)

Table 2: Definition of abbreviations used within this study

Chapter 1: Introduction

Before this thesis, a literature review was carried for the master thesis preparation. That literature review provided the basis for this thesis. This resulted in certain similarities with the paper written for the master thesis preparation course of the MoT program and this thesis. The overlap is present in the introduction, the literature study, methodology and theoretical framework of this thesis. The literature review is defined as Afriyie (2021) and can be found in the reference list.

1.1 Background

"Crisis is the mother of innovation" (Nam & Pardo, 2011b). Rapid urbanisation of the world's population confronts cities with new challenges and obstacles. These challenges are related to the organisational, social and technical aspects of a city and cause problems such as air pollution, inadequate infrastructure, and scarcity of resources, such as energy or water, which negatively affects the quality of life of people living in cities (Washburn et al., 2009). The current rate of urbanisation is creating extraordinary circumstances and call for a new and innovative approach (Nam & Pardo, 2011b). Therefore, cities are examining different theories and frameworks to find answers on how to transform into a Smart City. The Smart City concept exploits all the available resources, monitors conditions and uses ICTs to collect, analyse and integrate information through sensors and critical infrastructure. Thereby creating a data infrastructure that generates information and knowledge that can be used to make smart decisions for a city and its citizens. These decisions aim to optimise resource usage and reduce consumption by improving infrastructure and changing habits. Thus, creating more efficient, convenient and harmonious management of resources within a city. Which can also enable energy efficiency or better waste management for cities (Akcin et al., 2016).Therefore, the Smart City approach has gained much attention in the last few decades (Nam & Pardo, 2011b).

Following the Paris Agreement in 2015 and EU directives, the Dutch government and municipalities are transforming towards climate-neutral energy systems by 2050. Creating sustainable energy systems in cities is regarded as key since cities consume 75% of the total energy and are responsible for 60-80% of the global greenhouse emissions. However, cities only occupy 3% of the earth's landmass (Pieroni, Scarpato, Di Nunzio, Fallucchi, & Raso, 2018). Therefore, Dutch cities, including Rotterdam, have to simultaneously manage rapid urbanisation and transform towards more sustainable energy systems. The Smart Energy domain, including its various solutions within the Smart City concept, aims to optimise an urban energy system by utilising ICTs and improve the quality of life for citizens. However, researchers are increasingly discussing the barriers and negative externalities of the Smart City concept. According to de Oliveira Neto and Kofuji (2016) the central point of Smart City is often placed on the technology, without considering the role of the citizens in a Smart City. Therefore, Noori, Hoppe, and de Jong (2020) suggest that cities should deviate from the technology-driven approach towards the citizen-driven approach thus towards an inclusive Smart City.

Therefore, effective adoption of the innovative, inclusive Smart City approach can help combat the problems associated with rapid urbanisation for Rotterdam. Accordingly, municipalities have to identify sustainable energy solutions and systems utilising ICTs that follow a citizen-driven approach while balancing the complex aspects of introducing technical elements to society, since they interact with every element of society and economy.

1.2 Problem definition

A city struggling with the effects of rapid urbanization is Rotterdam. The energy consumption of Rotterdam is quite high compared to other cities and municipalities. Accordingly, Rotterdam CO_2 emission accounts for more than 20% of the Dutch CO_2 emission. This is related to Rotterdam's high energy-intensive industry and dense buildings stock. To turn the tide, the city of Rotterdam is turning to the integration of the Smart City concept to manage their energy footprint of the city and make the city smarter (van den Donker et al., 2020). As a result, the city is focusing on the Smart Energy dimension of the Smart City concept. Also, the municipality is leveraging ICTs to find Smart Energy solutions that improve some vital aspects of the city, such as the energy systems and housing. Therefore, the municipality aims to implement a Smart Energy solution that facilitates and allows the city of Rotterdam to become a Smart City.

Accordingly, Rotterdam has started an initiative that aims to incorporate the Smart Energy solutions and energy systems for the districts Prinsenland and Het Lage Land. This will result in The Next Generation Residential Areas. The Next Generation Prinsenland and Het Lage Land will be designed to become energy self-sufficient by self-generation of Distributed Energy Resources (DERs), such as solar panels and wind turbines. With the effective implementation of Smart Energy solutions, residents in Prinsenland and Het Lage Land will generate, distribute, store and consume sustainable electrical energy. In addition, the municipality of Rotterdam aims to create a market that enables citizens to trade their own generated energy. This is referred to as Peer-to-Peer (P2P) energy trading. P2P energy trading enables residents to trade their excess electrical energy production DERs with other residents. Thus, increase their overall benefits. Additional benefits include flexibility to end-users, transitioning to a low-carbon energy system, creating opportunities to consume clean energy, enabling energy efficiency and creating economic benefits for users (Soto, Bosman, Wollega, & Leon-Salas, 2020); (Zhang, Wu, Zhou, Cheng, & Long, 2018). To facilitate P2P energy trading, the city of Rotterdam also aims to create a local energy system that facilitates a P2P energy trading market. The introduction of P2P energy trading enables the introduction of technical elements to society that interact with every element of society and economy. Accordingly, this will makes the introduction of P2P energy trading complex. Furthermore, the development of P2P energy trading needs to follow a citizen-driven approach to ensure that the quality of life for all citizens is enhanced. Therefore, the development of P2P energy trading needs to include the concept of inclusion. However, little to no research was found on inclusive P2P energy trading, which revealed a knowledge gap in this field. Therefore, this research will investigate the development of a P2P energy trading market for local integration, identify how the development can follow a citizen-focused approach, as well as how the municipality can govern facilitating an inclusive local P2P energy trading market.

1.3 Research Objective and Research Questions

This research aims to investigate the boundary conditions to govern an inclusive local P2P energy trading market. This research objective enables the municipality of Rotterdam to manage inclusive local P2P energy trading, while also ensuring that it increases the quality of life for every citizen in Rotterdam. Therefore, this research defines boundary conditions as:

"The socio-technical constraints in order to facilitate a local P2P energy trading market."

Boundary conditions determine whether the necessary constraints are satisfied before a local P2P energy trading market can be facilitated (Behnke & Janssen, 2020).

The literature study revealed an abundance of technical and theoretical knowledge on P2P energy trading. However, it also revealed a knowledge gap on the social, market and regulation aspects of P2P energy. Accordingly, the existing literature did not focus on inclusive P2P energy trading. Also, the literature on P2P energy trading markets did not provide any knowledge on governance related to facilitating P2P energy trading. Therefore, this research identifies a theoretical framework to analyse and explain how change is coordinated in complex systems. The theoretical framework provides guidelines for analysing the regularities associated with the governance of change in socio-technical systems. Accordingly, the framework was extended to explore the national energy system and to include the concept of inclusion.

Therefore, the following research questions has been formulated and will be addressed in this thesis.

How and under what conditions can the city of Rotterdam govern and facilitates P2P energy trading within the inclusive Smart City concept?

To answer the main question, five sub-questions have been formulated:

1. What is the current state of inclusive local P2P energy trading market?
2. Who are the stakeholders involved with the P2P energy trading market for locally self-generated sustainable green energy?
3. What are the boundary conditions that enable an inclusive P2P energy trading market for locally self-generated sustainable green energy?
4. What are the governance requirements of the city of Rotterdam that enable an inclusive P2P energy trading market in terms of agents and opportunity structures, instrumentation and legitimacy?
5. What are the future directions for Rotterdam to enable an inclusive P2P energy trading market?

To answer these research questions, a literature study and embedded case study was conducted with different experts within the Dutch energy system and energy system of Rotterdam energy system. Based on the case study results, recommendations were derived for the municipality of Rotterdam to effectively facilitate an inclusive local P2P energy trading market.

1.4 Thesis outline

This thesis consists of ten chapters and is organised as follows. After introducing the research, defining the problem definition and presenting the research questions in chapter 4, chapter 2 will present a literature study on the technical, theoretical, social, market and regulation aspects of P2P energy. Chapter 3 will identify, elaborate and extend the the theoretical framework of Borrás and Edler (2014). Chapter 4 will explain the research methodology and design, they by discussing the embedded case, interviews as data collection method and data treatment. Accordingly, chapter 5 will elaborate on the case study and Prinsenland and Het Lage Land districts. Chapter 6 will provide a general overview of the stakeholders in the energy system. Concequently, the empirical case study result will be presented in chapter 7. In chapter 8 the results of the empirical research will be linked to the theoretical framework. Additionally, the recommendations derived from empirical research will be presented in 9. Therefore this chapter will present the recommendations for the interviewees. In the conclusion chapter 10, the research questions will be answered, an academic discussion and the limitations of this research will be presented. Moreover, this chapter will present the recommendations for the municipality of Rotterdam and future research, as well as elaborate on the link with the MOT program, and the academic and societal relevance will be presented.

Chapter 2: The Literature Study

The previous chapter formulated the research objective and research questions. In this chapter, the academic literature related to P2P energy trading will be discussed. Since this research aims to define the boundary conditions of an energy market, this literature study will address the different aspects of P2P energy trading. Therefore, this study will elaborate on the theoretical, technical and social aspects of P2P energy trading. The literature study addresses this by elaborating on the supporting elements, potential barriers and opportunities of P2P energy trading. Additionally, market and regulatory bodies are instrumental in determining whether P2P energy trading markets can be integrated into a national energy system. Therefore, this study will elaborate on the Dutch Energy Act. Relevant academic literature does not provide knowledge on the market and regulatory bodies, including Dutch market and regulatory bodies. With the theoretical, technical, regulatory and social insights on P2P energy trading, this chapter contributes to answering the following sub-question:

Sub-question 2: What is the current state of inclusive local P2P energy trading market?

First, section 2.1 aims to generate a better understanding of the Smart City background. Therefore, this section will review the concepts of Smart City by presenting academic literature on the definitions of Smart City and its various domains. The problem definition revealed and identified problems related to energy. Subsequently, this section will narrow the focus and elaborate on the Smart Energy domain and its solutions to better manage energy. Furthermore, section 2.2 will elaborate on the negative externalities and social implications of a Smart City. Therefore, this section will elaborate on the importance of the concept of inclusion within a Smart City.

Second, section 2.3 will elaborate on P2P energy trading and explain why academia considers P2P energy trading to be an innovative energy management solution that enables and contributes to the Smart City concept. Therefore, this section will focus on P2P energy trading, determine a definition and elaborating on the implications of P2P energy trading. Subsequently, 2.4 will elaborate on the different supporting technologies. Subsequently, section 2.5 elaborates on the connectivity of peers, which is regarded as an essential element of P2P energy trading. Thus, these sections aim to presents the theoretical and technical aspects of P2P energy trading.

Third, following the literature on P2P energy trading, section 2.6 lists and discusses the market designs form that have been proposed for P2P markets. It is relevant to note that these market designs are mostly considered theoretical because it does not discuss specific energy systems. Therefore, local energy systems might not support the integration of the discussed market form.

Fourth, the concept of inclusion related to P2P energy trading will be discussed. Contrary to the theoretical and technical aspects of P2P energy trading, this literature study found limited on the social aspects of trading. Since inclusion is regarded as a barrier and negative externality of Smart City, this will also have implications for P2P energy trading. Therefore, this section will shed light on the potential barriers to the implementation of P2P energy trading.

Lastly, section 2.8 will elaborate on the regulatory regime of the Dutch energy system. Most countries, including The Netherlands, do not have any market and regulatory rules that facilitate P2P energy trading. However, The Netherlands is proposing a new Energy Act that can encourage or discourage the implementation of P2P energy trading. Therefore, this section elaborates on the potential barriers and opportunities of P2P energy trading in the current energy market and the regulations, specifically for the Dutch energy system.

2.1 The concept of Smart City

The Smart City concept is relatively new. For this reason, the Smart City concept has various definitions, which enables a lack of consensus within the concept. However, the definitions of Smart City are not contradictory but partly overlapping (Trindade et al., 2017). In order to generate a better understanding of the Smart City concept, this section will present an overview of the main definitions and core concepts (Afriyie, 2021). Table 2.1 presents several working definitions of Smart City.

2.1.1 Definitions of Smart City

Author	**Definition**
Harrison et al. (2010)	"A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city."
Hollands (2008)	"Territories with a high capacity for learning and innovation, which is built in to the creativity of their population, their institutions of knowledge production, and their digital infrastructure for communication."
Kondepudi et al. (2014)	"An advanced modern city that utilizes ICT and other technologies to improve quality of life (QoL), competitiveness, operational efficacy of urban services, while ensuring the resource availability for present and future generations in terms of social, economic, and environmental aspects."
Nam and Pardo (2011a)	"A smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains."
Toppeta (2010)	"A city combining ICT and Web 2.0 technology with other organizational, design and planning efforts to de-materialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and livability."
Washburn et al. (2009)	"The use of Smart Computing technologies to make the critical infrastructure components and services of a city-which include city administration, education, healthcare, public safety, real estate, transportation, and utilities-more intelligent, interconnected and efficient."

Table 2.1: Working definitions of Smart City

Hollands (2008) determined that the discussion of Smart Cities has increasingly influenced the debates about the future of urban development. Therefore, he researched the many aspects behind the label Smart City, which he determined was often self-labelled by cities. Therefore, Hollands (2008) proposed the first definition of Smart City. Subsequently, other researches followed, and Harrison et al. (2010) also defined a definition for Smart City. In addition to defining Smart City, Harrison et al. (2010) identified three foundational concepts of Smart Cities: instrumented, interconnected, and intelligent. Harrison et al. (2010) defined instrumentation as the sourcing of real-time real-world data from both physical and virtual sensors. The data generated from the sensors can then are interconnected across various processes, systems, organisations, industries, or value chains. Therefore, Nam and Pardo (2011a) determine that combining an instrumented and interconnected system enables the effective connection of the physical world to the virtual world. Lastly, intelligent refers to the incorporation of complex analytics, modelling, optimisation, and visualisation in the operational business processes to make better operational decisions (Harrison et al., 2010). Subsequently, other researchers have proposed their definition of Smart City. Moreover, these definitions differ from Harrison et al. (2010)'s definition, this analysis finds significant similarities between the definitions.

The first similarity is the overall need to improve and create benefits for a city. All definitions indicate some sort of improvement needed within the Smart City concept. To effectively combat the challenges of urbanisation, an improvement is needed. For example, Washburn et al. (2009) refers to an improvement in efficiency, while Kondepudi et al. (2014) refer to an improvement of the quality of life, and Toppeta (2010) refer to improving sustainability and liveability. Therefore, this can be related to the foundational concepts intelligent of the definition of Harrison et al. (2010). Another similarity is the universal recognition of the importance of technology. The key part of Kondepudi et al. (2014) definition is "modern city that utilises ICT and other technologies to improve". ICT is an abbreviation of Information and communication technology, and it is defined as various sets of technological tools and resources used to transmit, store, create, share or exchange information (United Nations Educational, Scientific and Cultural Organization, 2021). Conversely, Nam and Pardo (2011b) argues that technology is merely an enabler of a Smart City. They find technological infrastructure to be a core concept of Smart City (Nam & Pardo, 2011b). In line with the research of Nam and Pardo (2011b), this literature review finds technical infrastructure to be a core concept of Smart City. Therefore, critiquing definitions without explicit mention of technical infrastructure. In addition to the technical infrastructure, the definitions of Washburn et al. (2009) and Harrison et al. (2010) mention an interconnected infrastructure. Due to the complex nature of Smart Cities which includes multiple sources of ICTs and other technologies, an interconnected infrastructure is needed (Ismagilova, Hughes, Dwivedi, & Raman, 2019). Subsequently, an interconnected infrastructure enables the integration of different systems and sub-systems in a Smart city (Yin et al., 2015). Therefore, affirming the importance of interconnected, which is a foundational concept identified by Harrison et al. (2010).

Due to the ambiguous nature of the definitions of Smart City, core concepts have been defined to enable a better understanding of the concept. Harrison et al. (2010) found three foundational concepts of Smart Cities: instrumented, interconnected, and intelligent. This analysis found that the other definitions partly integrated Harrison et al. (2010) foundational concepts. Thus, this literature review concurs with these concepts and regards them as core concepts of Smart City. Additionally, the analysis found three different core concepts: technical infrastructure, data processing and domain application. However, in recent years public administration, such as municipalities, have invested in Smart City to increase the efficiency and productivity of several services and systems. Subsequently, scholars have determined that the focus of Smart City should and have changed to consider the role of citizens (de Oliveira Neto & Kofuji, 2016). Therefore, a transition from a techno-centric Smart City approach to a human-centric approach has been realised. This transition is generating new generations of Smart City that emphasise on human-centric, or citizen-focused Lee, Woods, and Kong (2020), Smart City approach. Accordingly, it installs the concept of inclusion as an important concept within the Smart City context. Section 2.2 will elaborate on the concept of inclusion within Smart Cities.

2.1.2 Various domains of Smart City

Moreover, Yin et al. (2015) found two other core concepts of Smart City: domain application and data processing. Data processing refers to capturing data through the application of technologies, which can be integrated across multiple systems and therefore be organized to generate new insights. Domain application relates to disciplines and or sectors in which the Smart City concept can be applied. The definition of Washburn et al. (2009) includes administration, education, healthcare, public safety, real estate, transportation, and utilities. The definition of Kondepudi et al. (2014) refers to social, economic, and environmental domain aspects. In addition, Giffinger and Gudrun (2010) researched the different application perspectives of the Smart City concepts. The study of Giffinger and Gudrun (2010) identified six smart characteristics with which to define and assess smart cities: economy, people, governance, mobility, environment/energy and living (Yin et al., 2015). Smart Economy encompasses the features surrounding economic competitiveness, including entrepreneurship and innovation. Smart People refers to the level of education received by citizens, the citizens' social relations, and perceptions of public life. At the same time, Smart Governance concerns the citizens' involvement and engagement with political life, public services, and administration functions. Smart Mobility includes local and global accessibility, whereby ICTs and sustainability are incorporated in the relevant modes of transport systems. Smart Environment concerns attractive natural conditions, including reduced pollution and resource management. Lastly, Smart Living refers to the many features of quality of life composed of health, housing, culture, tourism, and safety (Ismagilova et al., 2019).

2.1.3 The Smart Energy domain

Within the Smart City concept, six application domains can be identified. From these six domains, the Smart Environment is regarded as one of the most important domains. The foremost reason for this is that cities consume 75% of the total energy and are responsible for 60-80% of the global greenhouse emissions. Yet, cities only occupy 3% of the earth's landmass (Pieroni et al., 2018); (Morvaj, Lugaric, & Krajcar, 2011); (O'Dwyer, Pan, Acha, & Shah, 2019); (Mutule, Teremranova, & Antoskovs, 2018). Within the concept of Smart Environment, the energy sector is regarded as the main source of greenhouse emission, hence the best sector for mitigation (Kamyab, Klemeš, Van Fan, & Lee, 2020). In addition, Mutule et al. (2018) find energy interacts with all six domains and is therefore required in the development of Smart City. They conclude that energy is the key to tackling issues such as climate change (Mutule et al., 2018).

Accordingly, researchers aimed to define Smart Energy. Ahuja and Khosla (2019) defined Smart Energy as an ICT architecture that helps to improve system efficiency and creates a way for the end-users to communicate with utilities and the network service provider. Thereby, they determine that low energy consumption, renewable energy, and carbon footprints reduction need to be the prime targets of a smart city. However, their definition lacks the practicality to combat some of the critical issues related to energy. Integrating a well-defined approach would create a better understanding of the concept, which is instrumental. Therefore, the definition of Silva, Khan, and Han (2018) present a holistic approach that includes green energy, sustainable energy, and renewable energy. They argue that Smart Energy aims to serve the given energy demands by incorporating renewable energy sources to maintain the sustainability of non-renewable energy sources. Thereby also minimizing adverse effects on the environment (Silva et al., 2018). Even though their definition includes a well-defined approach, it does not incorporate a technological infrastructure, which is instrumental for a Smart City concept. Therefore, adding a technological infrastructure in their definition enables a clear and complete definition of Smart Energy.

2.1.4 Smart Energy solutions

A consensus has been reached that confirms the importance of Smart Energy within the Smart City concept, which can enable a Smart City. However, utilising Smart Energy in a Smart City calls for a focused approach to selecting and adopting solutions necessary for the development. Therefore, Shivakumar et al. (2018) defines Smart Energy Solutions as innovative applications, services or devices where ICTs are integrated to measure, receive, transmit, create, store and communicate data to generate information for managing energy. Subsequently, the study of Mosannenzadeh et al. (2017) identified three domains where Smart Energy solutions could be found: buildings and districts, transportation and mobility and energy and ICT infrastructures.

Smart Energy solutions in buildings and districts aim to create more comfort, functionality, and flexibility through the integration of energy generation, storage, distribution, and automated control. Smart Energy solutions in the domain of transportation and mobility focus on shifting conventional vehicle technologies to alternative vehicle technologies. Additionally, the domains aim to incorporate Distributed Energy Resources (DERs) in urban traffic and transport management solutions. DERs refers to small-scale energy generation sources and units, such as solar cells, fuel cells and small wind turbines Alanne and Saari (2006). Also, DERs include energy storage systems, such as batteries (Koirala & Hakvoort, 2017). Additionally, Smart Energy solutions in the energy and ICT infrastructure domain are divided into electricity infrastructure (smart grid), thermal infrastructure, and data infrastructure. The Smart Energy solutions in this domain provide the means to make the infrastructure more resilient by integrating renewable resources. This enables interconnection, monitoring, control and two-sided energy flow inside the networks (Mosannenzadeh et al., 2017). The study of Mosannenzadeh et al. (2017) determined these domains through the findings of the European Commission. The European Commission determined that residential and commercial buildings, transport, and manufacturing industry sectors could save approximately 27%–30%, 26%, and 25% energy, respectively (Mosannenzadeh et al., 2017). This is regarded as a sufficient reference and therefore applied in this literature review.

Within these three domains, the foremost researched domain is energy and ICT infrastructure. Studies in this domain are related to renewable energy sources' renewable nature, potentially fitting the world's energy demands (Silva et al., 2018). Therefore, studies conducted in the energy and ICT infrastructure focuses on Smart grids. Smart grid combines ICT with electrical power grids. Since the main feature of ICTs is to create two-way communication in all grid nodes, using the advanced metering infrastructure. Additionally, engaging customers can improve energy efficiency and reliability of the grid, thereby decreasing energy consumption (Morvaj et al., 2011). Consequently, many studies were conducted on integrating DERs with Smart grids (Silva et al., 2018). In addition, Honarvar and Sami (2016) argues that a Smart grid will ensure an efficiently matched power supply and usage whereby users can effortlessly assess their energy needs (Ismagilova et al., 2019). Nevertheless, Morvaj et al. (2011) argues that solely focusing on Smart grids is an insufficient approach in combating energy concerns. They propose researching within multiple domains. In accordance, their research aimed to develop a system that incorporated Smart grids and buildings. Their research gave an overview of Smart Energy solutions, their features and their potential to enable a Smart City (Morvaj et al., 2011). They concluded that combining Smart Energy Solutions could enable real-time bidirectional communication with all participating entities, which enable energy efficiency for a city. They focused on DERs since they are (often) integrated and operated for local use. Moreover, DERs are often connected to a larger power grid at the distribution level. Morvaj et al. (2011) researched a cluster of distributed generation installation, virtual power plants, by using the demand-side management to enable near an uninterruptible power supply. Demand-side management refers to activities to manage and optimise energy consumption. They determined that their study could enable a building to respond to market price signals and generate economic benefits for households. Therefore, their study concluded that this could create new collaborative services and applications.

To sum up, enhanced usage of ICT and the creation of data services enable a wider span of services in a city and trigger a transformation in a city's operational methods and services, which allows for optimal management of a city's resources. Within the Smart Energy concept, three domains of intervention have been determined: buildings and districts, transportation and mobility, and energy and ICT infrastructures. According to (Calvillo, Sánchez, & Villar, 2013), these Smart Energy solutions combined with ICTs will affect a city's technical requirements for system architectures and operational constraints. Accordingly, this study determines that the path towards an efficient and sustainable approach for tackling challenges of rapid urbanisation can only be created by clean and cost-effective renewable energy generation. Thus, DERs are essential in providing adequate tools to combat energy challenges and thus enable Smart Energy solutions.

2.2 Inclusive Smart City

Increasing urbanisation impacts every aspect of a city's development, especially the developments related to the sustainability of a city. Therefore, researchers are investigating and providing smart and sustainable urban planning driven by Smart Energy solutions to manage a city's resources effectively. This is the basis for the development and implementation of the Smart City concepts. However, these developments often follow a technology-driven (Noori et al., 2020), or a profit-driven vision (Lee et al., 2020). Therefore, cities implementing the Smart City concepts do not link the developments of a city with the actual people living in the city. According to Malhotra, Manchanda, Bhilwar, and Basu (2021), these visions might end up causing more problems, especially for vulnerable and disadvantaged groups, which will create barriers. Additionally, he argues that ensuring sustainable development and maintaining the quality of life of all citizens are essential concerns and should be placed at the heart of Smart City.

Therefore, researchers are calling for a contextualised approach applicable to the citizens' actual lives. Ideally, these visions are to be informed by the voice of the public. This refers to a 'citizen focused' and 'community focused' approach (Lee et al., 2020), that aims to manage the challenges of urbanisation while also ensuring that the benefits of urbanisation are shared, and the unfavourable impacts of urbanisation are minimised (Janda, Fennell, Johnson, Tomei, & Lemaire, 2019). Malhotra et al. (2021) concurs and finds that the underpinning strength of a Smart City is the social inclusion of various urban residents while also enhancing the social capital in urban development. Therefore, these researchers discuss and suggest focusing on an inclusive Smart City. Accordingly, Blacutt and Roche (2020) defines Smart Inclusive Cities as: "A Smart City where citizens (not only a specific and well-off category of the population) can access social innovations and take the benefit of the technical ones in support to their daily urban life." Furthermore, de Oliveira Neto and Kofuji (2016) determines that a Smart City can only be recognised as "smart", if a city reinforces the participation of everyone recognising the diversity of citizens, struggle against the segregation of minorities, and try, as much as possible, to eliminate physical and also digital barriers. Janda et al. (2019) concurs but assess that policies are also required to ensure the inclusion of all citizens of the urban environment. Additionally, Mohamed and Manaf (2020) argues that cities should focus on designing solutions in line with the inclusive Smart City concept, aiming to create a convergence between citizens, technology, and the Smart City services. However, he acknowledges that limited research has been done, and this is easier said than done.

Consequently, Liang et al. (2021) defined five dimensions of the concept of inclusive Smart City: spatial inclusion, social inclusion, environmental inclusion, economic inclusion and political inclusion. Spatial inclusion is defined as a process of creating equal access to the living environment, including land, streets, housing and public infrastructure and facilities for all individuals. Spatial inclusion often depends on the degree to which public space, physically and socially, is open to all. Social inclusion focuses on strengthening and creating equal development opportunities for everyone. Whilst also attending to their needs as social members. Therefore, sustainable migration and public participation are two characteristics of social inclusion (Liang et al., 2021). Sustainable migration involves the entitlement to adequate and affordable accommodation and protection from forced eviction. In comparison, public participation involves the public's concern about social affairs and the degree of social acceptance and integration. Social inclusion strengthens when all individuals and social groups have equal access to social resources, such as education, information.

Additionally, their rights should be protected and secured in situations of vulnerability with diseases, crime, violence, food and accidents (Liang et al., 2021). However, Liang et al. (2021) argues that everyone should be aware and accept the responding risks and responsibilities when using social resources. Environmental inclusion involves meeting the needs of current generations regarding natural sources and the environment without compromising the interests of future generations. Meanwhile, it emphasises close and inseparable relationships between the allocation of resources, environmental pollution and responsibilities. Economic inclusion makes it possible for all people, especially the disadvantaged and typically low-income people, to share in rising prosperity (Liang et al., 2021). For example, to participate in and contribute to gains in social welfare and well-being. Economic inclusion considers two sub-dimension, community and finance, as well as segregation and economic regeneration. Lastly, political inclusion is related to significant democratic institutions, human rights, political participation, and national identity issues. A crucial aspect of the five dimensions of inclusion is that the dimensions can be distinguished from each other. Nonetheless, they are interconnected and mutually complement each other (Liang et al., 2021). Figure 2.1 gives a visualisation of the framework of the inclusive city proposed by Liang et al. (2021).

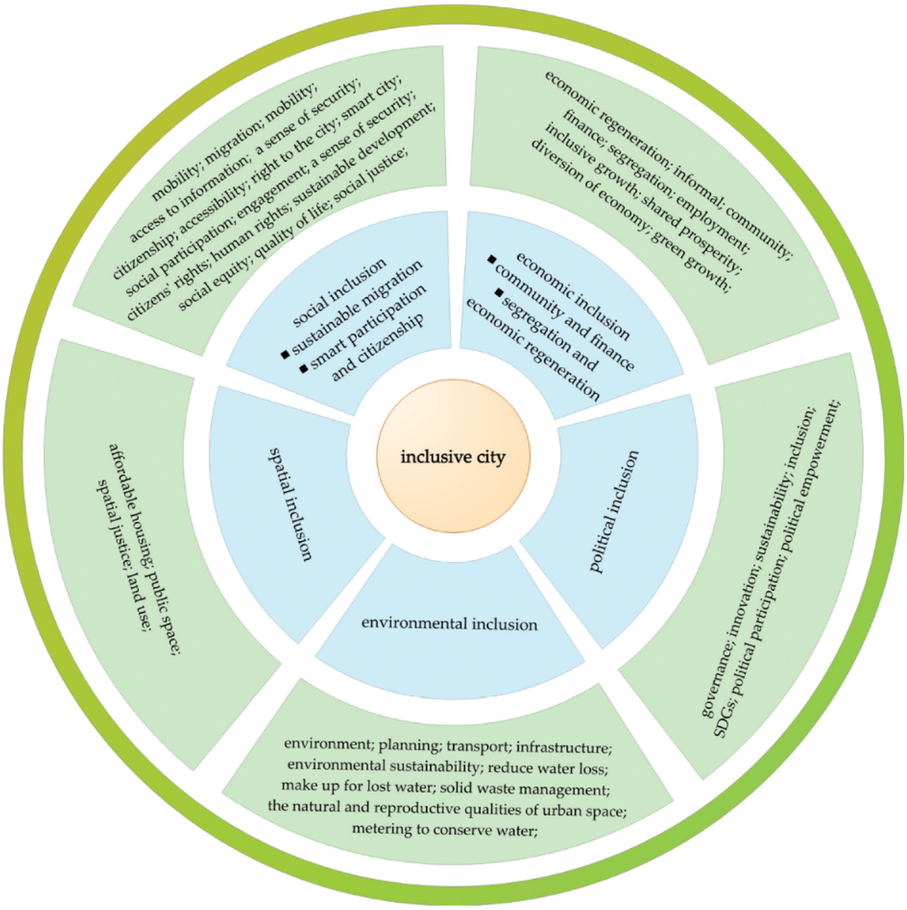

Figure 2.1: A multidimensional conceptual framework of the inclusive city, figure adapted from (Liang et al., 2021)

2.3 Peer-to-Peer energy trading

The academic literature regarding Smart Energy revealed that various domains and DERs that can enable Smart Energy solutions. Consequently, researchers determine that energy management at smart grids and smart homes will play an essential role in the future energy system (Soto et al., 2020). This refers to (Mosannenzadeh et al., 2017) Smart Energy solution in the domain buildings and districts and energy and ICT infrastructures. According to Koirala and Hakvoort (2017) the increasing penetration of DERs is empowering consumers to generate their electricity. Hence, DERs provides an opportunity to penetrate more sustainable and renewable energy into the system.

According to Bjarghov et al. (2021), traditional energy systems currently operate in a centralised fashion. Therefore, traditional energy systems involve a top-down approach where large-scale producers and industry consumers make upper-level decisions. However, due to the enhanced penetration of DERs, the traditional energy systems are moving toward more environmentally sound and decentralised generation systems (Riveros, Kubli, & Ulli-Beer, 2019). Bjarghov et al. (2021) concurs and adds that DERs and the enhanced usage of ICTs have enabled a bottom-up revolution in the energy system. Whereby DERs enables consumers to be involved as in the energy system. Therefore, the use of DERs can allow for more efficient energy use since they have a lower carbon footprint than conventional power production from thermal plants (Bjarghov et al., 2021). Additionally, they enable consumers to self-provision in their energy needs. This makes DERs based energy models economically competitive with centralised fossil fuel models (Brown, Hall, & Davis, 2019).

Tushar, Saha, Yuen, Smith, and Poor (2020) argues that the integration of DERs into the energy system does not necessarily threaten the centralised system. Accordingly, they assess that it generates opportunities to provide value streams for both the grid and the DER owners. From the grid perspective, it enables flexibility to improve localised network performance and therefore enable stability on the network. While from a DER owner perspective, increasingly comprised of consumers that have integrated DERs in their homes, DER owners can reduce their energy costs through self-supply and earning revenues by sharing the excess energy. DER owners can supply the excess energy with the grid and their peers. Therefore, the role of households is changing from passive consumers to active producers and consumers (Koirala & Hakvoort, 2017). This is known as the 'prosumer' phenomenon, typified by actors who produce and consume energy. Furthermore, prosumers can share their excess energy generated by their renewable energy sources with other consumers, such as their community (Zafar et al., 2018).

In response to the prosumer phenomenon, the Peer-to-Peer (P2P) trading energy paradigm has appeared, where consumers and prosumers can participate in the energy market and prosumers can share energy (Soto et al., 2020). Schneiders, Fell, and Nolden (2021) defines P2P energy trading as a data-driven business model that enables energy consumers to buy and sell. Whereas, Long, Wu, Zhang, Cheng, and Al-Wakeel (2017) defines P2P energy trading as flexible energy trades between peers, where the excessive energy from the small-scale DERs is traded with and among the peers. Whereby peers are defined as all potential active agents in the market (Soto et al., 2020). More generally, the market participants and end-users consisted of the consumers and prosumers. Accordingly, P2P energy trading relies on the participation of peers. Therefore, P2P energy trading enables prosumers to actively participate in the energy market by trading their excess energy with other prosumers. Additionally, a prosumer can sell their energy to consumers without renewables, thereby increasing their overall benefit. P2P energy trading utilises advanced ICTs and creates enormous data to enable this service in a city to satisfy this objective. From this perspective, P2P energy trading is considered to be a Smart Energy Solution Atasoy, Akınç, and Erçin (2015). Furthermore, P2P energy trading promises to reduce greenhouse gas emissions, which is essential for transitioning to an environmentally sound energy system. Moreover, P2P energy trading provides the additional actors in the energy market system with benefits, such as lessening the peak demand for electricity and increasing the reliability of the energy system Soto et al. (2020); Tushar et al. (2020). This study defines P2P energy trading as: *A Smart Energy data-driven business model/solution that enables flexible energy trades between peers, where the excessive energy from the small-scale DERs is traded with and among the peers*

However, the integration of P2P energy trading will affect a city's technical system architecture, affecting the energy market design (Tushar et al., 2018);(Soto et al., 2020), while also having implications on a social level (Wilkins, Chitchyan, & Levine, 2020). Researchers determine that the emergence of P2P energy trading is related to developments in technologies. Subsequently, these technologies are instrumental in designing a local P2P energy trading market and have implications for communities when integrated locally. To properly assess the opportunities and challenges offered by P2P trading, this literature study will conduct a comprehensive review of the technical and social aspects of P2P trading. Therefore, this literature study will also elaborate on the technologies supporting P2P energy trading, the different P2P market designs, community energy systems, and the concept of inclusion in P2P energy trading.

2.4 Supporting ICTs for the P2P energy market

According to Tushar et al. (2018), a P2P energy trading system consist of two main components: a virtual energy-trading layer and a physical energy network. The virtual energy-trading layer provides the technical infrastructure for the local integrated energy community. This ensures that every participant has equal virtual access to buy and sell energy (Tushar et al., 2020). At the same time, the physical energy network refers to the distribution grid used for the physical transfer of energy among peers. This section will elaborate on the different ICTs instrumental in the development of P2P energy trading. Therefore, what follows is an overview of technologies that can enable sharing of energy between prosumers to create an efficient and reliable system that also reduces energy use and peak demand. Thus, it enables P2P energy trading (Tushar et al., 2021).

Scholars have researched different designs for a P2P energy trading system. Their research and design focused on the ICTs used in the virtual layer. Different ICTs, models and approaches were discussed and proposed to design a virtual P2P energy trading layer. By analysing several papers published on P2P energy trading, this section will provide an overview of the foremost discussed ICTs, models and approaches in P2P energy trading systems. Soto et al. (2020) determined that the studies on the virtual layer often include multiple ICTs.

2.4.1 Trading platform

Trading platforms allow the participants to save all the information related to production, consumption, and contractual relations. Using the digital environment to the platform connects users with their resources, enabling the buying and selling of energy. Therefore, the trading platform can be seen as the central entity and intermediary for P2P energy trading. Secure and reliable trading platforms are critical to P2P energy trading because it holds and stores a significant amount of personal information (Soto et al., 2020). However, platforms are regarded as an important approach for the massification of P2P energy trading (Soto et al., 2020);(Kloppenburg & Boekelo, 2019). To enable this, reliable and secure platforms are essential for users and the P2P energy trading system. Therefore, trading platforms are being investigated in the traditional way, where one depends on an intermediary. Also researchers are investigating platforms without a central entity (Soto et al., 2020).

According to Morstyn, Farrell, Darby, and McCulloch (2018), four P2P energy-trading platform models can be identified: retail supplier platforms, vendor platforms, Blockchain-based platforms and microgrid and community platforms. Energy suppliers occasionally differentiate themselves by adding P2P energy trading as a service. These energy suppliers create a retail supplier platform that allows their consumers to obtain more value from their DERs and enable them to retain them as customers. Kloppenburg and Boekelo (2019) refer to this as provenance platforms and determines that transparency tends to be an important value on such platforms. Consumers value knowing where and from whom they are purchasing energy, also known as preference satisfaction. A Dutch energy supplier using a provenance platform is Vandebron. Vendor platforms are P2P energy-trading platforms provided by a specific DER vendor. For example, a home battery system vendor aims to increase their products' value by providing P2P energy trading for their customers. Microgrid and community platforms utilise the concept of ICESs by engaging the community and incentivising prosumers to support the formation of microgrids, coordination of DERs and other community energy initiatives (Morstyn et al., 2018). According to Kloppenburg and Boekelo (2019), the management of the energy for community platform often serves a predefined purpose, such as enhancing the autonomy of a local energy community, lowering energy prices by market trading, or providing grid balancing services. The following section will discuss the last trading platform, Blockchain-based platforms, in detail.

Researches have proposed different architectural design for the platform models. For example, Rusitschka, Gerdes, and Eger (2009) proposed a network of P2P homes with low-cost digital electricity meters, which allow optimisation of energy consumption. Their design is not solely based on energy exchange but also energy efficiency using smart electricity meters. At the same time, researchers are also focusing on other approaches for designing a P2P energy trading platform, such as game theory. However, most researches focus on creating an infrastructure with resource sharing microgrids and buildings connected by ICTs and incorporate different Smart Energy domains, such as buildings (Soto et al., 2020). However, developments of P2P energy trading platforms are (mostly) in pilot phases (Tushar et al., 2018). The studies on P2P trading energy platforms are focused on the architecture, testing, security and scalability of the architecture (Soto et al., 2020). P2P energy trading platforms offer three distinct value streams: energy matching, grid uncertainty reduction and preference satisfaction.

2.4.2 Blockchain

Trading platforms have to store a tremendous amount of user data to facilitate energy trading and function as an intermediary for P2P energy trading. Due to this, data security, data privacy, data integrity, and speed of financial transactions between prosumers have become critical (Tushar et al., 2021). Blockchain is an emerging ICT technology that offers new opportunities for Smart Energy solutions and can effectively address the concerns. Essentially, Blockchain is a distributed database of records, also known as a public ledger. A public ledger records every digital event that has been executed, and participating parties can access it. Additionally, every transaction in the public ledger is verified by the participants in the system, and once the information is entered, it can never be erased. Blockchain contains a specific and verifiable record of every single transaction ever made (Crosby, Pattanayak, Verma, Kalyanaraman, et al., 2016). Soto et al. (2020) defines Blockchain as a distributed database that can securely manage critical information such as contracts, data and monetary transactions. Therefore, the critical data is stored in blocks and linked with chains. Therefore, the design of The Blockchain technology increases security and decentralised transactions. An immutable, decentralised and publicly available shared database (Xie et al., 2019). Practically, Blockchain provides prosumers with a platform with transaction security to exchange information with their peers without intermediaries. Therefore, it (Tushar et al., 2021) defines Blockchain technology as necessary for the communication of information. Pee, Kang, Song, and Jang (2019) identify three characteristics the technology, data integrity, security, and decentralisation. In addition to these characteristics, Xie et al. (2019) add pseudonymity, transparency and democracy as characteristics of Blockchain.

Researchers have conducted studies to determine the implications of Blockchain on Smart Cities. According to Xie et al. (2019), Blockchain ensures data integrity, encourages organisations and individuals to share data and perform joint decision making, enables transparent city management, and promotes the implementation and deployment of a trusted, secure, transparent and democratised smart city. Tushar et al. (2021) determined that distributed ledger technologies often include ledgers, smart contracts, and consensus protocols. Ledgers record crucial information and data about the participants, whereas smart contracts define participants' preferences to ensure preference satisfaction of both parts are implemented. At the same time, the consensus protocols validate all the transactions.

In the P2P energy trading field, researchers focus on the security and scalability of the Blockchain network using the Internet. In addition, optimisation, decentralising energy resources and new architectures for Blockchain models have been researched. Therefore, Mengelkamp and colleagues a based Blockchain-based platform that allows prosumers and consumers to exchange energy without the need for a central intermediary. Their research utilises simulation, which will also be discussed. In the practical context, the Brooklyn Microgrid consists of a local community network covering a few streets in Brooklyn, New York. The homes in the project have PV solar panels installed. The participants can trade their excess production with other participants, and these trades are accounted for using Blockchain (Soto et al., 2020), which can enable researchers to analyse the energy consumption of the users. Therefore, Blockchain could increase energy efficiency in a city (Hwang et al., 2017). Other researches focused on the smart contracts of Blockchain by proposing models using existing and validated Blockchain platforms such as Ethereum for designing smart contracts(Tushar et al., 2021).

However, Ølnes, Ubacht, and Janssen (2017) determine that the benefits of Blockchain are often exaggerated.
specific. For example, trust because is not created by technology. Therefore, Ølnes et al. (2017) find that Blockchain can facilitate better control and audit, which ultimately might result in more trust. However, a condition for this is that necessary institutional arrangements need to be in place for it to be trusted. Whether the benefits of Blockchain are realised depends heavily on the Blockchain applications, their governance and the social and -institutional context for their use. In addition, Tushar et al. (2021) determines that providing security via Blockchain can be computationally expensive and therefore very costly. Moreover, Zhou, Wu, Long, and Ming (2020) determines that the mining procedure of Blockchain has a high energy consumption that could potentially increase the carbon emission. Accordingly, the research field of Blockchain based platforms is still developing because the methodologies, techniques and governance are still unclear. This needs to be identified and determined to confirm the benefits of Blockchain-based trading platforms (Ølnes et al., 2017);(Tushar et al., 2021).

2.4.3 Internet-of-Things

The Internet of Things (IoT) is a technology developed for the internetworking of various smart devices and humans (Tushar et al., 2021). The functionalities of IoT are sensing, communication, and taking automatic the appropriate action according to the data without any interplay. IoT devices often generate an enormous amount of data that needs to be accessible and managed in a distributed manner. Therefore, IoT requires an architecture that supports the retrieval, processing and storage of data (Khatua et al., 2020). According to Tushar et al. (2021), a vital part of P2P energy sharing is that prosumers can monitor their energy generation and demand, which enables them to gain insights into their energy consumption pattern and set the rules for the smart devices. Therefore, IoT is essential for smart homes since IoT can determine the demand and thus support energy management techniques. However, the connectivity of the smart devices also has some security and privacy risks. Therefore, scholars propose integrating Blockchain technology with IoT (Khalid et al., 2020).

2.4.4 Responsive buildings

Responsive buildings are buildings with the capabilities to respond to incentive signals sent from the energy grid, other buildings or third parties. The signals are then used to alter the buildings energy generation, consumption, and sharing behaviour. In addition, with the residents' preferences in the building, the responsive building can monitor and regulate their real-time energy generation, dispatch and optimize this according to the customers'/prosumers' preferences. While also providing energy services to the grid and other energy entities. Therefore, responsive buildings need reliable and low-latency two-way communication facilities to exchange vital information and communicate with devices, apparatuses, and other responsive buildings. (Tushar et al., 2021).

2.4.5 High-speed communication

According to Tushar et al. (2021), to enable P2P energy sharing and top-notch communication infrastructures would be needed. The infrastructure should have the capability to operate remotely and interact with various devices essential for P2P energy trading. Therefore, they determined that high-speed communication such as fifth-generation communication (5G) can fulfil these requirements and thus should be used for P2P energy trading.

2.4.6 Simulation

Simulation is a numerical technique to perform experiments about a process or a system (Soto et al., 2020). For P2P energy trading to gain acceptance on a larger scale, network operators should have the capability to model different P2P energy trading architectures and determine their impacts on the distribution networks and the potential effects on network performance and reliability (Hayes, Thakur, & Breslin, 2020). Therefore, simulation is a technology that is widely used in P2P energy studies. One of the characteristics of simulation is that it is a relatively cheap way to test new P2P energy trading mechanisms, which is not yet fully practically applied. Additionally, simulations tools can be used to compare different models (Soto et al., 2020). Practically, Hayes et al. (2020) propose a co-simulation methodology that includes P2P energy platforms and energy distribution networks. The impact of the large scale use of a P2P model and the potential benefits and impacts on the energy network were evaluated by using co-simulation. However, simulation alone would not enable P2P energy trading. Thus the technology is used with other technologies, such as game theory.

2.4.7 Game theory

Game theory is an area of applied mathematics that uses models to study interactions of actors in a system in formalized incentive structures called games (Soto et al., 2020). Researchers use the game theory approach, which includes various methods in various aspects of P2P energy trading that involve the decision-making process of entities with different interests. Therefore, a decision taken by one player depends on and affects the actions of other players (Tushar et al., 2018). Game theory is divided into two categories: non-cooperative games and cooperative games. In non-cooperative games, the strategic decision-making process of actors with partially or completely conflicting interests is analyzed to determine outcomes that are influenced by their actions. Conversely, cooperative games deal with incentives that enable independent actors to act together as one entity to improve their position in the game (Tushar et al., 2020). Researchers have utilized games theory to present different P2P energy exchange mechanisms. Thereby determining it to be feasible and effective energy management. Moreover, researchers have presented P2P energy trading mechanisms that enable feasible and effective energy management. The technology used for this P2P trading mechanism is Blockchain and simulation. Game theory is also used to develop a motivational psychology framework for encouraging sustainable and beneficial participation of prosumers in the P2P models. Thus, game theory aims to capture the competition and cooperation between different actors of the P2P energy market to deliver a stable and mutually beneficial solution to all (Tushar et al., 2020).

2.4.8 Optimisation and algorithms

Algorithms and optimization technologies both aim to optimize a P2P energy trading design. In the academies of math and computer science, an algorithm is defined as "a finite sequence of well-defined, computer-implementable instructions to solve a specific set of computable problems" (Duin & Pedersen, 2021). Practically, an algorithm is a sequence of instructions directing and telling a computer what to do. Therefore, in a P2P energy trading model, algorithms are in constant development to optimize the supporting processes of the model (Soto et al., 2020). Similarly, optimization is a tool that aims to optimize. However, the tool focuses on maximizing profits or minimizing losses. Therefore, the optimization mechanisms are often integrated to maximize the economic benefits of users. Additionally, the tool has been used to create a balance between energy supply and demand in microgrids and to minimize the prosumers' energy losses (Soto et al., 2020). Therefore, Steinheimer, Trick, and Ruhrig (2012) propose a P2P energy trading model where users can develop services to manage their devices and distributed energy resources. Additionally, the proposed model optimizes energy consumption through energy management, thereby managing smart grids and smart homes. This design utilizes home networking and algorithms for automated optimization of energy consumption in the homes of prosumers and communities without third parties' assistance (Soto et al., 2020).

Artificial intelligence

Lastly, artificial intelligence (AI) refers to computational techniques that simulate human intelligence in machines. Therefore, machines with AI exhibit characteristics associated with the human mind, such as learning and problem-solving. According to Ullah, Al-Turjman, Mostarda, and Gagliardi (2020), the utilization of ICTs will generate an immense amount of data, also known as big data. Therefore, Ullah et al. (2020) determine that in the presence of significant and complex data, AI is the most efficient and most accurate technology for the analyses of the data in a Smart City. Additionally, the authors determine that AI's accuracy and precision can be further enhanced by increasing the amount of training data. This will strengthen AI's learning capabilities, which also strengthen the automated decision efficiencies of AI. Practically, this technology could be used to learn the energy usage pattern of different flexible loads within a building as well as understand prosumers' responses (Tushar et al., 2020). Therefore, AI can assist prosumers in making efficient and sustainable choices for energy trading. Thus, AI enables efficient utilization of ICTs to enable data analysis, data communications and effective implementation of complex strategies to ensure the smooth and secure operation of a Smart City (Ullah et al., 2020).

2.5 Community energy systems

According to Schneiders et al. (2021), P2P energy trading can be defined as a complex socio-technical system, a system with a strong degree of complementarity enabled through physical and social network relationships (Koirala & Hakvoort, 2017). Accordingly, Koirala and Hakvoort (2017) determines that the physical system concerns the supply-side of the energy system. Therefore, the physical system includes energy generation, distribution, storage, and energy management technologies. Tushar et al. (2021) specifics the physical system and differentiate between the physical electrical system and the energy sharing system. The physical electrical system encompasses the distribution and transmission lines of the grid network, which connects peers in and across different communities. In contrast, the energy sharing system arises from different application-specific energy service providers. The energy sharing system is enabled through transactive energy frameworks using different technologies. 2.4 elaborated on the different technologies supporting P2P energy trading. These technologies also act as energy management technologies defined by Koirala and Hakvoort (2017). The physical system and the supporting technologies are vital because it facilitates the trading activities for the peers.

Accordingly, Koirala and Hakvoort (2017) elaborates on the social system and determines that it consists of many different actors, including governments, energy suppliers, technology providers and system operators. According to Bjarghov et al. (2021), the enhanced penetration of DERs provides the end-users, the peers, with new roles in the energy market. They argue that small-scale producers and consumers used to be categorised as reactive decision-makers. However, with the integration of DERs, they are instead seen as active decision-makers in the energy system. The changing roles of peers and end-users have huge implications, namely when these actors/stakeholders are situated in the same residential area (Bjarghov et al., 2021). Therefore, Tushar et al. (2021) argues for coordinating and connecting DERs and thus creating a connected community. Accordingly, they determine that connected communities rely on DER, flexible loads, grid integration and smart technology, the technologies discussed in 2.4. Peers in a connected community could reduce energy use and peak demand, improve energy efficiency and trade energy. The connected community is not restricted to a specific residential area or local community. Thus, a connected community allows peers to trade outside their local area or district. Therefore, they define a connected community as a building block for P2P energy trading.

Whereas, Dóci, Vasileiadou, and Petersen (2015) elaborates on a community energy system. They define a community energy system as a community that produces or invests in renewable energy to cover their own energy needs. Consequently, the community energy system does focus on residential areas or local communities, but it does not focus on Smart technologies or P2P energy trading. Therefore, Koirala and Hakvoort (2017) argues for an advanced form of a community energy system: an integrated community energy system (ICES). They determine that, whereas community energy systems solely focus on self-provision, ICES also aims to match supply and demand within a community. Whereby they determine that a community can range from a block of households to an entire district. According to Koirala and Hakvoort (2017), an integrating approach relies on smart-grid technologies and technologies that focus on managing energy efficiently, demand-side management. The added benefits of such an integrated approach are that it increases reliability, efficiency and enables balancing attributes to the energy system. Koirala, Koliou, Friege, Hakvoort, and Herder (2016) define an ICES as multi-faceted energy systems for the supply of communities, whereby a collection of DERs supported by demand-side management and storage are managed for and at a community level. Subsequently, they determine that ICES allows energy trading at a local community level.

Since both the connected community and ICES aim to connect the peers, which enables P2P energy trading, these communities are determined to be essential elements for energy trading. As discussed before, the changing roles of peers and end-users have huge implications, depicted in the decision-making activities and powers of the peers and communities. Collective action is needed to integrate P2P energy trading, which relies heavily on citizens and peers' acceptance, support, and participation. Therefore, Koirala et al. (2016) assess that communities are well-placed to bring peers together to achieve common goals and identify local energy needs. Additionally, they determine that this offers opportunities for the local energy production governance and enables a bottom-up revolution in the energy system.

However, these opportunities will impact the existing system architecture and influence future energy systems. Therefore, the new roles of peers enable a change in local energy requirements and energy systems, which changes the dynamics of the traditional energy system. The changes in the energy system will enable interactions with different decision-making entities, such as system operators, energy suppliers, technology developers, governed by national energy policies. This makes a P2P energy trading system complex. Since it includes different technologies that influence various actors and requires interaction with different social, technical and institutional elements of a national energy system.

2.6 P2P market designs

The design of a P2P energy trading market is based on the technologies discussed in section 2.4. These technologies have tremendous implications for the market structure of a P2P energy trading model because it defines the characteristic of the trading process and the method of communication of information among participants in the market (Tushar et al., 2020). A network, including an energy trading network, consist of ties and nodes. The nodes are the individual actors within a network. In an energy trading network, the nodes are the peers. The peers are often referred to as households and end-users. According to Koirala and Hakvoort (2017), the peers consist of consumers and prosumers. However, other studies also include businesses as peers (Sousa et al., 2019). In contrast, the ties within a network refer to the relationships between peers. Within an energy trading market, the ties are the energy flows between the peers. Additionally, Sousa et al. (2019) argue that the degree of decentralisation and topology is what distinguishes the different market designs from each other. With this knowledge at hand, three different types of markets that facilitate P2P sharing within an energy network have been defined:

1. Coordinated market
2. decentralised market
3. Community market

Figure 2.1 gives an overview of the different market forms.

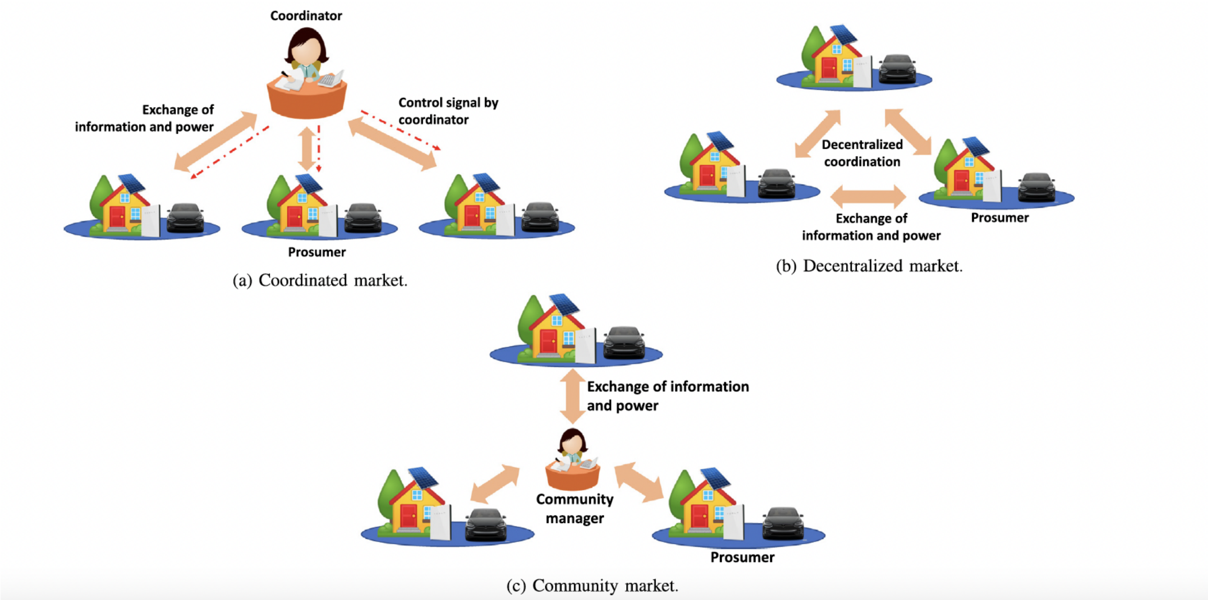

Figure 2.2: Overview P2P trading markets, figure adapted from (Tushar et al., 2021)

2.6.1 Coordinated market

The centralised procedure characterises the coordinated market. The trading process and the communication of information are both performed in a centralised fashion. Within the coordinated market design, a centralised coordinator communicates with each peer within the community. Therefore, connected communities are essential for the coordinated P2P energy trading market. Additionally, the centralised coordinator also has direct control over the amount of energy exchanged between peers. Once the trading is complete, the revenue is distributed by the coordinator among the peers, which is done following pre-set rules (Tushar et al., 2020). According to (Parag & Sovacool, 2016) the coordinator can enable a connection with the main grid, which would enable energy sharing with the main grid. These activities can generate an incentive for prosumers to produce energy since surplus energy generation can then be sold to the main grid. According to Tushar et al. (2020), a vital advantage of the coordinated market is the efficiency of a coordinator. The coordinator can enable a higher certainty of the market outcome. Also, the coordinator can maximise the social welfare, economic benefit of the participants within a coordinated market Zhou et al. (2020). However, with the increasing penetration of DER, the computational load of P2P energy trading could be extensive. Also, the centralised characteristic of a coordinator has implications on the privacy of the prosumers (Tushar et al., 2020).

2.6.2 Decentralized market

Conversely, in a decentralised market, both the trading process and the communication of information are performed through a decentralised method. Prosumers within a decentralised market can directly communicate with each other and define their energy trading parameters without the involvement of a coordinator (Tushar et al., 2020). Therefore, Blockchain is at heart in a decentralised market (Harrison et al., 2010). Tushar et al. (2020) determines that a connected community is essential for the decentralised P2P energy trading market. Additionally, Parag and Sovacool (2016) determine that this market design emerged from the bottom-up energy system approach. In addition, some researchers argue that the decentralised trading market is inspired by the sharing economy concept, which relies on numerous agents. Therefore, they suggested Airbnb and Uber models for the grid. Since, similar to Uber and Airbnb, P2P energy platforms match suppliers with customers who seek to rent access to the product for a limited period (Wilkins et al., 2020);(Morstyn et al., 2018).

Furthermore, in a decentralised energy trading market, the distribution grid is paid for its management and distribution function, which depends on the type and amount of service and the distance between the prosumers (Parag & Sovacool, 2016). The main advantage of a decentralised market is the prosumers autonomy in their decision-making process. Due to prosumer-centric properties, prosumers are better served in a decentralised P2P market. Moreover, Tushar et al. (2020) determines that the scalability of the decentralised market is higher compared to a coordinated market. Nonetheless, without centralised control, the efficiency of decentralised markets is relatively low. Therefore, the economic benefit for prosumers within this market would never reach a maximum value. In addition, there is no insight on the total amount of overall energy that can be traded in this market form. More importantly, challenges arise for maintaining the network constraints and improving the power system's operational efficiency. Thus, the decentralised market has negative implications for the reliability of the grid (Tushar et al., 2020);(Sousa et al., 2019). Without insight into the prosumers trading behaviour, essential actors in the energy system such as network operators, retailers, and transmission system operators will have difficulties managing and controlling this market. Therefore, determining a decentralised energy market's boundary conditions and governing it will be complex. Consequently, the essential actors in the energy system can take drastic measures to maintain the grid's reliability, such as blocking prosumers from the market. Therefore, a decentralised market relies on technologies that can provide accurate assumptions on the decision-making activities of peers. Therefore, the supporting ICTs proposed for a decentralised P2P energy market include Blockchain, game theory and simulation (Zhou et al., 2020);(Sousa et al., 2019).

2.6.3 Community market

The third and final market is the community market. The trading process in a community market occurs decentralised, while the communication between the participating prosumers occurs in a centralised manner (Bjarghov et al., 2021);(Tushar et al., 2020). According to Tushar et al. (2020), a community market includes a community manager that operates as a coordinator of P2P energy trading among the peers. For this P2P energy trading market, the connected community and ICES could be created for the connectivity of the peers. However, unlike the centralised market, the community manager does not directly control the trading activities of the different prosumers within the market. The community manager can only indirectly influence the prosumers to participate in trading through informing them of specific pricing signals (Zhou et al., 2020);(Tushar et al., 2020). Thus, compared with a decentralised market, a community market uses a coordinator to enable better coordination between the peers within the community. Moreover, compared with centralised markets, community markets require less information from the prosumers, and the coordinator does not have direct control over the prosumers' devices (Zhou et al., 2020). Thus, in a community market, prosumers maintaining a higher level of privacy (Tushar et al., 2018).

According to Bjarghov et al. (2021) the main advantage of a community market is its compatibility with existing regulatory frameworks. Grid operators in the energy systems can better predict the trading behaviour of prosumers, which allows for a smoother and regulated integration of the community P2P energy trading market into the existing energy system. Another advantage of the community market is the scalability of the ICT infrastructure. In contrast, the challenges are the coordination of trades, the integration and handling of extensive data sets and multi-market coordination (Bjarghov et al., 2021). In addition, Tushar et al. (2020) and Zhou et al. (2020) determine that the core issues of community markets are determining a proper pricing mechanism for P2P energy trading. Since the pricing schemes focus on engaging a large number of prosumers, ICTs such as game theory, AI, and simulation have been discussed for this (Tushar et al., 2020). Nonetheless, a community P2P energy trading market is likely to operate in a Smart City Environment. A community energy market presents opportunities for local organisations, neighbourhoods or communities to manage their energy needs efficiently while also taking the grid reliability into account (Parag & Sovacool, 2016)

2.7 Inclusive P2P energy trading markets

Section 2.2 described the importance of inclusion within the Smart City concepts. Therefore, inclusion also has implications on the Smart Energy and Smart Energy solutions. This section will review the implications of inclusion on P2P energy trading because it has tremendous implications for a Smart City development. According to Liang et al. (2021) technological innovations in the urban environment can exclude large segments of society, which can pose a moral liability. Therefore, for a Smart Energy solution, such as P2P energy trading, the concept of inclusion will also have implications.

Within P2P energy trading, limited research has been done on inclusion. Koirala and Hakvoort (2017) research found that local energy projects within a community are inclusive, democratic, and sustainable. However, his research provides little detail on its definition of inclusive. Their research of Koirala and Hakvoort (2017) focused on ICES and argued that citizens and peers within ICES would share a sense of place, identity and have the same values. Moreover, they assess that communities are well-placed to identify local energy needs, which they can use to determine and create services that can bring the citizens together to achieve common goals, such as self-provision. However, Shelton and Lodato (2019) disagrees with this and assess that the citizens in the community, and a Smart City, are not universal. Therefore, the citizens will have different values and identities within a community. This reveals the importance of creating local value since presumptions of citizens enables exclusion.

The research of Zhou et al. (2020) discusses the advantages of different P2P market forms. Their research determines that a major advantage of centralised markets is maximising the social welfare of a P2P community. In this research, social welfare refers to economic and monetary benefits, to which Liang et al. (2021) refers to as economic inclusion. Furthermore, Wilkins et al. (2020) discuss digital exclusion of P2P energy trading technologies. According to Wilkins et al. (2020), the current market includes older participants. These participants have a financial disadvantage because of limited internet access, low computer literacy, and distrust of digital technology. Older participants were unable to access online-centric benefits. In regards to this, Fell, Schneiders, and Shipworth (2019) discussed inclusive technology, which refers to the non-inclusive nature of technologies aimed at encouraging sustainable energy management. His research determined that often households that are interested in sustainability and monetary incentives are motivated to participate in Smart Energy solutions. Reis, Gonçalves, Lopes, and Antunes (2020) concurs and adds that prosumers' and investments in generation, storage and other enabling technologies may hinder the participation of vulnerable consumers. They define vulnerable consumers as: "end-users who, due to socio-demographic circumstances, have limited financial capacity to purchase energy products and services". Therefore, the vulnerable consumers are not expected to have the financial means to purchase and integrate DERs. This leaves this group excluded from participating in the P2P energy trading. However, to ensure a fair energy transition, all segments of society should benefit from and have access to clean and cheaper energy, as well as having the same opportunities to become active participants in energy markets (Reis et al., 2020).

This section aims to identify the importance of inclusion within P2P energy trading. However, this section determines that limited research has been done on inclusive P2P energy trading. Liang et al. (2021) elaborated on inclusive Smart City and defined the five dimensions of an inclusive Smart City. Researchers within the P2P energy trading field often focus on a single dimension of inclusive P2P energy trading. Whereas Reis et al. (2020) focuses on two dimensions, economic benefit and social inclusion. Reis et al. (2020) argues that these two dimensions hold significant implications to ensure that all sections of society are active participants in the growth and the development process of a city. Whereby the needs and demands of all the citizens are reflected in the solutions that the city administration implements (Malhotra et al., 2021). However, Liang et al. (2021) argues that all five dimensions are essential and should be understood.

2.8 The Dutch energy system

The previous section has elaborated on the different aspects of making a city smart by facilitating an inclusive P2P energy trading market. Therefore, researchers have provided in-depth knowledge on the theoretical, technical, social aspects that enable opportunities and challenges for P2P energy trading. However, the actual benefits and opportunities of facilitating a P2P energy trading market rely on the national market and regulatory bodies (Tushar et al., 2021). The literature on P2P does not specify for The Netherlands. Therefore it is fundamental to elaborate and analyse the market and regulatory bodies of The Netherlands. Since this determines the market designs form that facilitates local P2P energy trading. Accordingly, it could explain how the market form can be integrated into the Dutch energy system. Thus, the analysis of the Energy Act is instrumental in defining the boundary conditions. This study defines boundary conditions as:

"The socio-technical constraints in order to facilitate a local P2P energy trading market."

Boundary conditions determine whether the necessary constraints are satisfied before a local P2P energy trading market can be facilitated (Behnke & Janssen, 2020). Accordingly, the Dutch government and the national Energy Act can support or discourage the implementation of P2P markets. Therefore, this section will elaborate on the current Energy Act.

2.8.1 The Electricity and Gas Act

Currently, the Electricity and Gas Act accepted in 1998 is enforced in the Dutch energy system. The energy Act introduced liberalisation in the energy supply of The Netherlands (Tanrisever, Derinkuyu, & Jongen, 2015). According to The Dutch Minister of Economic Affairs and Climate Policy (2020b), the Energy Act enabled the transition from a supply-driven energy supply to an energy supply based on a market model. The market model enabled market forces and demand management. Therefore, the Act provided customers with more freedom to procuring energy and suppliers to sell energy. Fundamental for this was the concept of unbundling, the separation of the market functions traditionally provided by a single utility into functionally independent entities. This resulted in establishing the state-owned transmission system operator, Tennet, that manages the high voltage grid. Later, the Dutch government also unbundled the medium and low voltage transmission grids. This created additional actors that manage this grid, called distribution system operators (DSOs). Thus, the Act provided and established a market framework that is focused on reliability, sustainability and efficiency. These three objectives were of utmost importance and necessary to safeguarded public interests (The Dutch Minister of Economic Affairs and Climate Policy, 2020b);(Tanrisever et al., 2015).

According to VEMW (2021), the Electricity and Gas Act accepted in 1998 determined the organisation and the rules for the Dutch energy supply and is the basis for the free market for electricity. The Electricity Act focused on:

1. The organisation of the national Energy market
2. The unbundling of electricity production and grid management
3. The protection of small-scale consumers
4. The organisation of transport and distribution of energy
5. Determining definition for the entities and elements of the national energy market
6. Guaranteed access to the net
7. Determining transport and distribution tariffs

The current Energy Act focused on the liberalisation of the national energy market. Therefore, the Act does elaborate nor define any supporting elements of P2P energy trading. Additionally, the Act determines that renewable energy and climate-neutral electricity can only be generated in (hybrid) production plants. Therefore, this Act focuses on top-down approaches and does not allow for bottom-up approaches and Smart Energy solutions. Furthermore, the Act forbids supplying energy without a licence. Therefore, Article 95.a reads:

"It is prohibited to supply electricity without a permit to small-scale customers".

Therefore, the premise of P2P energy trading is prohibited through this article. Thus, this Act does not allow for P2P energy trading.

2.8.2 The proposed Energy Act

On 17 December 2020, the Dutch Minister of Economic Affairs and Climate Policy published the draft version of the proposed Energy Act. With this Energy Act, the Electricity and Gas Act accepted in 1998 will be replaced. Additionally, the sustainability goals of the European Union proposed in 2019, the Clean Energy Package, will be adapted and implemented through the proposed Energy Act. Moreover, the proposed Energy Act has integrated measures drawn up in the Paris Climate Agreement to reduce CO_2 emission. Therefore, the proposed Energy Act is an crucial development in the national energy system and has enormous implications for the Dutch energy system and a future P2P energy trading market.

According to The Dutch Minister of Economic Affairs and Climate Policy (2020b), the proposed Energy Act focuses on four energy transitions:

1. Transition to a climate-neutral economy and society
2. Transition to more decentralised and sustainable energy generation
3. Transition to a (more) digital society
4. Transition to a greater degree of 'self-determination' of end customers

To support the energy transition, the Energy Act introduces new energy terms and definitions. Table 2.2 gives an overview of these terms. In addition, the table describes the definitions of the terms introduced in the Energy Act.

Energy terms	**Definition of the energy term**	**Act number**
Energy community	Legal person/entity acting on behalf of its members or shareholders, to preform activities in the energy market for the sole purpose to provide environmental benefits or economic or social benefits to its members or shareholders or to the local territories where the person is employed and whereby the entity does not make any profits	Art 2, section 11, Rl 2019/944
Smart metering devices	Electronic metering device that measures the consumption or electricity input. The devices have an additional functionality that enables them to both transmit and receive data through a form of electronic communication	Art 2, section 23, Rl 2019/944
Demand response management	Changes in the end-users electricity load compared to their normal or existing consumption patterns in response to market signals	Art 2, section 20, Rl 2019/944
Balancing responsibility	A natural or legal person who is granted the authorized by the transmission system operator to run and manage an electricity programme	Art 5, Vo 2019/943
Aggregator	A natural or legal person who bundles and sell electricity generated by the end-users on the electricity market, or bundles and sell flexibility through the changes of end-users electricity load compared to their normal or excising consumption patterns	Art 2, section 18, Rl 2019/944
Second measuring device	An end-user is free to enter into a contract with any energy supplier. In addition, an end-user can enter into multiple contracts, as long as the end-user has a smart metering device or a second measuring device	Art 3, fourth paragraph, 4, 13, first and second paragraph Rl 2019/944]
Congestion management	Procedures that prevents congestion from occurring and measures that ensure that congestion is removed	N/A

Table 2.2: Overview of energy terms introduced in the Energy Act, derived from The Dutch Minister of Economic Affairs and Climate Policy (2020a)

Due to human-induced climate change, the Netherlands has committed itself to transition to a climate-neutral society and economy in the course of the next three decades. To enable the transition to a climate-neutral economy and society entails a fundamental change in the national energy production. To realise this, the Energy Act focuses on two major amendments. Firstly, reducing and eventually transitioning from fossil resources to renewable energy resources. A large part of the traditional centralised energy production will be replaced by large-scale wind farms in the North Sea. In addition, a small and yet substantial part of energy production is expected to be generated through decentralised energy generation, which includes solar parks and solar panels on roofs. However, the Energy Act acknowledges the unpredictable and uncontrollable nature of these energy resources. Therefore, the Energy Act and energy transition have real consequences for the energy market. In addition to the energy production being influenced, the end-users will also be affected. Therefore, the Energy Act also mentioned congestion management. Moreover, the Energy Act focuses on flexibility and expects the future energy market to have flexibility characteristics. Therefore, the Act emphasises the importance of digitisation. Digitisation has already penetrated society. Therefore its can also be expected that digitisation will also be utilised in the energy system. Furthermore, the Act prioritises the use of smart meting devices. Moreover, the Act demands that DSOs, Stedin, provide their end-users with smart metering devices. This is in support of a large-scale roll-out of these devices. Smart meting devices provide fast, more efficient, more detailed and provide real-life information on energy data related to consumption and production. This, in turn, enables the exchange of data between the different actors and generates new innovative applications. The new smart metering devices aim to provide new opportunities to meet supply and demand and thus better manage the grid. Also, the devices are expected to assist in creating flexibility in the energy system to cope with the unpredictable and uncontrollable nature of renewable energy sources. More importantly, the Energy Act expects that integrating smart metering devices will also significantly and positively affect the position of the end-user in the energy market. Since the combination of transitioning to a more decentralised and sustainable energy generation and a more digital society also offers end-users the opportunity to create 'self-determination' within the electricity system. Where previously large-scale and central production installations full filled the energy needs, now an end-user can self-provision in their energy demand, for example, through the storage or sale of self-generated electricity. Therefore, the Act introduces balancing responsibility, demand response management, aggregators, a second measuring device and energy community (The Dutch Minister of Economic Affairs and Climate Policy, 2020a);(The Dutch Minister of Economic Affairs and Climate Policy, 2020b).

Whereas the current Energy Act focused on liberalisation, the proposed Energy Act focuses on climate-neutral energy supply. Therefore, the proposed Energy Act elaborates on DERs for large-scale production and small-scale consumers. Additionally, the Energy Act discusses Smart Energy solutions, specifically demand management technologies for smart metering devices. Additionally, the Energy Act includes an objective that enables a greater degree of 'self-determination' of end customers (The Dutch Minister of Economic Affairs and Climate Policy, 2020b). This objective and the integration of smart metering devices aims to put end-users and the centre of the Dutch Energy system. Accordingly, the term energy community is adopted in the Energy Act. The Dutch Minister of Economic Affairs and Climate Policy (2020b) argues that energy communities will enable higher participation in the energy transition, more investments and greater choice for consumers. They determine that an energy community will concurrently act as an energy producer and as an energy supplier. Since the energy community can produce energy and supply this to its members. The integration of an energy community and smart metering devices can be related to the integration of ICES. Also, since the definition of an energy community does not elaborate on districts nor residential areas, connected communities could be created. Both ICES and connect communities are determined to be an essential element of P2P energy trading. However, the proposed Energy Act still prohibits energy trading. Therefore, Article 2.2.15 reads:

"It is forbidden to supply electricity or gas to an end-user without an ACM energy supply permit"

Therefore, the proposed Energy Act does not allow for all the P2P energy trading market designs. The Energy Act does enable the integration of a connected community and ICES, which are essential elements of P2P energy trading. Additionally, the Act determined that an energy community could act as an energy producer and an energy supplier. For this, an aggregator will be crucial because an aggregator can bundle the DERs and subsequently sell the energy generated. Therefore, an aggregator could function as a centralised coordinator or a community manager, which could result in organising a centralised or community-based P2P energy trading market. Therefore, the Act does not allow for decentralised P2P energy trading.

This section focused on the Dutch market and regulatory bodies by elaborating on the current Energy Act and proposed Energy Act. The Energy Act identified certain boundary conditions of P2P energy trading. This study revealed that the current Energy Act does not allow for any P2P energy trading market because the Act focused on transitioning to the liberalisation of the national energy market. However, the proposed Energy Act focuses on multiple transitions, including decentralised energy generation, digital society and self-determination of end-users. Therefore, the proposed Energy Act has integrated terms such as energy community, smart metering devices. These terms can generate a connected community and ICES, essential elements of P2P energy trading. Additionally, the Act introduced aggregators, which can function as centralised coordinators or community managers. Accordingly, this could enable a P2P energy trading market. Therefore, these terms are identified as possible boundary conditions for facilitating P2P energy trading.

2.9 Conclusion

Rapid urbanisation is presenting cities with a variety of new challenges ranging from scarcity of resources to global environmental and human health concerns (Washburn et al., 2009). The Smart City concept is emerging as a strategy that utilises ICTs to combat the challenges of rapid urbanisation, alleviate cities, prevent an urban crisis, and increase the quality of life of citizens and contribute to the sustainable development of a city. In order to effectively use the Smart City approach, this study examined the definitions, identified six core concepts and the various domains of a Smart City. However, this study also determined that the Smart City concept could create barriers and social implications. This occurs when the developments of a Smart City follow a profit-driven approach. Therefore the concept of inclusion was deemed to be crucial in developing a Smart City. In addition, this study determined that the Smart Energy domain holds crucial implications for cities with high energy requirements. Therefore the Smart Energy domain is regarded as instrumental for tackling climate issues, such as greenhouse emissions. This study elaborated on the Smart Energy domain and identified Smart Energy solutions within three domains, narrowing its focus on P2P energy trading. This is defined as a Smart Energy data-driven business model/solution that enables flexible energy trades between peers, where the excessive energy from the small-scale DERs is traded with and among the peers. Additionally, this study determined that P2P energy trading is a complex socio-technical system that aims to put citizens at the centre of an energy system. Therefore, the integration of P2P energy trading in a national market requires interactions with different social, technical and institutional elements since it will affect a city's technical system architecture. Therefore, this study elaborated on the supporting elements of P2P energy trading, namely, the supporting ICTs, the connected communities and the P2P market designs. This revealed that an abundance of academic literature was available on the concept of Smart City and P2P energy trading. However, academia does not focus on countries or even continents. Therefore, the academic literature provides abundant theoretical and technical knowledge but does not define any boundary conditions for facilitating P2P energy trading or inclusive P2P energy trading. Accordingly, this revealed the technology-driven approach of researchers in this field. Hence limited research is done on the social aspect. Inclusive Smart City emphasises citizen or community-focused approaches in developing a city and defining five dimensions of inclusion. Researchers within inclusive P2P energy trading discuss the importance of providing monetary incentives for every citizen and elaborate on valuable citizens and digital exclusion. Thereby, focusing on two dimensions of an inclusive Smart City, social inclusion and economic inclusion. Therefore, this study determines that limited research is done on inclusive P2P energy trading. Subsequently, revealing an additional gap in the academic literature of P2P energy trading, the social implications of P2P energy trading. Since the establishment of P2P energy trading relies on the national market and regulatory bodies, this study elaborated on the Dutch energy market and regulatory bodies. The study determined that the current Energy Act does not allow for P2P energy trading. Conversely, the proposed Energy Act does. Therefore, the proposed Energy Act introduces energy community, smart metering devices and aggregators. The academia elaborated on three P2P energy trading market forms. Based on the proposed Energy Act, two of these designs could (theoretically) be integrated into the national energy system, the coordinated and community-based P2P energy trading market. Therefore, this study identified three possible boundary conditions.

After addressing the literature on the technical, theoretical, social, market and regulation aspects of P2P energy trading, the following chapter will identify a theoretical framework. Since P2P energy trading is defined as a complex socio-technical system, its integration into the national energy system will also be complex. Therefore, a comprehensive framework will be needed to determine how a local inclusive P2P energy trading can be facilitated in the national energy system.

Chapter 3: Theoretical Framework

This chapter aims to identify a theoretical framework to analyse and explain how change is coordinated in complex systems. The research of Borrás and Edler (2014) provides a comprehensive view of the underlying processes and interactions of socio-technical and innovation (ST&I) systems. The framework of Borrás and Edler (2014) has conceptualised concepts, elements and pillars that provide a better understanding of the governance of change in ST&I systems. Therefore, the theoretical framework of Borrás and Edler (2014) provides guidelines to analyse the regularities associated with the governance of change in ST&I, which can enable facilitating a local inclusive P2P energy trading in the Dutch energy system. This will be instrumental for this research since it can determine the governance requirement for facilitating a local P2P energy trading market.

First, section 3.1 will elaborate on the choice for the framework of Borrás and Edler (2014). Additionally, section 3.2 will define the key concepts and elements, as well as introduce the three pillars of the theoretical framework.

Second, the three pillars of the framework of Borrás and Edler (2014) will be discussed in detail. Each pillar focuses on an essential part that enables the complex process of governing change in a socio-technical system. Therefore, each pillar elaborates on the nature and dynamics of change and governance of change, the 'who', the 'how' and the 'why' of governance of change (Borrás & Edler, 2014). Section 3.3, 3.4 and 3.5 will, respectively, focus on the three pillars of governance of change.

Lastly, since the objective of this research is to facilitate a future P2P energy trading system, the key questions related to governance of change defined by Borrás and Edler (2014) were a bit modified to meet this object. Section 3.6 will elaborate on the changes and present the extended framework used to meet the research objective. Figure 3.1 presents a visualisation of the modified framework.

3.1 Identifying a theoretical framework

Technology and innovation have become increasingly important in society and economy since they interact with every element of society and economy. Accordingly, the Dutch energy system is undergoing changes through the energy transition and the integration of DERs, since this enables bottom-up Smart Energy solutions. These Smart Energy solutions also aim to put the end-users at the heart of the energy system. Koirala and Hakvoort (2017);Tushar et al. (2021) explains that these Smart Energy solution, in the present centralised and top-down energy systems, causes multitudes of technical, socio-economic, environmental and institutional dynamics and interactions in society. Additionally, they argue for the importance of changing the energy system to enable a system design, where the technical, socio-economic, environmental and institutional requirements of the Smart Energy solution are accommodated. Accordingly, an energy system needs to be created. The technical and institutional coordination of this socio-technological system is well aligned to safeguard the performance of the Smart Energy solution and its prospected benefits. Since P2P energy trading utilises different technologies and emerges from a bottom-up approach, it has been defined as socio-technical system. Accordingly, P2P energy trading encompasses different technologies that influence various actors and requires interactions with different elements in a system (Koirala & Hakvoort, 2017).

Creating a system that accommodates the requirements of a P2P energy trading system requires interacting with various actors and stakeholders embedded in the energy system. These actors have different decision-making powers that can forester or prevent a change in a system. Accordingly, these actors can forester or prevent a system that facilitates P2P energy trading. Furthermore, these actors are governed by national government policies. The objective of this research is to develop a market that facilitates P2P energy trading. This research requires a framework that conceptualises and focuses on the interaction with the actors embedded in a system. Accordingly, the framework needs to include how the change can be coordinated with the actors embedded in the system. Moreover, P2P energy trading relies on the participation of end-users and aims to put the end-user at the centre of the energy system. Therefore, acceptance and support from the citizens need to be generated for P2P energy trading.

Accordingly, Borrás and Edler (2014) developed a theoretical framework to analyse the changes and dynamics of socio-technical and innovation (ST&I) processes. Therefore, their framework aims to understand governance of change in ST&I systems. The framework consist of three pillars, that concern themselves with the 'who', the 'how' and the 'why' of governance of change. Each of the pillars analyses the nature and dynamics of change and governance of change. Furthermore, the three pillars interact and influence each other. The interactions of the three pillars are continuous and complex. Therefore, the framework of Borrás and Edler (2014) has been identified for this research. Since it aims to determine the regularities associated with enabling a change in a system, it could subsequently determine regularities associated with enabling change to accommodate facilitating P2P energy trading in the national energy system.

3.2 The governance of change in socio-technical and innovation systems

To understand on governance of change in ST&I systems, Borrás and Edler (2014) first elaborate on the notions 'socio-technical and innovation (ST&I) systems. Similar to Koirala and Hakvoort (2017), they determine that ST&I systems refer to the fact that innovations and technical artefacts do not operate in isolation. However, they elaborate on this by determining that the functioning of technical artefacts and innovations is highly dependent on a specific and complex composite of elements in which they are embedded. Thereby, empathising that the interplay technologies and innovations with and embedding in other technical and non-technical elements in society and the economy are crucial and should therefore be studied. Subsequently, Borrás and Edler (2014) define socio-technical and innovation (ST&I) systems as:

"Articulated ensembles of social and technical elements which interact with each other in distinct ways, are distinguishable from their environment, have developed specific forms of collective knowledge production, knowledge utilisation and innovation, and which are oriented towards specific purposes in society and economy."(Borrás & Edler, 2014)

Accordingly, the determine that the key element of a system are the innovations, technological artefacts, the individual and organisational actors that produce, adopt, diffuse and also use it. Also, a system includes the various infrastructure that enables the production, adoption, diffusion and use of technologies and innovations, such as physical and regulatory (Borrás & Edler, 2014). The definition of ST&I aims to highlight the importance of the interactions in a system. Additionally, they discuss the unstable nature of systems. New knowledge, regulation and societal concerns can lead to new demands from a system, making it unstable and fostering changes and developments. This reveals the importance of governance within a ST&I system, such as P2P energy trading. Subsequently, Borrás and Edler (2014) define governance as:

"The mechanisms whereby societal actors and state actors interact and coordinate to regulate issues of societal." (Borrás & Edler, 2014)

Additionally, they elaborate on the intentions and motives of the individuals and organisational actors to forester or prevent the elements in a system. Since this also enables different developments and can subsequently enable a new market in a system. This highlights the importance of agents that are capable of changing the dynamics of a system. Accordingly, they define this as a pillar for governance of change.

Therefore, Borrás and Edler (2014) define governance of change as:

"The way in which societal and state actors intentionally interact in order to induce change in the systems, by regulating issues of societal concern, defining the processes and direction of how technological artefacts and innovations are produced, and shaping how these are introduced,absorbed, diffused and used within society and economy."(Borrás & Edler, 2014)

Actors that want to induce change in the ST&I system have to define the processes and directions of how technological innovations are produced. The same actors also have to define how they are shaped, introduced, absorbed, diffused and used within society and economy (Borrás & Edler, 2014). In addition, societal concerns can influence a system and subsequently make it unstable. Therefore, actors also have to regulate issues of societal concern. These processes and regularities are deemed to be crucial for the governance of change in ST&I systems. These regularities will be instrumental in determining how a municipality, and other practitioners, can create and facilitate an inclusive local P2P energy trading market. Therefore this study defines governance requirements as:

The regularities associated with governance of change

Therefore, Borrás and Edler (2014) defined three pillars that form the basis in the framework:

1. The relation between opportunity structures and capable agents.
2. The instrumentation through which intentional definitions of collective solutions are put into practice.
3. The sources and hindrances of legitimacy in the process of governing change.

The first pillar, the relation between opportunity structures and capable agents, focuses on determining the 'who' and 'what' of governance of change. The second pillar, the instrumentation through which intentional definitions of collective solutions are put into practice, aims to determine the 'how' of governance of change. Lastly, the third pillar, the sources and hindrances of legitimacy in the process of governing change, aims to determine the 'why' of governance of change. Accordingly, the three pillars interact and influence each other and are continuous and complex. These pillars will provide clear sets of tools that allow for analysing the governance requirement in ST&I systems to facilitate an inclusive P2P energy trading market. (Borrás & Edler, 2014).

3.3 The first pillar: The relation between opportunity structures and capable agents

According to Borrás and Edler (2014), the first pillar focuses on the main question regarding governance of change in ST&I systems, 'who' and 'what' are the drives of change. Accordingly, they elaborate and conceptualise the 'who' and 'what' since these are essential elements in the processes of governance of change. First, the 'what' refers to opportunities structures, which are defined as:

"Co-evolution of technology and social institutions, that sequentially or simultaneously generate opportunities for change that actors and/or agents might take.' (Borrás & Edler, 2014)

Practically, opportunity structures are offered by the interactions of new technologies, knowledge and specific institutional set-ups in a system. Therefore, it is essential to note that opportunity structures do not solely focus on technology or new knowledge. The emphasis of opportunities structures lies in the interaction between and co-evolution of social institutions and their nature to co-evolve with technology, which is at the centre of the process of the governance of change (Borrás & Edler, 2014). These interactions eventually allow for the embeddedness of a particular technology, knowledge and innovation into a set of specific social institutions. Additionally, social institutions such as regulation and worldviews interact strongly with certain technologies, new knowledge and innovation. Hence, social institutions can allow or constrain the production and use of technologies. Accordingly, social intuitions shape and co-evolve with these technologies.

Even though opportunity structures are placed at the centre of the process of the governance of change, opportunity structures alone do not generate change. Therefore, the role of actors and agents are important. Notably, the role of capable agents is determined to be crucial in ST&I systems. Therefore, the 'who' in the processes of governing change is determined to be capable agents. Capable agents are defined as:

'Visionary and powerful actors that can strategically position and navigate themselves in complex system. These actors are capable of triggering, directing and inhibiting change in the system by co-creating and/or making the most of the new opportunities' (Borrás & Edler, 2014)

Therefore, the interaction between opportunities structures enables governance of change. Subsequently, the interaction is defined as crucial and key dimensions governance of change. The activities of capable agents include bargaining, negotiating, framing problems and solutions. Borrás and Edler (2014) empathises capable agents need to understand that opportunity might be ethically problematic and socially contested. Hence, opportunity structures are not necessarily 'good' in normative terms.

Additionally, Borrás and Edler (2014) explain that capable agents often operate for their preferences, interests and expected outcomes. Therefore, capable agents' objectives in taking advantage of ST&I system features are trying to change it or prohibit change from occurring. Accordingly, capable agents can use their resources to enable their preferences. Resources include expertise, time, influence, credibility, monetary or economic resources. Additionally, the interpretative abilities of capable agents are defined as resources, such as communicative and coordinating (Borrás & Edler, 2014). To sum up, Borrás and Edler (2014) determined that the key questions related to the first pillar are:

- Who are the primary agents of change?
- What is their capacity to induce/inhibit change?
- What capabilities do they have (resources and interpretative abilities)?
- What is the distribution of the agents' capabilities within the system?

3.4 The second pillar: The instrumentation through which intentional definitions of collective solutions are put into practice

The second pillar of the framework is concerned with the specific ways by which capable agents can induce change in the ST&I systems and can design and give direction to that change. Therefore, Borrás and Edler (2014) elaborates on the different forms of instruments that can be used to induce change.

Instruments can be divided into state-led policy instruments and societal-led social agents' instruments. First, Borrás and Edler (2014) elaborate on state-led policy instruments and explain that academia traditionally defines state policy as the most prominent actor in the governance of change. Since the state is mainly responsible for creating policy instruments. State intervention that enables policy instruments are based on three justification: correcting market failure, correcting systems failure and achieving particular missions or goals (Borrás & Edler, 2014). Policy instruments for correcting market failure are concerned with the need to support public and private investment in science and research to address problems related to the lack of limited private incentives due to the long-term returns of those investments. Whereas correcting system failure focuses on inducing change in the system by addressing specific problems, deficiencies, or bottlenecks. The state can intervene to address problems on the supply side, the demand side, and regarding the interplay of the two. Lastly, the state can intervene to supporting the achievement of specific goals or missions. This policy instrument is increasingly becoming important since it is concerned with address grand social challenges (Borrás & Edler, 2014).

Additionally, Borrás and Edler (2014) elaborated on societal-led social agents' instruments, also referred to as societal-led instruments. These instruments encompass the interactions of social agents. Accordingly, they assess that this includes the different strategies of governance within heterarchical governance structures that co-evolve around certain techno-scientific areas and/or specific concerns or opportunities associated with them. Therefore, social instruments rarely focus on assessing technologies but are primarily concerned with assessing the influence and uncertainties in ST&I systems. Hence, societal-led instruments aim to harness market, peer and community energies to influence behaviour and draw on the infrastructure of the agents for rule development and implementation.

However, Borrás and Edler (2014) suggest going beyond studying the effectiveness of policy instruments and the socially-led social agents' instruments. Accordingly, they argue that a broader perspective of instruments is crucial for understanding the governance of change in ST&I systems. Combining the different instruments in certain situations might collectively induce change, while others might not. Therefore, Borrás and Edler (2014) argue and elaborate on governance instruments, and define them as:

"An umbrella concept that include state-led policy instruments and the socially-led social agents' instruments to focus on a broad range of mechanisms for social action." (Borrás & Edler, 2014)

According to Borrás and Edler (2014) the notion of governance instruments generates an understanding of who is designing, shaping and using the instruments. Furthermore, it brings forward questions about how the instruments are shaped and by whom, and how they are put into practice and implemented. Additionally, they argue that the co-existence of the state-led policy instruments and social agents' instruments enables an understanding of how these instruments interact and how potential tensions are resolved or the instruments' different goals coordinated. Therefore, governance instruments provide a broader perspective of the instruments that could be used for changing a ST&I system and determine how these instruments interact. Thus, the second pillar focuses on the 'how' governance instruments can enable specific ways and mechanisms for capable agents to induce change, and subsequently design and give direction to that change in ST&I systems (Borrás & Edler, 2014).

Accordingly, Borrás and Edler (2014) determined that the key questions related to the second pillar are:

- What are the instruments used?
- By whom are they used?
- How are they implemented?
- How are the instruments shaped?
- How do public and private instruments interact?
- How and why do they 'work' or not work, and how do they interact with other instruments?
- What are the instrumental tensions, and how are they resolved (if at all)?

3.5 The third pillar: The sources and hindrances of legitimacy in the process of governing change

The last pillar, the third pillar of the framework, focuses on the concept of legitimacy. Legitimacy refers to the 'why' ST&I systems are or are not accepted, and 'why' the process of governing change is or is not accepted.

Changing a system is often accompanied by the uncertainty and/or contestation of scientific and technological change. Additionally, shaping the direction of change in ST&I systems inevitably affects all stakeholders' interests, material benefits, and value systems. Therefore, Borrás and Edler (2014) emphasise that the concept of legitimacy must be at the heart of the discussions about governance of change in ST&I systems. Accordingly, ST&I systems are legitimate if they enjoy wide acceptance and support. Therefore the process of governance of change needs to be legitimate.

Therefore, Borrás and Edler (2014) differentiate between input legitimacy and output legitimacy. Input legitimacy refers to the support social communities grants a political system, a specific set of political institutions, to carry out collective problem-solving for that community. Conversely, output legitimacy refers to the support given to a system due to its real capacity to solve collective problems, and it is eminent that the solutions are in line with the main societal preferences of the social community. Therefore, lack of problem-solving capacity and or support has the potential to de-legitimise the processes and objections to the system can be raised (Borrás & Edler, 2014).

According to (Borrás & Edler, 2014), governance and change of ST&I is legitimate when the input is characterised by a normatively appropriate process, such as liberal-representative, participatory and deliberative. Moreover, output legitimacy is characterised by levels of social support through mechanisms of participation and representation. Additionally, the concept of legitimacy is related to the readiness of societies to contribute to the process and comply with directions taken. Therefore, they determine that this is a fundamental aspect of governance as a collective social process. Moreover, Borrás and Edler (2014) emphasises that the input and output dimensions of legitimacy cannot be disconnected from each other in the process of governing change in a system. Since both are needed to grant legitimacy to the process of governing change, accordingly, if one dimension of legitimacy is absent, the process of governing change will be compromised. Thus, this pillar underlines the notion of actors' interaction and coordination to regulate issues of societal concern (Borrás & Edler, 2014).

Accordingly, Borrás and Edler (2014) determined that the key questions related to the third pillar are:

- What are the challenges for legitimacy emerging from the combination of specific actor arenas and the poly-centrality of governance?
- What is the cultural embedding of governance instruments that are applied and how does it change over time?
- How socially accepted are the governance processes and outcomes, and why is this?
- How is contestation of outcomes and processes dealt with?

3.6 Governance of change in the Dutch energy system

According to Borrás and Edler (2014), to change a system calls for an intentional transformation of the socio-technical system. Therefore, they created a theoretical framework that conceptualised the underlying processes, conditions and interactions in socio-technical systems. Subsequently, their theoretical framework can be used to analyse and understand governance of change in socio-technical system. The theoretical framework consist of the three interrelated pillars:

- The opportunity structures and capable agents in a system
- The instrumentation of governance of change
- The legitimacy and acceptance of change

Therefore, facilitating an inclusive local P2P energy trading market will require an intentional transformation of the national energy market. The theoretical framework of Borrás and Edler (2014) will be adapted and used in this research to analyse and determine the regularities associated with governance of change, the governance requirements to induce an inclusive P2P energy trading market. Therefore, the key questions related to the interrelated pillars will be modified to understand change in the national energy system. Subsequently, the theoretical framework of Borrás and Edler (2014) was (a bit) extended. Since the municipality of Rotterdam aims to facilitate P2P energy trading, the interactions of capable agents and instruments are important. Therefore, the framework aims to identify capable agents and instruments, as well as determine how the capable agents and instruments can interact to change the system to allow inclusive P2P energy trading. Also, the framework focuses on input legitimacy because output legitimacy can only be determined after a system has been created. Furthermore, the concept of inclusion was integrated into the framework. Section 2.2 and 2.7 elaborate on the concept of inclusion and inclusive P2P energy trading. The sections explained the importance of linking the development of P2P energy trading to the citizens living in the city. This ensures that citizens (actually) use, profit and support P2P energy trading (Mohamed & Manaf, 2020). Therefore, the concept of inclusion is (closely) related to legitimacy, the third pillar. Accordingly, the extended framework integrates inclusion in the third pillar. Thus, the extended framework concept reformulated the questions into concepts and included inclusion in the third pillar. Figure 3.1 provides a visualisation of the framework, which is based on the theoretical framework of Borrás and Edler (2014).

Furthermore, sub-research question 4 integrates the terms governance requirements, agents of opportunity structures, instrumentation and legitimacy. Therefore, sub-question 4 is related to the theoretical framework of Borrás and Edler (2014). Appendix A gives a visualisation of the framework of (Borrás & Edler, 2014). Accordingly, the theoretical framework will be adapted in the interview guide presented in Appendix B.

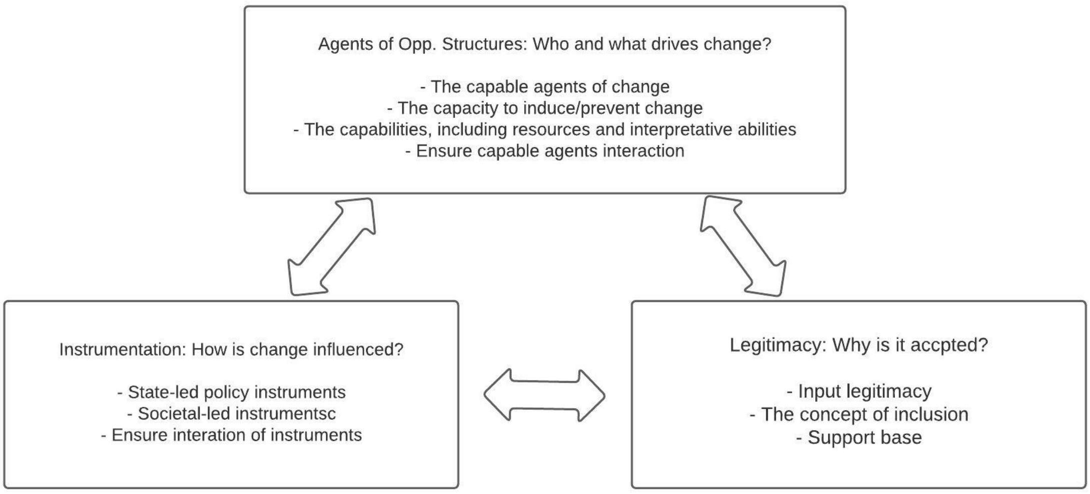

Figure 3.1: The theoretical framework, including the key concepts for governance of change in ST&I systems, figure based on the theoretical framework of (Borrás & Edler, 2014)

3.7 Conclusion

Borrás and Edler (2014) created a theoretical framework to understand governance of change in ST&I systems. Therefore, they identified three pillars that interact and elaborated in the three pillars. Borrás and Edler (2014) determine that change in ST&I system is driven by the interplay between the opportunity structures and the actions and reactions of various capable agents, which is related to the first pillar of governance of change is. Governance instruments include a broader understanding of the dynamics and processes of governance. Therefore, governance instruments focusing on both policy and social instruments. This enables a better understanding and broadens the focus on a range of mechanisms for social action, which is related to the second pillar. Additionally, Borrás and Edler (2014) discuss the importance of the concept of legitimacy. Since this is related to the readiness of societies to contribute to the process and comply with directions taken. Therefore, they differentiate between input and output legitimacy and assess that these dimensions cannot be disconnected from each other. Therefore, the framework has identified three important underlying governance processes and dynamics for governance of change. This study uses the framework to determine the governance requirement that enables facilitating an inclusive P2P energy trading market. Therefore, the key questions of each pillar were modified and reformulated to concepts. Subsequently, the framework was extended to meet the research objective of this study.

Chapter 4: Research design and methodology

Chapter 1 provided a general overview that introduced the objective and research questions for this research. In addition, this research presented a literature study and identified a theoretical framework. This chapter will elaborate on the methodology, structure and tools used for this research. Thus, this chapter will present the empirical research design, which will be used to answer the research questions. The theoretical framework of Borrás and Edler (2014) was extended, and the extended framework, presented in figure 3.1, will be used for the empirical analysis of this research. The empirical research utilises a case study, which will also be elaborated on in this chapter.

4.1 Research approach

Several research strategies will be used to answer the research questions in section 1.3. This research uses a case study method, in particular, an embedded single-case study design. The case study is executed as a qualitative case study, whereby the primary approach for data collection are interviews. According to Bhattacherjee (2012), qualitative case studies can derive in-depth and a more contextualised interpretation of the phenomenon of interest, which in this case is the governance requirements for the development of local P2P energy trading for the municipality of Rotterdam. As discussed in chapter 3, the theoretical framework of Borrás and Edler (2014) was extended through the modification of their proposed key questions. The framework 3.1 will be applied to help understand governance of change in the Dutch energy systems, specifically for the districts Prinsenland and Het Lage Land. Therefore, this research will also build theory. The literature study is underlying for the qualitative and embedded case study. The literature study provides a comprehensive analysis of published information in the inclusive Smart City and energy trading field. From this study, several knowledge gaps were identified. An additional literature review will be presented to provide an extensive system analysis and stakeholder analysis. The stakeholder analysis is needed to properly assess the agents within the Dutch and the local energy system. In contrast, the system analysis is needed to assess the current dynamics of the energy system properly. The system and stakeholder analysis aims to answer sub-question 2 and 3. Additionally, these analyses can enable the identification of capable agents and detailed knowledge on the concept of legitimacy for the energy trading markets for self-generated sustainable green energy. Therefore, the analysis assists the theoretical framework, which is deemed essential for this case study analysis. Since Borrás and Edler (2014) determined that the capability of agents in the systems and the influence of knowledge and technologies can provide new opportunity structures in the system. Additionally, the combination of public, private and mixed forms of instrumentation (state-led and societal-led instruments) can also induce change in a system. Whereby it is important that these systems enjoy support and thus are legitimate. Additionally, the extended framework adds the concept of inclusion. Therefore, understanding and studying these regularities will provide the municipality with knowledge on how to govern change in ST&I systems, such as the energy system.

The qualitative research consists of a study for Rotterdam's municipality to generate an understanding of the boundary condition for P2P energy trading. To determine the boundary conditions for P2P energy trading will require qualitative research, which relies primarily on non-numeric data such as interviews with experts (Bhattacherjee, 2012). Data collected from the interview will be used to build knowledge and gain insight into certain processes that are confined in time and space (Verschuren, Doorewaard, & Mellion, 2010). Therefore, this research is a case study. Case research is an in-depth investigation of a problem in one or more real-life settings over an extended period of time (Bhattacherjee, 2012). The benefit of the qualitative case study is that a great deal of information can be generated from the interviews on the local issues regarding P2P energy trading. With the use of a case study, research questions 3, and 4 can be answered. Lastly, sub-research question 5 uses the information generated from sub-question 2, 3 and 4 to determine the recommendations. Thus, this research aims to provide insight into the design of a future P2P energy trading market based on the case studies of Prinsenland and Het Lage Land. The literature review, system analysis, stakeholder analysis and interviews will be done to obtain data for this. The data will be reflected on the framework visualised in firgure 3.1. This will enable identifying the governance requirements that enable P2P energy trading market for locally self-generated sustainable green energy for the municipality of Rotterdam. Additionally, a design for the future energy trading market will also be given.

Figure 4.1 illustrates the detailed research process for this thesis in a research flow diagram. The research flow diagram visualises the movements and actions required in the research process of this thesis.

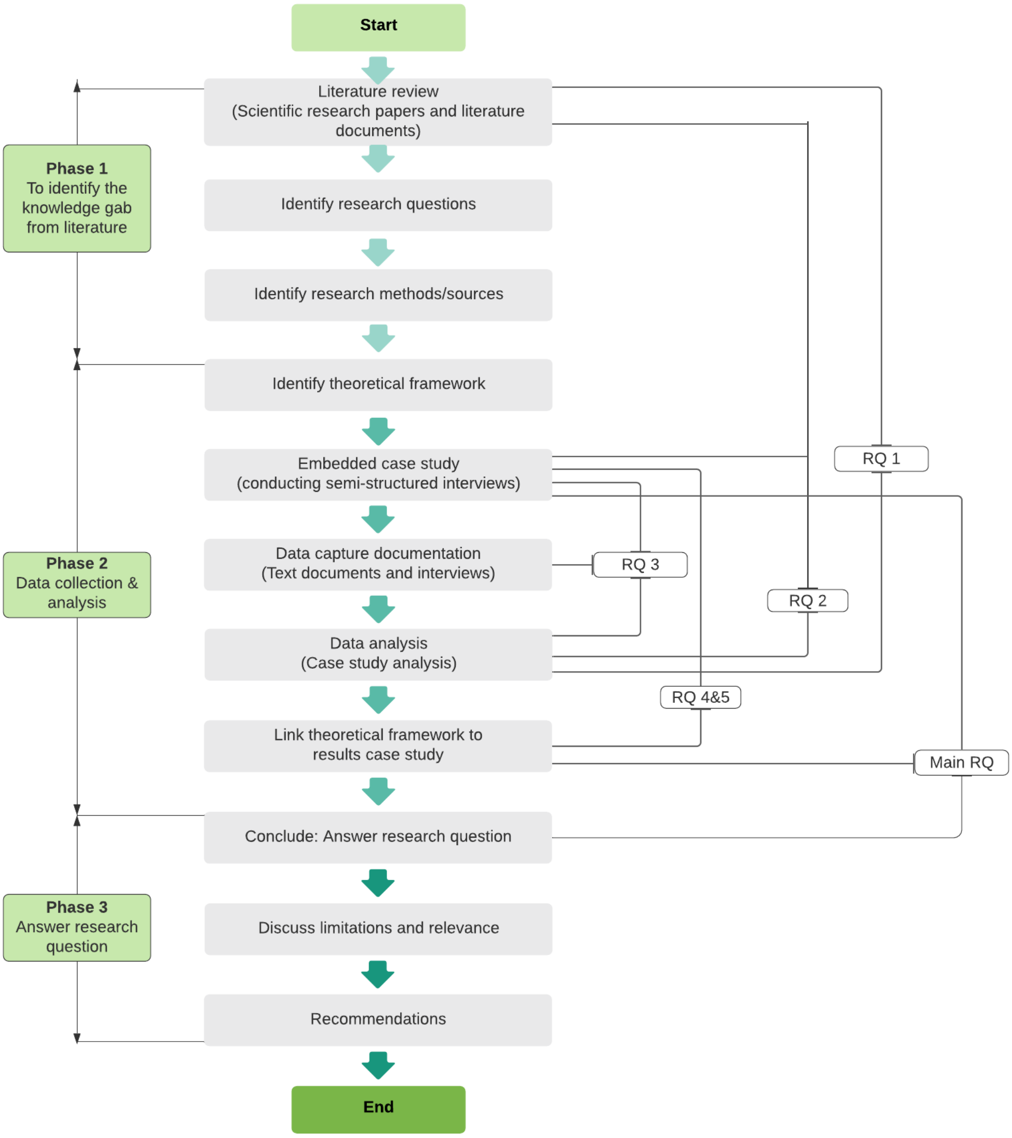

Figure 4.1: Research Flow Diagram

4.2 Case-study Research

Case research is an in-depth investigation of a problem in one or more real-life settings over an extended period of time. Data collection is done using a combination of interviews, personal observations, and internal or external documents. Case studies can be interpretive therefore aiming to create theory-building research. The strength of a case studies lies in its ability to discover a wide variety of social, cultural, and political factors potentially related to the phenomenon of interest. In this case study, the phenomenon in question is P2P energy trading (Bhattacherjee, 2012). The case study design encompasses the municipality of Rotterdam as the embedded case, and the data collection for this case study is done by the primary means of interviews. Section 4.3 will further elaborate on the data collection. According to Baxter, Jack, et al. (2008), an instrumental case study provides insight into an issue or helps to refine a theory. The case is often looked at in-depth, its contexts examined, its ordinary activities detailed, and helps the researcher understand the interactions of the complex socio-technical system. Thus, the instrumental case study applies to this research. In addition, since this research takes place in one environment, this research is considered a single holistic case study is considered (Baxter et al., 2008).

An important decision-making process for this case study is the case study selection. According to Noori et al. (2020), the emergence of new technologies has encouraged cities to formulate smart city policies, including Rotterdam. As discussed in 1, Rotterdam is a high energy-intensive city, partly due to its port, the largest port in Europe. As part of the Dutch energy vision, triggered by earthquakes from gas drillings, every city will be disconnected from natural gas. For a high energy-intensive city such as Rotterdam, this will have huge implications. More importantly, this will have enormous social consequences for the citizens of Rotterdam. Therefore, Rotterdam has created The Rotterdam Climate Agreement. In addition, Rotterdam is participating in a European project called RUGGEDISED. Through RUGGEDISED, six European cities are joining forces to accelerate the path towards a sustainable future by creating model urban areas. Therefore, within the RUGGEDISED project, Rotterdam aims to demonstrate innovative and integrated Smart Energy solutions in three domains identified by Mosannenzadeh et al. (2017). Additionally, Rotterdam has identified five districts for the integration of the Smart Energy solutions, including Prinsenland and Het Lage Land. Furthermore, the city is creating an integrated approach for these districts and thereby including citizens. Also, these integrated approaches focus on vulnerable districts, whereby new housing designs are being created for both vulnerable and not vulnerable citizens, more fortunate citizens. Therefore, based on these theoretical aspects, Rotterdam is one of the Dutch cities where these sets of circumstances generated a solid commitment to realise Smart Energy solutions. Therefore, the decision for Rotterdam was made based on the following objectives: 1) Rotterdam has formulated clear energy goals in The Rotterdam Climate Agreement 2) Rotterdam is putting its goals into practice by initiating pilots for The Rotterdam Climate Agreement 3) Rotterdam is not solely focused on their port but also on their citizens 4) The municipality is actively including their citizens 5) The municipality is focused on housing for all of their citizens, both vulnerable and more fortunate citizens. This makes Rotterdam the forerunner on inclusive sustainability. Moreover, a pragmatic reason is that Rotterdam initiated their Smart Energy objectives, which piqued my interest and motivated me to focus on the municipality of Rotterdam. The embedded case of Rotterdam will be elaborated on in the following sub-section.

4.2.1 The embedded case: The municipality of Rotterdam

To conduct proper research, it is important to consider what the case is and determine what the unit of analysis is. The case is defined by Miles and Huberman (1994) as "a phenomenon of some sort occurring in a bounded context. The case is, "in effect, your unit of analysis" (Baxter et al., 2008). In this study, the unit of analysis is the municipality of Rotterdam. According to Baxter et al. (2008)a researcher using the case study method looks at a situation as it is and tries to find out what meaning that situation has to the participants. For the municipality of Rotterdam, this case study aims to determine whether P2P energy trading can be implemented as a sustainable innovation project.

The municipality of Rotterdam is located in the South-Holland province in the Netherlands. Rotterdam is the second-largest city and municipality in the Netherlands. It is in the province of South Holland and covers a surface area of 324,1 km². In 2020, Rotterdam counted 652.497 residents, divided over 317.800 households. In 2020, the city of Rotterdam, which encompasses its residents, the port and the industry, was responsible for more than 20% of the Dutch CO_2 emissions which is a substantial amount (Gemeente Rotterdam, 2020a). In response to the climate ambitions set in Paris 2015, the municipality of Rotterdam created the Rotterdam Climate Agreement in collaboration with more than 100 companies and social organisations in Rotterdam. The Climate Agreement consists of 49 climate objectives that aim to reduce Rotterdam's greenhouse gas emissions.

The Rotterdam Climate Agreement aims to:

- In 2022, the annual CO_2 emission of Rotterdam emission is turned into a declining trend.
- In 2030, Rotterdam's CO_2 emission will be 49% lower compared to 1990
- In 2050, Rotterdam will be climate neutral.

Subsequently, the municipality of Rotterdam created initiatives to help realise the Rotterdam Climate Agreement. Therefore, the municipality created five pilots for five residential areas, known as The Next Generation Residential Area. The focus of The Next Generation Residential Area is to scale up clean and sustainable energy generation to self-provide at least 50% of the electricity demand by 20305. Therefore, the municipality has identified five themes for The Next Generation Prinsenland and Het Lage Land: Smart Digital Delta, Smart Energy Delta, Circular Economy, Entrepreneurial Region and Next Society (JHK Vastgoedmanagement, 2018). Figure 4.2 gives a visualisation of the five key elements of the Next Generation Residential Areas.

Figure 4.2: Elements of the Next Generation Residential Area, figure adapted from (JHK Vastgoedmanagement, 2018)

To meet this ambition, the municipality is utilising different Smart Energy solutions and thereby focusing on the three Smart Energy domains defined by Mosannenzadeh et al. (2017). Currently, the municipality is focusing on initiating Smart Energy projects. Additionally, the municipality is placing DERs, solar panels and wind turbines in the residential areas. Practically, the municipality is placing solar panels on buildings, covering parking lots up with solar panels and placing solar panels on the road surface. The city is also planning on placing wind turbines on some of the "high rise" buildings. In addition to creating sustainable living, the municipality aims to create additional economic and environmental benefits for its citizens. Therefore, the municipality is investigating new sustainable energy systems, such as P2P energy trading, by initiating The Next Generation Residential Area pilots and integrating Smart Energy projects for the pilot.

The municipality aims to obtain or increase the support for the new Smart Energy solutions and assist their residents with the energy transition (JHK Vastgoedmanagement, 2018);(van den Donker et al., 2020);(Gemeente Rotterdam, 2020b).

4.3 Data

In this section, the strategy used to collect the data and analyse the data will be discussed.

4.3.1 Data selection

An important aspect and hallmark of case study research is the use of multiple data sources, a strategy that also enhances data credibility. These data sources may include but are not limited to documentation, archival records, interviews, physical artefacts, direct observations, and participant observation. In a case study, data from these multiple sources are converged in the analysis process rather than handled individually. Therefore, each data source can be seen as one piece of the "puzzle," with each piece contributing to the researcher's understanding of the whole phenomenon. This convergence adds strength to the findings as the various strands of data are braided together to promote a greater understanding of the case (Baxter et al., 2008).

4.3.2 Data collection

As determined in section 4.3.1 multiple data sources can be used for research. Therefore, it is crucial to collect the important data source, which aims to answer the derived research questions. Table 4.1 provides an overview of the different types of information, sources, and methods needed to answer the research questions.

Research Question	**Information**	**Sources**	**Methods**
1. What is the current state of inclusive local P2P energy trading market?	Data & Explicit knowledge	Documents	Content analysis & Literature review
2. Who are the stakeholders involved with P2P energy trading market for locally self-generated sustainable green energy?	Data & Explicit knowledge	Documents	Content analysis & Literature review
3. What are the boundary conditions that enable P2P energy trading markets for locally self-generated sustainable green energy?	Data, Implicit & Tacit knowledge	Documents & Experts	Literature review, Interviews & Case-study analysis
4. What are the governance requirements of the city of Rotterdam that will enable a P2P energy trading market in terms of agents and opportunity structures, instrumentation and legitimacy?	Data, Implicit & Tacit knowledge	Documents & Experts	Interviews & Case-study analysis
6. What are the future directions for Rotterdam to enable a P2P energy trading market?	Tacit knowledge	Experts	Case-study analysis

Table 4.1: Data collection

According to Bhattacherjee (2012), the primary mode of data collection in case research are the interviews. Therefore, an interview strategy was created that included the interview protocol's design to guide the interview process. An interview protocol is designed to follow a semi-structured protocol, which allows open-ended questions and a discussion with the interviewee. The interview questions are based on the research questions, the theoretical framework of Borrás and Edler (2014) and questions that provide an understanding of the national energy market. Additionally, the interview guide focuses on three key aspects of P2P energy trading, technology development, laws and regulations, and inclusion.

These interviewees were approached via the network of the municipality of Rotterdam and TU Delft. In addition, the snowball approach was used to find more interviewees. The closing question of the interview guide asked for additional documents and names or contact details of other experts on P2P energy trading. Table 4.2 gives an overview of the interviewees, including the organisation to which the interviewee is associated. In appendix B the questions for the semi-structured interviews are presented.

Name Indication	**Organisation**	**Stakeholder type**	**Interview type**
Interviewee 1	LENS-Energie	Energy service supply	Videocall
Interviewee 2	Gemeente Rotterdam	Municipality	Videocall
Interviewee 3	Delft University of Technology	Research & Education Institute	Videocall
Interviewee 4	Entrnce	Data product and service provider	Videocall
Interviewee 5	Spectral	Consultancy or Advisory firm	Videocall
Interviewee 6	Stedin	Network company operator	Videocall
Interviewee 7	Stedin	Network company operator	Videocall
Interviewee 8	ToBlockchain	Data product and service provider	Phone call
Interviewee 9	PowerHouse bv	Energy supplier	Videocall
Interviewee 10	Utrecht University	Research & Education Institute	Videocall
Interviewee 11	Alex Energie and resident	Community energy corporation and cooperative in Prinsenland and Het Lage Land	Video call
Interviewee 12	Energie van Rotterdam	Community energy corporation and cooperative in Rotterdam	Video call
Interviewee 13	Gemeente 87 Rotterdam	Municipality	Videocall
Interviewee 14	Eneco	Energy supplier	Videocall

Table 4.2: List of interviewees for the case-study analysis

4.4 Data management and treatment

Due to COVID-19, the interviews were done in a virtual manner using Microsoft Teams. Additionally, the interviews were audio-recorded using the iPhone Dictaphone application with the consent of the interviewee. After obtaining all the qualitative data, the interviews were transcribed for analysis. Data analysis is considered the most challenging part of case study research. Researchers must remember that each data source can be seen as one piece of the "puzzle". Thus, not treating each data source independently and thereby reporting the findings separately. In addition, Baxter et al. (2008) notes that one important practice during the analysis phase of any case study is the return to the propositions.

For the data analysis, the program ATLAS.ti 9.1.0 Mac, by ATLAS.ti Scientific Software Development GmbH was used. ATLAS.ti is a data analysis tool that provides an environment to create codes for the structure, process and analyse of the qualitative data. The research questions, the three pillars to understand governance of change in ST&I, the five dimensions of inclusion, and the three themes (legal, technical, social) were used as codes. Also, additional codes were derived, such as believed in P2P, does not believe in P2P and other directions for Rotterdam. The transcripts, quotes and data that are extracted from the analysis have been anonymised. Additionally, a data steward for the Faculty of Technology, Policy and Management at the TU Delft was consoled for the data management plan. The data management plan describes how the data will be collected, managed, stored and made available during the research. The data management plan also describes how the data will be shared after the research is completed. This is important to ensure good practice in data management. Therefore, the interviewees were asked for the audio-recording and their participation in this master thesis. This is in line with the TPM Delft University of Technology data management and ethics policy.

4.4.1 Data analysis

The codes derived in ATLAS.ti enables analysing the data. The goal of data analysis is to generate in-depth knowledge on P2P energy trading. Therefore, generating knowledge on the underlying processes, instruments and decision-making activities that enable energy trading. Accordingly, knowledge on how the development can be inclusive and the boundary conditions for a future P2P energy trading market. Sub-question 2 will determine the general stakeholders in the energy market. The interviews generated additional knowledge on the stakeholders/actor in the energy system, specifically stakeholders/actors relevant to Rotterdam. Moreover, the interviews will give insight into the decision-making activities, and therefore their ability of stakeholders to become capable agents to induce change for the energy market. This is related to the first pillar of Borrás and Edler (2014) and determines 'who' and the 'what' are fundamental in processes of governing change. Thus, fundamental in the processes of inducing energy trading market. Additionally, the interviews will describe the developments of the energy market and subsequently developments needed for an energy trading market. Therefore, knowledge will be generated to 'how' agents induce change is ST&I and can design and give direction to that change, which relates to the second pillar of Borrás and Edler (2014). Sub-question 3 aims to determine the boundary conditions for energy trading. Therefore, the second pillar will aid in determining these conditions. Lastly, sub-question 4 focuses on the framework of Borrás and Edler (2014). Additional information will be generated on whether energy trading can solve problems for the citizens of Rotterdam and also elaborate on the concept of inclusion.

4.5 Validity, reliability and validation of research

According to Yin (2014), a case study investigator must maximise the quality of a research design. Therefore, Yin (2014) assess that four tests may be considered when judging the quality of a research design: construct validity, internal validity, external validity, and reliability.

Accordingly, Yin (2014) determines that construct validity is especially problematic in case study research. Since case study investigators can lose their objectivity when collecting the data. Therefore, researchers fail to develop a good operational set of measures. To prevent losing objectivity, Yin (2014) assess to select the specific types of changes that are to be studied and demonstrate that the selected measures reflect the specific types of change that have been selected. Therefore, ensuring that the method of measurement matches the construct intended to measure. In addition, Yin (2014) discusses validity, specifically internal validity and external validity. Whereby internal validity refers to a researcher capability to accurately determine a causal relationship in the research. In comparison, external validity refers to the generalizability of the research. So, whether the research outcome can be applied to other settings, this research aims to explore the energy system and determine whether inclusive local P2P energy trading could be induced. Yin (2014) determines that internal validity is only a concern for causal or explanatory research. Since this research aims to explore, internal validity will not be a concern. However, external validity has implications for an exploratory case study. However, since this research focuses on the embedded case study, Prinsenland and Het Lage Land, this research is more generalisable than single-case studies. Additionally, Yin (2014) asses that case studies rely on analytical generalisation. Whereby, the researchers aim to generalise a particular set of results to some broader theory. In this research, the theoretical framework of Borrás and Edler (2014) will be used to generalise the results for Prinsenland and Het Lage Land. The last test Yin (2014) discusses is reliability, which is defined as demonstrating the overall consistency of a study. Nevertheless, this can be achieved by accurately documenting the research procedures.

Moreover, this research aims to determine the boundary conditions and also create an energy trading design. The proposed design will be validated with the experts/interviewees through qualitative research. Also, the design will need to be validated by the municipality.

4.6 Conclusion

This chapter elaborated on the design of the qualitative embedded multiple-case study. The case study explores the Dutch energy system and determines whether inclusive local P2P energy trading can be implemented. Therefore, this qualitative research, the interview, aims to generate in-depth knowledge from the experts that will be interviewed. Additionally, this chapter elaborated on the data treatment process, which consists of coding through ATLAS ti. The research questions, the three pillars to understand governance of change in ST&I, the five dimensions of inclusion, and the three boundary condition (legal, technical, social) were used as codes. These codes will enable the structure and analysis of the qualitative data. Also, this chapter discussed the importance of data management and ethics policy.

Chapter 5: The case of Next Generation Prinsenland and Het Lage Land

This chapter will elaborate on the embedded case. In addition, the residential districts, Next Generation Prinsenland and Het Lage land will be discussed.

As mentioned in 4.2.1, Rotterdam is the second-largest city and municipality in the Netherlands. Rotterdam covers a surface area of 324.1 km^2 and has 652,697 residents divided over 317,800 households. In line with the Dutch government, the municipality of Rotterdam also has set energy goals for 2030. Since, the city CO_2 emission accounts for more than 20% of the Dutch CO_2 emission. Therefore, the municipality has created the Rotterdam Climate Agreement, which aims to reduce the city's objectives for CO_2 emission.

- In 2022, the annual CO_2 emission of Rotterdam emission is turned into a declining trend.
- In 2030, Rotterdam's CO_2 emission will be 49% lower compared to 1990
- In 2050, Rotterdam will be climate neutral.

As a result of the Rotterdam Climate Agreement, the municipality created several initiatives to realise its objectives. In 2016 the municipality announced its plan to disconnect from natural gas and becoming a gas-free city. The motive for this was the Dutch government announcing their plan to phase out the gas extraction in Groningen. The municipality has created a different initiative for their objectives from that moment forward, including a Smart Energy system subsidy provision. The subsidy aims to encourage startup companies to create innovative energy solutions. Also, the municipality has initiated five pilots for five of their residential districts, which aim to create a "future proof" residential area, also referred to as 'The Next Generation Living'.

Figure 5.1: The map of Rotterdam, adapted from (Kaart en Plattegrond, Blokplan, 2018)

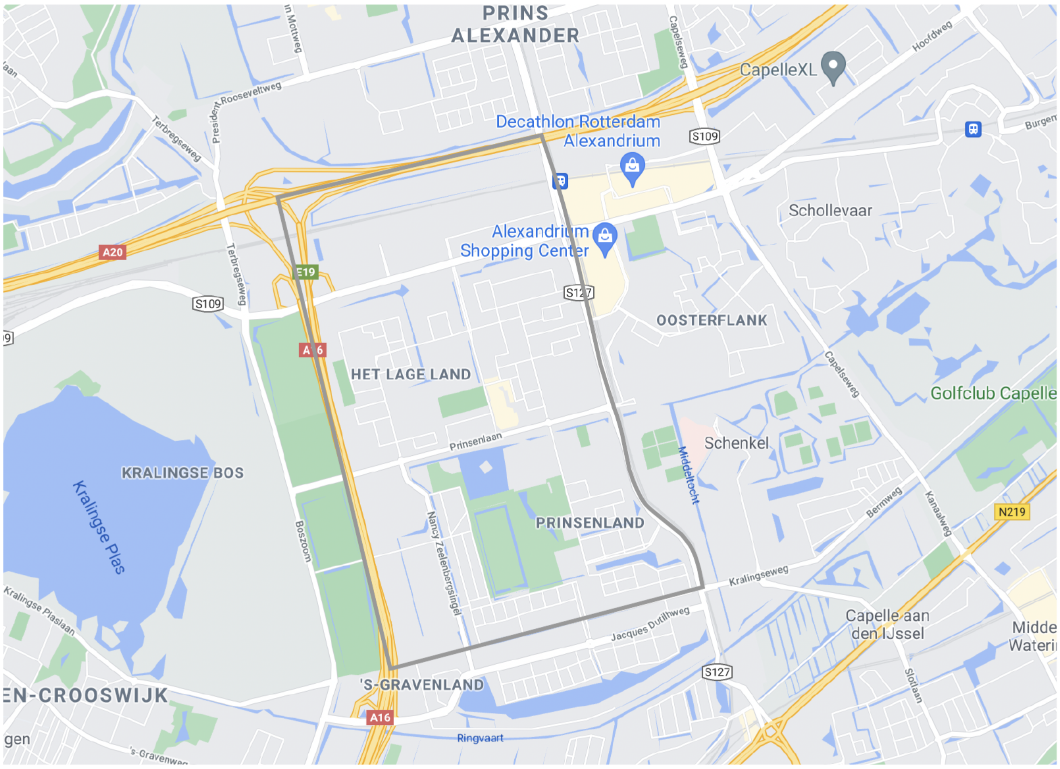

Figure 5.2: The map of Prinsenland and Het lage Land, adapted from Google Maps

Figure 5.1 shows the map of Rotterdam and 5.2 shows the map of Prinsenland and Het Lage land. Prinsenland and Het Lage Land were both chosen for the pilots. Prinsenland covers a surface area of 1.79 km^2 and has 10,000 residents. Het Lage Land covers a surface area of 2.16 km^2 and has 10,650 residents. The majority of the residents in the districts have a migration background. Also, the districts are both experiencing the ageing of the population. The houses in the districts were mainly built in 1960. In 1990 the municipality added residential buildings for the Prinsenland district. The houses in the residential areas consist of a mix of low, medium and high-rise buildings. Unfortunately, the majority of the houses in both residential areas are poorly insulated. This hurts the climate and also causes high energy expenses for the resident. Additionally, the municipality is concerned about the effects of disconnecting natural gas. Since the transition to sustainable energy resources can cause a price rise and enable energy poverty. Energy poverty occurs when households spend approximately 10% of their income on their energy consumption.

In line with the five elements of The Next Generation Living, the municipality has the ambition to create and build a modular energy system for Prinsenland and Het Lage Land is to create and build a modular energy system. This aims to enable a smooth transition from natural gas to electricity. In addition, the municipality is helping their residents to better insulate houses by cooperating with energy coaches and community energy collectives. In addition to their sustainable energy initiatives, the municipality has also created social initiatives to combat social isolation and provide citizens with Dutch language courses. Therefore, the municipality is working on an integrated approach to link sustainability with different themes, such as climate adaptation, healthy living environment and digital transition. This is in line with the fifth element of Next Generation living: Next Society. Subsequently, the municipality is investigating several different Smart Energy solutions. Together with a housing corporation, Woonstad, the municipality is creating various housing projects. Also, the community energy initiatives, Alex Energie and Energie van Rotterdam, are planning to become involved with the projects. This will result in the generation of 'Next Generation Prinsenland and Het Lage Land. One of the most important aspects of the Next Generation Residential Area is the electrification of the areas. Since disconnecting from natural gas will lead to higher electricity demand. This could result in congestion on the energy grid. To cope with the increased energy demand, the municipality integrates DERs, solar panels, and wind turbines in residential areas. Practically, the municipality is integrating solar panels on buildings, covering parking lots up with solar panels, placing solar panels on facades and roads surfaces. In addition, the city will be placing wind turbines on some of the 'high-rise' buildings. To assess the impact of electrification, the municipality created three scenario's and determined the electricity demand for each scenario.

Electricity demand	**Prinsenland**	**Het Lage Land**	**Total**
Current demand	18.0 GWh	25.7 GWh	43.7 GWh
Scenario A: No electrification	18.0 GWh	25.7 GWh	43.7 GWh
Scenario B: Only electrification of transport	28.5 GWh	38.6 GWh	67.1 GWh
Scenario C: All-electric	41.9 GWh	53.9 GWh	95.8 GWh

Table 5.1: The scenarios for future electricity consumption, derived from (van den Donker et al., 2020)

Table 5.1 presents the future scenarios, with their prospected energy demand. The table shows three scenarios. The first scenario, scenario A, can be considered the current situation in Prinsenland and Het Lage Land. In this scenario, the districts continue as it now. This means that no DERs or sustainable innovation will be implemented. In the second scenario, scenario B, the municipality will focus on electrifying transportation. This suggests that the municipality and the districts will solely focus on the electrification of cars and public transportation. The last scenario, scenario C, will focus on electrification of every aspect in the districts. Thus, creating an all-electric district.

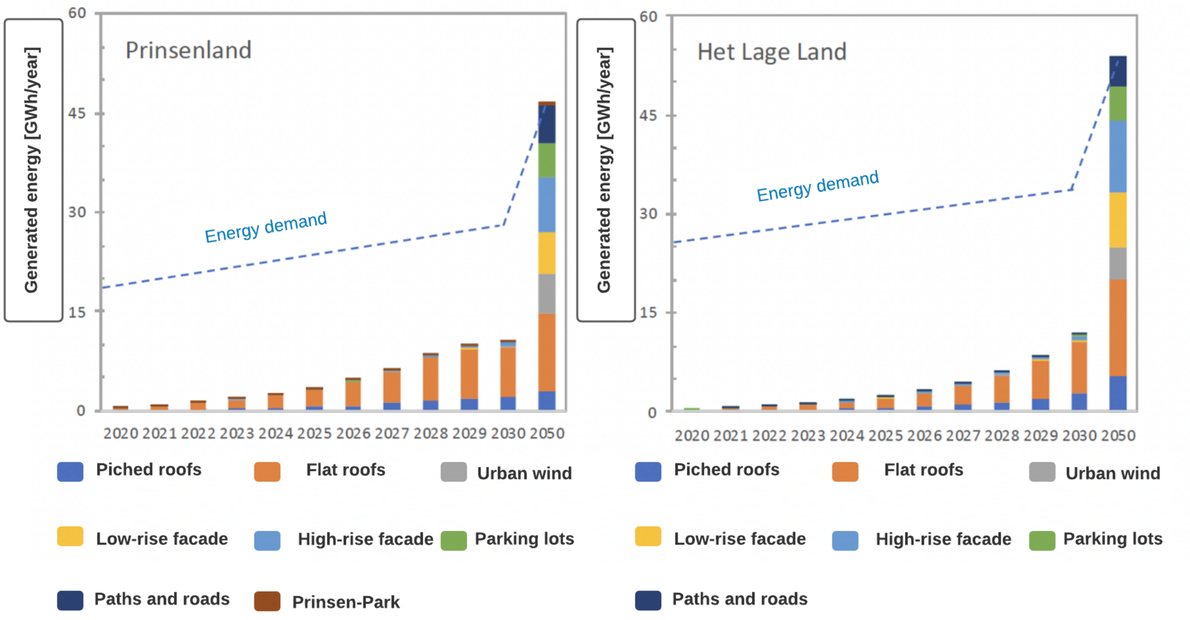

Figure 5.3: Electricity generation from solar energy and urban wind in the Prinsenland and Het Lage Land, derived from van den Donker et al. (2020)

Additionally, the municipality also determined how much electricity the DERs, for scenario C, can generate in Prinsenland and Het Lage Land. Figure 5.3 gives a visualisation of the prospected energy generation, including the electricity demand of each district. Therefore, the figure reveals that the districts are prospected to be electricity neutral in 2050. However, the integration of DERs only covers the first steps in creating a modular energy system. The third and last domain of (Mosannenzadeh et al., 2017), energy and ICT infrastructures, will also be investigated for creating a modular energy system. The investigation of energy and ICT infrastructures aims to create additional benefits for residents and creating Smart Energy solutions. The envisioned benefits include economic and environmental benefits. Therefore, the Smart Energy solution the municipality is investigating is P2P energy trading.

P2P energy trading is expected to enable environmental benefits. Since the residents can share their excess energy production with each other, also, the residents can create economic benefits by trading. This could also help prevent energy poverty. This Smart Energy solution enables the city of Rotterdam to become a Smart City. Additionally, the municipality aims to prevent energy poverty and create an inclusive society.

To sum up, this chapter elaborated on the case of Prinsenland and Het Lage Land. Therefore, it first discussed The Rotterdam Climate Agreement, which initiated The Next Generation Living pilots and includes Prinsenland and Het Lage Land districts. The municipality aims to make Prinsenland and Het Lage Land all-electric districts. Therefore, the municipality determined the future electricity consumption for both districts. To ensure that Rotterdam and the districts Prinsenland and Het Lage Land will become climate neutral in 2050, the Smart Energy solution P2P energy trading will be researched.

Chapter 6: Stakeholder analysis

After elaborating on the technical background of this study in chapter 2, this chapter will proceed with the analysis of the stakeholders within a P2P energy trading system. Therefore, the general stakeholders of the P2P energy trading ecosystem will be described, which is done through a literature study. Therefore, this chapter will partly present the results to the sub-question:

(Partly) sub-question 2: Who are the stakeholders involved with P2P energy trading market for locally self-generated sustainable green energy?

6.1 Stakeholder analysis

This section aims to determine the actors and stakeholders within a P2P energy trading system. The current energy system consists of many public and private actors with different interests and functionalities. The implementation of P2P energy trading enables complexity to the energy systems by adding additional stakeholders. Also, the complexity arises from the system consisting of different decision-making entities and technological artefacts that are governed by energy policy in a multilevel institutional space (Koirala & Hakvoort, 2017). Accordingly, a new ecosystem will emerge consisting of new players, including community groups and aggregators, who are all keen to participate and create revenues (Brown et al., 2019). Accordingly, these stakeholders will have different power and interest within a P2P energy trading system.

6.1.1 End users

Within a P2P energy trading system, the end-users are the consumers and prosumers. Therefore, these stakeholders are expected to generate, consume and sell energy, thus the market participants. The energy trading system can create active participation in the energy market for end-users, making the end-users essential participants. The end-users consist of prosumers, consumers and communities. P2P energy trading is expected to create more flexibility for the end-users, provide them with more opportunities to consume clean energy and transition to a low-carbon energy system. Additionally, end-users are expected to obtain environmental and economic benefits.

Prosumers, consumers

Through the enhanced penetration of DERs, households and citizens are becoming prosumers that can produce energy, self-consume and modulate their energy consumption (Brown et al., 2019). Prosumers are determined to be essential stakeholders since their active participation in the energy system could create intermittency challenges but could also stabilise the grid Brown et al. (2019). However, this is often not the main interest of a prosumer. Researchers argue that prosumers are more interested in the economic benefits of the system. Whereas, some prosumers are interested in the sustainable energy transition and thus focus on using local, affordable and clean energy. Accordingly, prosumers also have environmental benefits in the system (Tushar et al., 2020). Consumers are also determined to be important stakeholders in the P2P energy systems. Even though consumers do not have DERs integrated into their houses, P2P energy trading enables them to participate in low-cost energy trading (Tushar et al., 2021). However, end-users within the current energy system are often categorised as passive (Koirala & Hakvoort, 2017). Therefore, it can be expected that the power and decision-making capabilities of prosumers and consumers will be limited in a P2P energy trading market. Specifically when their powers are compared to a municipality or the national government.

Communities

In addition to the individual prosumer, the community can also find benefits in a P2P energy trading system. Consumers without DERs can participate in a P2P energy trading market through the purchase of excess energy. Therefore, communities are formed by consumers and prosumers who are willing to share and purchase energy. According to Ableitner et al. (2020) the success of P2P energy trading hinges on a community. A community participating in P2P energy trading can enable the active participation of individuals. Thus improve the social cohesion and foster a sense of community for the prosumers and consumers. In addition, a community can adopt storage systems, such as batteries, and integrated them with the aggregated PV generation. Communities can also coordinate their DERs (Ableitner et al., 2020);(Soto et al., 2020). Thus, a community enables multiple local Smart Energy solutions, such as the community P2P energy market form, which translates into a stronger decision-making power for the community than for the individual prosumer. In addition to this, the interest of a community for P2P energy trading is also higher compared to an individual prosumer since the community can create self-provision of local energy and resiliency (Koirala & Hakvoort, 2017).

6.1.2 Energy market

According to Koirala and Hakvoort (2017) an P2P energy trading system consist of a physical layer that enables energy trading in the distribution grid. This layer comprises different stakeholders, all with different interests and power. This section will discuss the stakeholders within the physical layer.

Energy producers

Energy producers are tasked with generating energy. Therefore, energy producers utilise gas fields, coal-fired power stations and windmills. The energy generated is then transferred to the grid, where it can be distributed. The energy producers can then sell the generated energy on the wholesale market. Energy suppliers purchase the produced energy on the wholesale market and distribute it to their customers. The increased penetration of DERs and the implementation of P2P energy trading has created the prosumers phenomenon. An increase in small-scale energy producers characterises the prosumer phenomenon. This has led to a decrease in energy demand for the energy producers (Tushar et al., 2020). Therefore, the interest of energy producers for P2P energy trading is low. In addition, the power of the energy producer in P2P energy trading systems is also relatively low since they cannot influence the DERs penetration and the P2P energy trading system.

Energy suppliers

An important stakeholder within the physical layer is the energy supplier. In the current traditional energy system, every household is obligated by law to have an energy supplier. The energy supplier is responsible for the distribution and sale of electricity. In some cases, the energy supplier is also responsible for energy generation (The Dutch Minister of Economic Affairs and Climate Policy, 2020a) Additionally, energy suppliers are also (partly) responsible for the balancing mechanism and ancillary service markets. These markets sit alongside wholesale trading and are designed to optimise voltage and match supply and demand. Therefore, an energy supplier has a relatively high interest in P2P energy trading markets. Every household is obligated to have an energy supplier. Therefore, an energy supplier will always have a demand (The Dutch Minister of Economic Affairs and Climate Policy, 2020a). Some researchers expect that their market share will reduce due to the active prosumers participation in P2P energy trading. However, Kloppenburg and Boekelo (2019) explains that some energy suppliers occasionally differentiate themselves by creating a retail platform for their customers. This enables energy suppliers to create a business model within P2P energy trading. Accordingly, researchers have created market forms that aim to remove the energy supplier as an intermediary in energy trading. These models are often based on an coordinator or aggregator, which will be elaborated on in the following section. Nevertheless, energy suppliers and prosumers could support each other. Energy suppliers can utilise the prosumers energy generation to balance the grid. Conversely, the prosumer can purchase energy from the supplier if they cannot self-supply their energy demand. Therefore Fell et al. (2019) determines that P2P trading markets operated by an energy supplier positively impact the participation of end-users. It enables confidence in such a market. Therefore, energy suppliers also have high power in P2P energy trading.

Aggregators

An aggregator is an entity that organises the energy demand by bundling the DERs to engage as a single entity. This enables better coordination of DERs and competitive energy purchase. The aggregator aggregates the generation of supply and demand for DERs to provide service in the wholesale market. Aggregation is a role that can be met by existing market actors or can be carried out by a separate actor, such as the community manager in a community P2P energy market. The aggregator can also have commercial agreements with Transmission System Operators (TSOs), Distribution System Operators (DSOs) and prosumers. To enable maximum benefit for the P2P energy system and the network grid. Thus, an aggregator is beneficial for P2P energy trading because it allows prosumers to provide a range of services to the energy market. An aggregator can produce meaningful changes in supply and demand for network operators at specific periods, often related to the weather. This often involves a mix of demand-side response and dispatchable generation and storage to improve the networks operation and efficiency (Pouttu et al., 2017);(Brown et al., 2019). Some researchers refer to an aggregator as an intermediary (Sousa et al., 2019).

Energy service companies (ESCOs)

An energy service company is an organisation that arranges the supply, management, maintenance, and monitors the energy supply for a building or client. The ESCO assesses the potential for renewable energies or energy efficiency interventions and then finances these projects. Often, ESCOs finance the costs for equipment purchases and installations of the energy efficiency intervention. The ESCO is then reimbursed by the customer over time, based on the energy savings incurred (Brown et al., 2019). Therefore, the interest of an ESCO in P2P energy systems are quite high. Since the organisation profits from energy efficiency, operation and management of local generation. However, ESCOs also encounter hurdles related to creating capital for the projects. This has a negative impact on the growth of many ESCOs. A bank or financial institution is then involved in financing the upfront investment for the purchase and installation (Schletz, Cardoso, Prata Dias, & Salomo, 2020). ESCO have a moderate interest and power in P2P energy trading.

Community (energy) initiatives and collectives

As in section 2.7 discussed, inclusion is an important aspect of P2P energy trading. Actively engaging citizens can enable inclusion of all citizens. Therefore, community initiatives and collectives are instrumental. They can position themselves to motivate energy users to cooperate with utilities to provide P2P energy trading services. Thus, enable benefits for the residents and the energy system (Scuri & Nunes, 2020). Therefore, a community energy collective can perfectly position themselves within a community to identify the energy needs and concerns of the residents. Additionally, the needs and concerns of the residents can be incorporated into the design of the future P2P energy market, which includes the needs of vulnerable users.

6.1.3 Virtual market

The virtual market consists of actors involved in establishing the technical infrastructure. In the research of Tushar et al. (2020), the research further differentiates the virtual market. Accordingly, they explain that the virtual market needs a network system and an energy management system before it can operate effectively. The network system refers to the layer that is responsible for the communication of the technologies and the grid. In contrast, the energy management system is related to the market and information system of the virtual layer. The energy management system accounts for the user data and thus determines the energy needs of the participants.

Technology providers

Technology providers are responsible for the development of computation and communication technologies, such as smart meters. The interest of technology provides in the P2P energy market is to create technologies that provide the virtual layer infrastructure (Koirala & Hakvoort, 2017). Therefore, the interest in the P2P energy market is moderate-high, compared to the other stakeholders. Different technologies enable different types of P2P architectures or markets. This also provides different opportunities for inclusion, control, anonymity and transparency. However, technology providers do not have the power in determining the P2P design. However, the technology provides are an important stakeholder for P2P energy trading.

System operators

System operators are the providers of an energy management system. The energy management system includes the information system, market operation and pricing mechanism of a P2P energy trading (Tushar et al., 2020). Therefore, a system operator core focus is to create a virtual infrastructure for P2P energy trading, which an aggregator can then use to match the needs of the prosumers (Abdella & Shuaib, 2018). Accordingly, prosumers can use the infrastructure without relying on an aggregator. System operators can also create a trading platform for the system. This is important for a decentralised energy trading system. The organisation tasked with providing this platform could be seen as the system operator. Therefore, compared to the other stakeholders, a system operator has a moderately high interest in the P2P energy trading market. Since the system operator has limited influence on the adaption and or design of the market, the power of the system operator is relatively low.

6.1.4 Regulating parties

According to de Almeida, Cappelli, and Klausmann (2021), P2P energy trading is a new energy supply concept that can be considered in the context of digitalisation and the sharing economy. How to conduct this in the current energy system is strongly determined by energy law and regulation. The energy law and regulation are created to ensure a secure, environmentally friendly, and cost-effective energy supply. As a result, new energy supply concepts such as P2P trading are subject to legal rules. Therefore, they are either inhibited and therefore cannot be implemented. Additionally, they expose problematic parts of the legal framework in such a way that the legislator tries to adapt them de Almeida et al. (2021). Therefore, the law and regulation stakeholders can be seen as decision-making stakeholders for P2P energy trading. This section will overview the decision-making stakeholders and explain their interest and power in P2P energy systems.

European Union

The European Union (EU) is a unique economic and political union between 27 EU countries, including the Netherlands. The EU aims to ensure that Europe has secure, affordable and sustainable energy. Recently, the EU proposed and approved several regulatory reforms in the Clean Energy Package. The Clean Energy Package includes several EU legal instruments and policies. These instruments and policies are put in place to ensure different frameworks function and establish new energy supply concepts such as P2P energy trading. Moreover, the use of data is regulated in the European Union. Data is also an essential aspect of energy trading and cannot simply be collected, stored, used or passed on. Since these policies and instruments also apply to The Netherlands, the EU has enormous power in P2P energy trading systems. In addition, the EU has defined P2P energy trading and energy communities in the Clean Energy Package. Accordingly, the introduction of these terms are instruments for the new energy supply concept (de Almeida et al., 2021). Also, the EU has different projects to induce Smart Energy projects, such as RUGGEDISED in Rotterdam. Therefore, the EU is an important stakeholder and has an interest in P2P energy trading.

National Government

The government is the highest authority in The Netherlands. The national government includes different Ministries, such as the Ministry of Infrastructure & Environment and the Ministry of Economics. In addition, the Dutch government includes the Dutch Data Protection Authority and Netherlands Authority for Consumers and Market. Also, the Netherlands is a parliamentary democracy, and parliament, therefore, has the final say. Related to energy, the Dutch Government signed the Paris Agreement, which aims to limit global warming to well below 2 degrees Celsius. In line with this, the Dutch government has created goals to reduce its greenhouse gas emission by 49% by 2030 and a 95% reduction by 2050, compared to the level in 1990. Additionally, the national government has proposed an new Energy Act, which has an enormous influence on P2P energy trading. The Act has adopted certain EU directives and the Paris Climate Agreement. Additionally, the national government plans to phase out the gas extraction in Groningen, which is in line with the Paris Agreement. However, this decision was also motivated by earthquakes from gas drilling in Groningen. This objective of the National Government enabled the municipality's decision to focus on all-electric residential area's. From this, it can be assessed that the national government has a high interest and power in Smart Energy solutions, such as P2P energy trading.

Municipality of Rotterdam

In line with the energy goals of the Dutch government, the municipality of Rotterdam also has set energy goals for 2030. Therefore, the municipality has created the Rotterdam Climate Agreement, which includes initiatives and concrete measures to commit to the government goals. The Rotterdam Climate Agreement aims to reduce Rotterdam's CO_2 emission by approximately 49% compared to 2017. Therefore, the municipality is actively investigating different Smart Energy solutions to implement in different residential area's. The municipality is committed to their climate agreement and, therefore, also committed to the Smart Energy initiatives and supporting energy systems. Thus, the municipality has a high interest in P2P energy trading. In addition, the municipality of Rotterdam is in more direct contact with its citizens compared to the Dutch Government. This enables the municipality to determine the needs of its citizens better. It also helps in determining local Smart Energy solutions for the city.

Distribution systems operators (DSOs)

Distribution system operators (DSO) operate and manage regional electricity distribution networks. DSOs are tasked with managing energy use from the energy generation to the end-users. In addition, DSO is also tasked with maintaining system balance and create a safe, reliable and affordable grid (Koirala & Hakvoort, 2017). DERs have an enormous influence on the reliability of the grid. Residential consumers and prosumers are often connected to low voltage distribution systems. Their active participation in P2P trading can cause an overvoltage issue and reverse power flow. Reverse power flow occurs when the generation of DERs exceeds the demand, which causes power to flow in the opposite direction (Tushar et al., 2020). Therefore, DERs have negative influences on the grid, which makes the job of a DSO harder. However, coordination of DERs, which can be met through some P2P energy trading market forms, is a potential solution for DSOs to manage the grid. Therefore, DSOs have a moderate to high interest in P2P energy trading. In addition, they have high power. Even though they cannot prohibit DERs penetration, they can, however, block peers from trading. This is done to maintain the reliability of the grid (Sousa et al., 2019). Therefore, DSOs can exercise their power on the grid and negatively affect P2P energy trading. The DSO for Rotterdam is Stedin.

Transmission system operator (TSO)

The transmission system operator (TSO) is tasked with the reliable transmission of power for the energy producers to the DSO by utilising the high voltage electrical grid, the transmission lines. The objective of the TSO is to create a secure and continuous supply of electricity. TenneT manages the high-voltage grid in the Netherlands and is, therefore, the Dutch TSO. In addition, Tennet also oversees the wholesale market. This is the market where energy producers compete to fulfil the demand of large industries and electricity suppliers in the Netherlands. Tennet continuously monitors the electricity supply and maintains an equilibrium between supply and demand (Morstyn & McCulloch, 2020). Whereas the DSO is responsible for the electricity grid on a regional level, Tennet is responsible for it on a national level. Thus, the TSO also has a moderate interest and power in P2P energy trading. However, they are both responsible for the grid.

6.1.5 Intermediates

The last group of stakeholders will be referred to as intermediates. This group consist of institutions and academia interested in the development of P2P energy trading.

R&D institutions and academia

P2P energy trading has attracted increasing attention from academia and industry in many countries, translated through the rapidly growing number of papers and projects in this field. Academia and R&D institutions provide this field with new and essential knowledge. In addition, the important viewpoint can be derived from their research. Therefore, critical aspects of P2P energy trading, such as market design, trading platforms, social science perspectives, and governance, have been identified and discussed. These stakeholders have a great interest in P2P energy trading. However, their power and interest in P2P energy trading are low compared to the other stakeholders. Since their contribution to P2P energy trading is not necessarily adopted Zhou et al. (2020)

Financial institutes

Financial institutes make significant monetary contributions to P2P energy trading. Financial institutes often cooperate with ESCOs to realise new Smart Energy projects. Financial institutes can also provide monetary contributions to the energy suppliers, energy producers and end-users. Unlike, ESCOs their interest is not necessarily on sustainability or even energy-related. However, their investment contributes to the development of P2P energy trading. Therefore, financial institutes have low interest and low power for P2P energy trading.

6.2 Conclusion

This chapter identified a substantial amount of stakeholders that could be divided into five categories: end-users, energy market, virtual market, regulating parties and intermediates. The end-users consist of prosumers, consumers and communities. The energy market consist of energy suppliers, energy producers, aggregators, ESCOs, community (energy) initiatives and collectives. The virtual market consist of technology providers and system operators. Whereas, the regulating parties encompasses the EU, national government, the municipality of Rotterdam, the DSOs and the TSO, Tennet. Lastly, the intermediates consists of financial institutes, R&D institutions and academia. This chapter aimed to determine the stakeholders regarded necessary for P2P energy trading market. The next chapter will determine whether these stakeholders are also important for facilitating a local P2P energy trading system. Therefore, through the interviews, knowledge will be generated on the stakeholder ecosystem in the current energy system and energy trading system in Rotterdam, specifically Prinsenland and Het Lage Land.

Chapter 7: Results: case study

The previous chapter elaborated on the stakeholders in the literature defined as important for P2P energy trading. This study will proceed with the empirical problem analysis regarding P2P energy trading in the Dutch energy system, specifically for Rotterdam. Therefore, this chapter will discuss the results of the interviews within the embedded case study. The interviewees provided an abundance of in-depth knowledge that could be linked to the theoretical framework. Additionally, the interviewees provided knowledge on the national energy system, the proposed Energy Act and the design of an inclusive local P2P energy trading system. Therefore, this chapter will only elaborate on the empirical result of the interviews. Subsequently, chapter 8 will reflect and review the theoretical framework.

First, a descriptive and analytical market analysis will be given. Therefore, section 7.1 will discuss the assessments of the interviewees and their views regarding the proposed Energy Act. Also, the interviewees provided knowledge on the Dutch energy system and the stakeholders and capable agents within the energy market. This provided empirical knowledge for additional stakeholder analysis. Section 7.2 will present the stakeholder analysis, which aims to determine the stakeholder landscape for Rotterdam. Furthermore, a system analysis will be presented in section 7.4, which will explain how the Dutch (local) energy system work.

Secondly, section 7.5 will present the results of the embedded case study. The empirical results are presented concerning the market form, the social aspects, the supporting technologies, the key actors and the legal aspects of P2P energy trading. Accordingly, the empirical results were the basis for deriving the boundary conditions. Section 7.6, will present the Community-Energy trading market, which is the proposed local P2P energy trading system design for Rotterdam. Figure 7.4 present a visualisation of the Community-Market energy trading system. Additionally, this section will present an overview of the boundary conditions in table 7.1.

Lastly, section 7.7 will concludes this chapter.

Therefore, this chapter will present the results to the sub-questions:

sub-question 2 : Who are the stakeholders involved with P2P energy trading market for locally self-generated sustainable green energy?

Sub-question 3: What are the boundary conditions that enable P2P energy trading markets for locally self-generated sustainable green energy?

7.1 Assessments and views regarding the proposed Energy Act

As discussed in section 2.8, the Dutch government has proposed a new Energy Act. The interviewees discussed the changes in the Act and the national energy system. This section will present the views and assessments of the interviewees regarding the proposed Energy Act.

Interviewees 2, 4 and 5 reaffirm that the objective of the proposed Energy Act is to engage end-users in the energy transition, whereby the ultimate goal is to put the end-user and the centre of the energy system. However, most interviewees argue that the proposed Energy Act is not comprehensive and progressive enough to allow these objectives. Interviewees 5 and 10 explained that the proposed Energy Act adopted certain directives of the Clean Energy Package created by the European Union. However, the Clean Energy Package has additional directives that better serve the objectives and enable a climate-neutral energy system. However, the interviewees determined that these directives have not been adopted in the proposed Energy Act.

"[..] The funniest thing is, the Dutch legislator is mainly looking at the European directive for electricity. The European Union's renewable energy directive elaborates on energy sharing, accessibility for vulnerable households and low-income families. The proposed Energy Act does not distinguish between energy sharing and supplying energy. Also, it includes terms that do not really enable accessibility for vulnerable households and low-income families. For example, the second measuring device. Because this will costs about 500-800 euros, including the refurbishment of your net. So you're excluding the weak. That is exactly what you do not want! (respondent 5)

The interviewees explained that the directives of the European Union include terms such as energy sharing, renewable energy communities and energy performance in buildings (European Commission, 2021). Accordingly, these terms better support the objectives of the proposed Energy Act. Also, the directives better support the implementation of P2P energy trading. Therefore, interviewee 5 elaborated on energy sharing and explained that the Energy Act, through Article 2.2.15, does not distinguish between energy sharing and supplying of energy. Hence, the national government levies a tax on the supply and consumption of electricity. Interviewees 1 and 4 add that the national government has created a complex system regarding energy taxes. According to interviewee 1, the national government also taxes the use of batteries they tax. Therefore, prosumers with solar panels pay taxes when they supply their excess energy to their neighbours. They pay taxes when they store the excess energy in batteries and when they supply it back to the grid. Whereas, with energy sharing, the national government would only levy a tax on energy consumption. Accordingly, the interviewees assess that this would better serve the small-scale consumers and the objectives of the proposed Energy Act. Subsequently, this would enable P2P energy trading. Interviewees 1 and 4 also explain that the regulatory framework for large-scale consumers, businesses, is considerably different. Businesses have different ACM energy permit regulations and energy taxes. This enables energy trading between businesses.

Furthermore, interviewee 5 explains the implications of the term congestion management. Accordingly, he explains that this term forces DSOs to seriously consider Smart energy solutions or services to avoid unnecessary costs for increasing the grid size. Therefore, if a service, such as P2P energy trading, could ensure grid stability. This would make upgrading the grid redundant. Through the proposed Energy Act, DSOs are required to choose the cheapest option. He explained that the cost of upgrading a grid include, cables, transformers and social cost. Accordingly, he assessed that the social costs of upgrading a grid are sustainable. Therefore, DSO would contribute to the development of Smart Energy services and solutions. However, interviewees 6 and 7 disagree with this assessment and explain that the enhanced integration of DERs and the energy transition demands upgrading grids in every city. Also, they argue that congestion is always a temporary problem. More importantly, they emphasise that Stedin's main objective is facilitating the energy market as a neutral party. Therefore, DSOs often choose to upgrade the grid rather than participating and possibly influencing or forcing end-users into a Smart Energy solution. Therefore, the proposed Energy Act does not affect nor change the objective of DSOs.

Interviewees 5 and 10 argue that the EU directives regarding energy are far more progressive, and the proposed Energy Act could have adapted more. Accordingly, they assess that the national government is a bit hesitant in adapting more comprehensible and sustainable directives. Interviewee 10 explained that this could be due to a former energy supplier going bankrupt. The energy supplier allowed a complex form of P2P energy trading. Moreover, when it went bankrupt, it also revealed the sensitive nature of that particular P2P energy trading construction. Therefore, this has cautioned the national government in fostering and enabling Smart Energy solutions, such as P2P energy trading. Thus, making it a sensitive topic for the national government.

"[..] The Netherlands has had ten years to enable things like this! These kinds of projects are not new at all, not the energy community nor the energy corporations. Also, P2P has regularly been discussed. However, The Netherlands consistently choose not to regulate it!" (respondent 10)

7.2 Stakeholder landscape in the Rotterdam energy system

This section aims to define the Dutch energy system for the municipality of Rotterdam. The stakeholders within the Dutch energy system are a vital part of the energy system. Chapter 6 provided a general stakeholders analysis for a P2P energy trading system. This section will provide a stakeholder analysis specifically for the Rotterdam case. To determine the stakeholder landscape of energy trading, the following question was derived in the interviews:

Interview: Who are, in your opinion, the primary stakeholders that should be involved in the development of P2P energy trading in Rotterdam?

7.2.1 End-users

The prosumers, consumers, SME and community assets in Prinsenland and Het Lage land

From the interviews, it can be derived that the end-users are valued as essential stakeholders in the development of P2P energy trading. According to interviewee 5, the end-users are responsible for the energy demand. He refers to this as the energy management system. According to Sinopoli (2009), an energy management system generates and analyses information on energy usage and related costs. Subsequently, interviewee 6 argues that P2P energy trading relies on controlling, forecasting, steering, and having insight into the energy demand and consumption. End-users have a specific energy demand which needs to be determined. In addition to the demand, the production capabilities also need to be determined. Figure 5.3 presents the expected energy demand and production for Prinsenland and Het Lage land. However, the interviewees refer to 'real time' energy demand and production. According to participant 4, forecasting production is challenging and often relies on forecasting mechanisms. Real-time data on energy demand and production can enable P2P energy trading. Moreover, the end-users are solely responsible for the energy demand, and they are viewed as the most critical stakeholders. The interviewees assessed the end-users in Prinsenland and Het Lage Land, including prosumers, consumers, small-medium enterprises, and community assets, such as schools.

"[..] When you ask an important stakeholder, of course simply, the resident themselves! Or groups of residents, or maybe homeowners' association, or however they have organised themselves." (interviewee 7)

7.2.2 The national government

The national government was also discussed as stakeholders. The qualitative research affirmed the power of the stakeholder. Interviewees 4, 5, 6, 8 and 10 all determine that the EU and the EU energy directives are ahead of the Dutch energy laws. Since the European energy directives include terms such as renewable energy community, energy community aggregator etc. The Member States, including the Netherlands, have to transpose the EU directives into national legislation. However, the interviewees determined that the national government has not been stern in integrating the directives of the European Union. Therefore, currently, the Dutch government is proposing a new Energy Act. The Act will merge the outdated Electricity and Gas Act with the EU Clean Energy Package directives and the Paris Agreement. However, as discussed in chapter 2.8 elaborated on the proposed Energy Act and determined that it adopted some directives and terms proposed by the EU. However, the interviewees explained that the national government is hesitant in fostering and enabling Smart Energy solutions. Therefore, the proposed Energy Act is not as progressive as the directives of the EU. Also, the interviewees explained that the national government is removing the Experiments Electricity Act, which enabled municipalities and DSOs to deviate from the traditional Electricity Act and create Smart Energy projects. Accordingly, this reaffirms the hesitancy of the national government to create or facilitate Smart Energy solutions, such as P2P energy trading. Furthermore, interviewee 10 emphasised that this Energy Act is still in a concept version. Therefore, the Energy Act needs to be approved by the Dutch government. Accordingly, she explained that approving the Energy

Act might take a substantial amount of time. This is due to the fact that the current Dutch cabinet has a demissionary status. In addition, the Act needs to pass the council of states, the house of Representatives and the Senate. After which, the proposed Energy Act could have had some substantial changes. Terms could be removed, changed and added. Furthermore, the interviewees explained that the national government provides subsidiaries to aid in the energy transition and also integrate Smart Energy solutions. Therefore, the interviewees assessed that the national government has the resources and power to facilitate Smart Energy solutions.

7.2.3 Distribution system operators and transmission system operator

DSO is Stedin and TSO is Tennet

In addition, the distribution system operator, Stedin, was determined to be an important stakeholder. Interviewee 3 stated that the grid operator obtains the true and actual benefits from P2P energy trading. The interviewee assessed that energy trading could stabilise the local grid. However, according to interviewee 5, the premise of P2P energy trading, a peer supply another peer of energy does not involve the DSO. In addition, interviewee 7 defines the role of Stedin as secondary within the P2P energy trading market. However, most of the interviewees agreed with interviewee 3, and stated that Stedin obtains benefits from P2P energy trading. Moreover, interviewees 1, 3, and 6 stated that DSOs could benefit from energy trading. Additionally, interviewee 9 explained that DSOs are responsible for real-time data, which allows for energy trading. However, the foreseen grid benefits of energy trading can only be created on an aggregated level. The interviewees added that a residential area rarely reaches that specific level for it to affect the grid. Therefore, the interviewees questioned whether the DSO would be involved in energy trading for Rotterdam. However, interviewees 2, 6 and 7 explained that DSOs and municipalities had access to the Experiments Electricity Act. This enabled them to create Smart Energy projects. Subsequently, Stedin has participated in a few Smart Energy projects. However, the Experiments Electricity Act has been removed. Consequently, interviewee 6 emphasised that Stedin's main objective is facilitating the energy market as a neutral party. Therefore, it can not and would rather not participate in Smart Energy projects since it can influence or force end-users into a Smart Energy solution. Thus, Stedin operates in the current energy market by enforcing three objectives for market freedoms: freedom of connection capacity, freedom of transaction and freedom of dispatch. These objectives are also known as the "copperplate" principle. Nevertheless, the majority of the interviewees refer to the DSOs as a stakeholder. Conversely, the Dutch TSO, Tennet, was barely mentioned. Interviewee 5 referred to Tennet as a secondary stakeholder.

7.2.4 The municipality of Rotterdam

The municipality of Rotterdam was also determined to be a primary stakeholder for P2P energy trading. This could be related logically, due to the municipality is the unit of analysis. However, some interviewees questioned the role of the municipality in the development of P2P energy trading. More importantly, some interviewees questioned the role of a municipality in the Dutch energy transition. The reason for this is related to the fact that the municipality does not create the technology nor produce energy. However, interviewee 13 explained that the Dutch government placed the municipalities in charge of the energy transition of their district. This enables the municipality to regulate the course of the energy transition and thereby the Smart Energy solutions developed in Rotterdam. In response to this, the municipality created the Rotterdam Climate Agreement. Furthermore, according to the interviewee, the municipality has created a Smart Energy system subsidy, which provides and encourages startup companies to develop innovative solutions for the energy transition in Rotterdam. Therefore, interviewees 7, 9 and 11 argued that the municipalities are instrumental in facilitating and enabling Smart Energy projects within their city. Since the municipality can approve and refuse the implementation of particular projects. Furthermore, interviewee 10 discussed the importance of the municipality to ensure benefits for all their citizens when implementing specific innovative projects.

7.2.5 The European Union

The national government were also discussed as stakeholders. The qualitative research affirmed the power of the stakeholder. Interviewees 4, 5, 6, 8 and 10 all determine that the EU and the EU energy directives are ahead and more progressive than the Dutch energy laws. Accordingly, the EU energy directives include terms such as renewable energy community and aggregator. The Member States, including the Netherlands, have to transpose EU directives into national legislation. However, the interviewees determined that the national government has not been stern in integrating the directives of the European Union. Therefore, currently, the Dutch government is proposing a new Energy Act. The Act will merge the outdated national Electricity and Gas Act with the European Clean Energy Package. The interviewees explained that the proposed Energy Act had adapted some directives. However, they determine that they could have adapted more to achieve the objective of the proposed Energy Act. Interviewee 10 explained that Member States are forced to implement the EU directives. If the EU determines that The Netherlands has not adequately implemented their directives, the EU can initiate an extensive procedure that forces The Netherlands to implement the EU directives correctly. Furthermore, the interviewees explained that the EU provides subsidiaries to aid in the energy transition and integrating Smart Energy solutions. Accordingly, the EU has funded a Smart City project called RUGGEDISED. Currently, Rotterdam is a part of this Smart City. Therefore, interviewers assessed that the EU has resources for Smart Energy solutions.

7.2.6 Energy suppliers

Energy suppliers were also discussed as a stakeholder of a P2P energy system. Interviewee 4 assessed that energy suppliers would have an essential role in the future P2P energy trading market, similar to their role in the current energy market. Currently, energy suppliers are responsible for managing the commercial contracts by establishing a price for the energy. According to interviewee 5, the European energy directives distinguish between energy sharing and energy supplying. However, the national government does not make this distinction. The interviewee reasoned that this enables the national government to obligate the households, by law, to have an energy supplier. Interviewee 4 explained that, in the current energy system, energy suppliers create a portfolio. The portfolio contains the energy supply and demand of their customers. Energy suppliers use these portfolios to participate in the wholesale market. Interviewees 4 and 5 argue that for this reason, energy suppliers will also be necessary for P2P energy trading. Since they would operate as a backup for peers within the energy trading system. Interviewee 10 explained that an energy supplier enabled a complex infrastructure for P2P energy trading in the past. Ultimately, the energy supplier went bankrupt, which revealed the sensitive nature of that particular P2P energy trading construction. Therefore, she assessed that the Dutch government encourages end-users to trade their generated surplus energy with an energy supplier and not with their peers. Interviewee 12 also discussed energy suppliers in the energy trading system. According to him, energy suppliers could create additional services that allow for energy trading. However, he assessed that involving energy suppliers would not benefit an inclusive P2P energy trading system. Therefore, he cautions that energy suppliers could enable a sharing economy such as Uber and Airbnb. Interviewee 14 disagreed with this notion, assessed that energy suppliers are aware of the social pressure of the energy transition. He also explained that energy suppliers are active in energy trading but only focus on business trading. Additionally, he explained that energy suppliers have resources, knowledge, and monetary incentives to aid in the energy transition and therefore provide resources for energy trading.

7.2.7 Community energy corporation and cooperative

Alex Energie and Energie van Rotterdam

Similarly to the 6, the interviewees determined that actively engaging citizens is important for energy trading. Therefore, they assessed that including community energy corporations and initiatives would be essential. For the residential area Next Generation Prinsenland, a community energy corporation has already been introduced, known as Alex Energie. Alex Energie focuses on locally generated sustainable energy for all residents in Prinsenland and aims to secure joint benefits from the proceeds. Therefore, this community energy corporation is perfectly positioned to identify the energy needs and concerns of the residents. The resident's input can be incorporated into the design requirements of the P2P energy market. However, interviewee 11 revealed that Alex Energie envisioned themselves as energy producers. Therefore, Alex Energie aims to assist the residents with integrating DERs into their houses and in the neighbourhoods. Subsequently, Alex Energy will sell the energy generated to an energy supplier for a specific price. In addition, Alex Energie expects to receive a subsidiary for the Dutch government. The combined revenue will then be divided amongst the participants of the energy collective. Additionally, the interviewee explained that Alex Energie also empowers residents by helping them better handle their energy bills by advising them on how to reduce their energy demand. Conversely, interviewee 4 envisions a different role for Alex Energy in a P2P energy market. He asses that Alex Energy could fulfil the role as an energy supplier in the P2P energy market. In this case, an energy supplier is also responsible for the production. Therefore, the role of Alex Energie will expand and will also be essential in the P2P energy trading system in Rotterdam. Additionally, interviewee 12 envisions are more proactive role for the cooperative sector. He determines that the cooperative sector can ensure that the public interest in energy trading will be safeguarded. Therefore, he assesses that the cooperative sector should be involved in the development of P2P energy trading. Thus, community energy corporations and cooperatives have a high interest and a moderate-high power in P2P energy trading.

7.2.8 Energy service companies, Energy producers, R&D institutions, financial institutes and academia

ESCOs, aggregators, R&D institutions, financial institutes and academia were also discussed during the interview. Interviewee 3 expects that energy service companies, aggregators and financial institutes will have an important role in the P2P energy trading system. Since these actors will be creating a flexible market for energy trading, their role would be to support the end-users and thereby claiming monetary incentives. This stakeholder will assist the end-users and energy suppliers. However, the interviewees did not identify any ESCOs, R&D institutions and financial institutes that could assist the end-users and energy suppliers. Also, energy producers were not mentioned as an important stakeholder.

7.2.9 Aggregators

Similar to the 6, aggregators were discussed and identified as important stakeholders for energy trading. Interviewees 3, 5 and 10 argue that aggregators will have a more prominent role in the energy trading system. Additionally, interviewees 5 and 10 stress that aggregators have been defined in the EU clean energy directive. Therefore, the aggregator is also defined in the concept version of the proposed Energy Act. However, whether the aggregator will be recognised in the final version of the Energy Act remains to be seen. Interviewee 14 recognised the importance of an aggregator. However, he determined that an aggregator alone could not manage an energy trading system. He discussed additional actors, a forecaster and an energy supplier within the energy trading system.

7.2.10 The virtual market

The stakeholders within the virtual market were not specifically discussed. However, the interviewees did discuss the importance of a virtual market. Similarly to Tushar et al. (2020), the interviewees differentiate between a network system and an energy management system. The interviewees focused on the energy management system and determining it to be an essential part of energy trading. Interviewees 1, 6, 9, 10 and 13 discussed the importance of smart meter devices in the current and future energy market. Interviewee 10 explained that the DSOs provide the traditional smart metering devices. The European Union sets the standard for these devices. According to her, these devices do not work properly and are also not 'smart'. Interviewee 13 explained that the design and thus technology for these devices were determined by the EU ten years ago. Subsequently, a lot of new technologies have been developed, making the traditional smart metering technologies obsolete. However, interviewees 9 and 10 stressed that 'working' smart meter devices should first be integrated into the residents' houses. The interviewees might refer to the non-traditional smart metering devices. Therefore, interviewees 10 and 13 discussed devices that can determine the real-time data on energy price, demand and production, thus can provide real benefits. Additionally, the interviewees discussed the network system, whereby they assessed that a third party, such as an aggregator or energy supplier, would provide this. Interviewees 12 and 13 discussed the importance of the trading platform. According to interviewee 12, decentralisation also refers to end-users participating in that trading market. Therefore, he assessed that platform would be essential for P2P energy trading since this enables end-users to participate in trading. Interviewee 12 emphasised that platform developers could shape the future of energy trading. Considering it could create a sharing economy business model such as Uber. He argued that within such a business model, the social value and public value of energy trading would be obsolete. Interviewee 13 determines that these business models would not occur if there is competition. Interviewee 14 concurs with this notion and discusses the importance of integrating batteries and other Smart Energy solutions. Based on the qualitative research, the actors in a virtual market are defined as important stakeholders.

7.3 Inter dynamics of the stakeholder network in Prinsenland and Het Lage Land

The interviews generated new knowledge on the stakeholders determined in The interviews generated new knowledge on the stakeholders determined in 6. The interviews revealed that the vast majority of the stakeholders identified in the literature were also present in the case of Prinsenland and Het Lage Land. Based on the interviews, the inter dynamics between stakeholders of the current energy market was defined. A visualisation of the relations between stakeholders is given in figure 7.1 and the power-interest grid is presented in 7.2

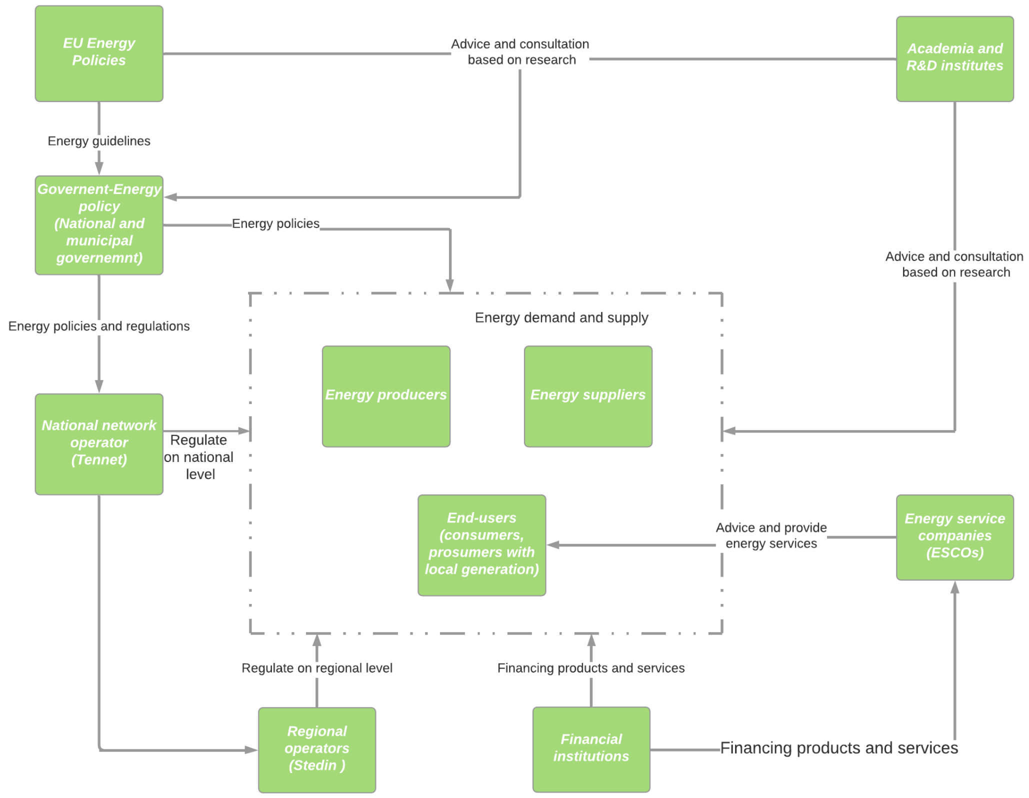

Figure 7.1: The relation between the stakeholders, own image derived from interview data

For the case study Prinsenland and Het Lage Land, a power-interest grid was determined. Figure 7.2 gives a visualisation of the power-interest grid for Prinsenland and Het Lage Land. The figure is based on the data generated from the interviews.

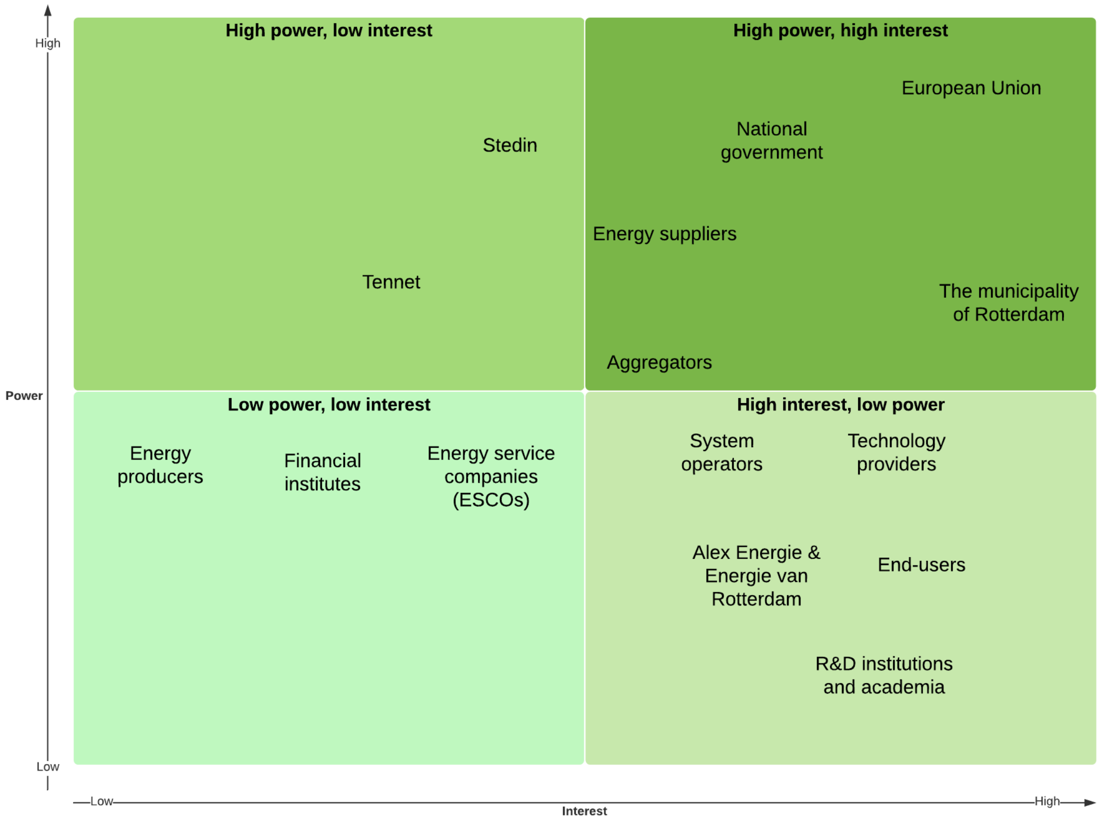

Figure 7.2: Power-interest grid for P2P energy trading, own image derived from interview data

High power, high interest The interviews revealed that the EU, the national government, energy suppliers, the municipality of Rotterdam and aggregators have high power and interest in the development of P2P energy trading. According to the interviewees, the aggregator will have a prominent role in energy trading. Additionally, the interviewees determined that energy suppliers could also have a prominent role in energy trading. The national government, EU and the municipality are also determined to have high power and interest. This is mostly related to the urgency of the energy transition. Additionally, the interviewees determined that the EU, national government and energy suppliers have many resources for the development of energy trading markets. The municipality eventually decides whether energy trading will be chosen for the districts. Additionally, the municipality can ensure that the energy trading design will enable benefits for all its residents.

High power, low interest The interviews revealed that the EU, the national government, energy suppliers, the municipality of Rotterdam and aggregators have high power and interest in developing P2P energy trading. According to the interviewees, the aggregator will have a prominent role in energy trading. Additionally, the interviewees determined that energy suppliers could also have a prominent role in energy trading. The national government, EU and the municipality are also determined to have high power and interest. This is mainly related to the urgency of the energy transition. However, they discussed the hesitance of the national government to integrate progressive directives. Additionally, the interviewees determined that the EU, national government and energy suppliers have many resources to develop energy trading markets. The municipality eventually decides whether energy trading will be chosen for the districts. Additionally, the municipality can ensure that the energy trading design will enable benefits for all its residents.

High power, low interest Stedin (DSO) and Tenner (TSO) were also identified as stakeholders with high power. However, interviewee 5 assessed that Tennet would be a secondary stakeholder. However, Tennet is responsible for the energy market, which makes them have high power in the development of energy trading. The interviewees determined that Stedin would be an important stakeholder. However, Stedin stressed that their main objective is to facilitate an energy trading market. Therefore, the interest of these stakeholders is low.

Low power, high interest The end-users, system operators, technology providers, academia, R&D institutes and community energy corporations and cooperatives are determined to be stakeholders with low power and high interest. These stakeholders do not have much influence on the design of the market. In comparison, the community corporations and cooperatives could have a more prominent role in the development of energy trading. However, Alex Energie assessed that their focus would be on integrating DERs. Therefore, the decision-making activities of these stakeholders are assumed to be low, and they will have low power. However, their interest will be high since the energy trading could provide benefits for these stakeholders.

Low power, low interest While ESCOs in 6 had a more prominent role in the development of energy trading, the interviewees did not discuss their role in the case of Prinsenland and Het Lage Land. Additionally, the energy producers and financial institutes were not discussed by the interviewees. Therefore, these stakeholders have low interest and low power.

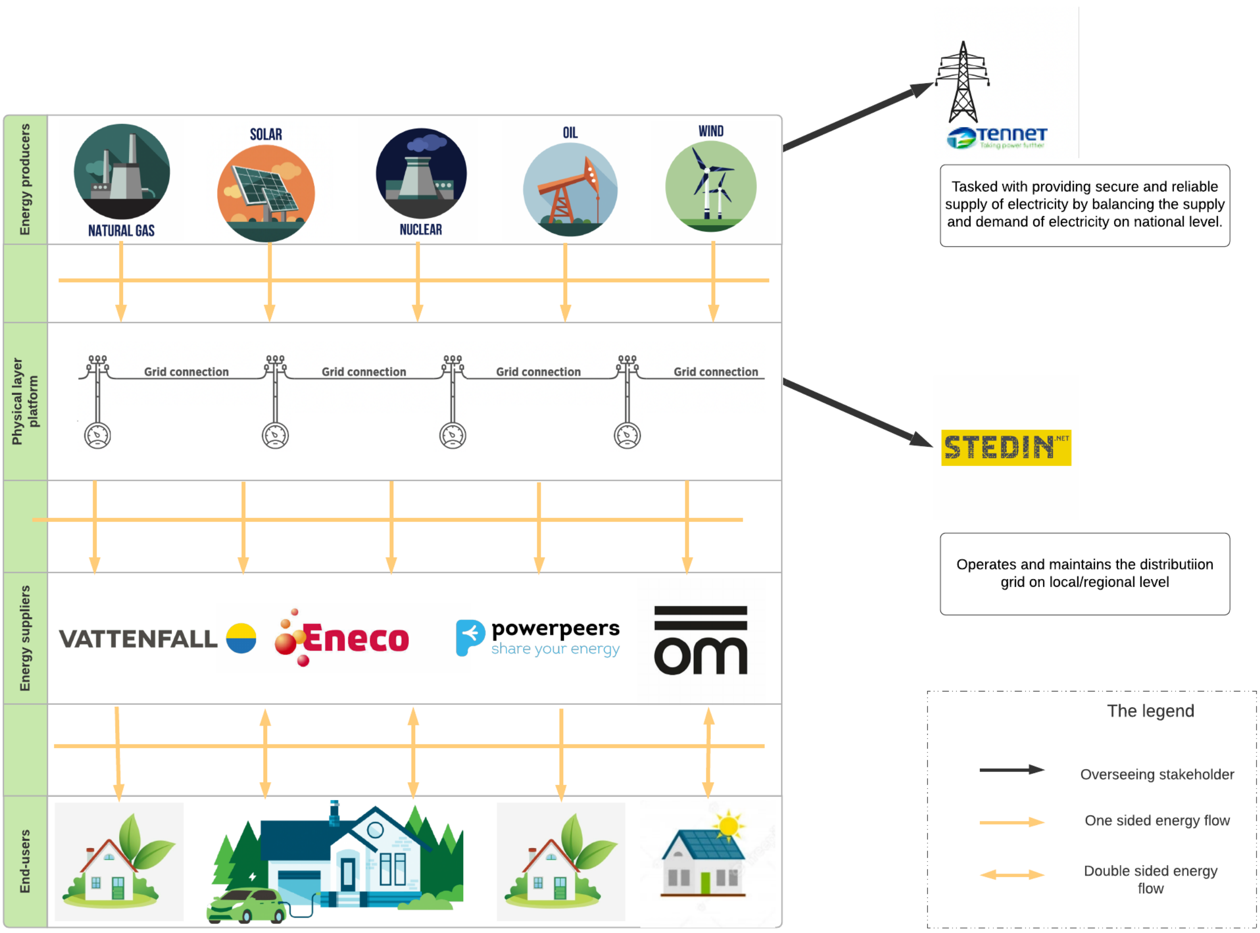

Figure 7.3: Visualisation of the current energy system, own image derived from interview data

7.4 The system-analysis for the energy system in Prinsenland and Het Lage Land

In addition to the relation between the stakeholder, the interview generated knowledge on how the current energy market works. Therefore, this section will describe the national energy market since the national energy system applies to every district, including Prinsenland and Het Lage Land. Figure 7.3 gives a visualization of the current Dutch energy market. Furthermore, this section will describe the Dutch energy market. Thereby detailing how the market works for locally self-generated sustainable green energy.

According to 2.5, the traditional energy market follows a top-down approach. This is reaffirmed by interviewees 3, 4 and 10. According to the interviewees, the national energy market is also organised in a top-down approach. Therefore, the energy system for electricity in the Netherlands is based on centralised production by power plants. Interviewee 4 elaborated on the Dutch energy market and explained that power plants often produce electricity through natural gas and oil combustion. Other energy sources include solar photovoltaics, wind turbines and nuclear fission. The electricity is then supplied to consumers via the transmission and distribution grids. First, the electricity is supplied to the transmission grid. Tennet, the TSO in the Netherlands, is responsible for operating and balancing the Dutch energy system on a national level. TenneT transports the electricity from the producers via the high-voltage grid, the transmission grids, to the substation. Then the DSO, Stedin, ensure that the electricity from the substation enters the low-voltage grid. From the low-voltage grid, all end-users are supplied with energy. Therefore, Tennet and Stedin are responsible for a secure and continuous supply of electricity. Interviewees 4 and 5 empathised that, contrary to popular belief, the energy supplier is only responsible for managing the commercial contract. The energy supplier determines the price for the energy demand of the end-user. Interviewee 4 also explained that energy suppliers create a portfolio, which contains the energy supply and demand of their customers. The sum of this determines whether an energy supplier has an energy surplus or deficiency. The energy supplier then uses the portfolio to participate in the wholesale market. According to Tennet (2021a), balance responsible parties (BRPs) are also active in the national energy system. These parties are financially responsible for maintaining the balance between the portfolio's supply and demand for energy. The large energy suppliers often also operate as BPRs. In addition, prosumer can place their generated energy back to the grid. The current energy systems enable this, and the energy supplier pays the prosumer a specific rate for their energy. Additionally, it is important to know the actual consumption and production of energy. Therefore, the national energy market also has metering companies. According to Tennet (2021b), a metering company registers and validates the consumption per area. Companies wanting to provide these services need permission from Tennet. For the national energy system to operate effectively, the actors within the energy system need to communicate. He also explained that the actors use a communication system, ensuring that the energy market operates effectively.

However, the vast majority of interviewees concluded that the traditional energy system, the Dutch top-down approach, is experiencing challenges due to DERs. The penetration of DERs is creating challenges for the current energy market. Interviewee 7 elaborated on these challenges and discussed grid congestion as a challenge due to DERs. According to interviewee 1, grid congestion occurs when the existing transmission or distribution lines cannot accommodate all required loads during periods of high demand. In addition, interviewee 4 explained that the traditional energy production methods have a controllable and predictive nature. Conversely, DERs are less predictable and controllable since they rely on the weather, which is often very difficult to predict. Another challenge discussed is solar cells producing at unfavourable times. Interviewee 1 explains that solar cells have a high production capacity during the day. However, residential area's do not have a high demand for energy during the day. Conversely, in the evening, the demand will be high. However, solar cells will often not be able to meet that demand.

7.5 The findings from the interviews regarding the design of a local P2P energy trading system for Rotterdam

The embedded case study consisted of interviews with multiple experts and agents in the Dutch and Rotterdam energy system. The interviews were conducted by means of an interview guide, presented in appendix B, and were based on the theoretical framework and the research question. This section will describe the results of the case study regarding the design of a local P2P energy trading system. The results will be presented regarding the market form, the social aspects, the supporting technologies, the key actors and the legal aspects of P2P energy trading. Therefore, this section will identify and define several boundary conditions for a local P2P energy trading system in Rotterdam.

7.5.1 The market form

The premise of P2P energy trading is prohibited through Article 2.2.15. Accordingly, the interviewees determined that P2P energy trading based on the individuals DERs could not be facilitated in the national energy market. Interviewees 1 and 10 emphasised that they do not expect a future Dutch energy market that allows P2P energy trading. Therefore, interviewee 10 discussed the bankruptcy of a former energy supplier that allowed a complex form of P2P energy trading. This revealed the sensitive nature of that particular P2P energy trading construction. This could have aided in the apprehensiveness of the national government in supporting P2P energy trading. Therefore, she assessed that the national government would encourage energy trading with an energy supplier. Accordingly, interviewee 1 explains that centralised P2P energy trading already exists and falls under the job description of an energy supplier. For this reason, centralised P2P energy trading was rejected by the interviewees. In addition, decentralised P2P energy trading was also rejected by the interviewees. Interviewee 3 explained that decentralised P2P energy trading systems are challenging to manage because peers are free to trade whenever they want. He assessed that this would negatively impact the energy grid, making it unreliable. As a result, the envisioned benefit of grid stabilisation through P2P energy trading was rejected by interviewees 1 and 6. Also, interviewees 3 and 5 discussed privacy issues related to decentralised energy trading systems.

Moreover, interviewee 6 argues that the individual peers have a small energy demand and production compared to the whole system. Therefore, their contribution to the energy system would not be substantial. The majority of the interviewees also recognised this observation. Therefore, interviewee 1 explains that energy trading systems are not novel systems because energy trading occurs on aggregated levels. He explains the notion of Business to Business (B2B) energy trading. Companies that participate in are B2B energy trading bundle the solar panels of businesses on large industrial estates, which is used for trading with energy-intensive companies. Therefore, B2B trading encompasses trading a substantial amount of energy. B2B trading companies assist DSOs by matching energy supply and demand to prevent congestion on the grid, thus assist in stabilising the grid. He also assesses that congestion will also occur in residential areas, such as Prinsenland and Het Lage Land. Because municipalities are focussing on all-electric residential areas will increase, and thus more congestion will occur. However, he also assessed that any market form of P2P energy trading would not prevent congestion. Since individual households with five or six solar panels will not meet the demand specifically during peak time, which is around diner time. Whereas, during the day, the demand for electricity in these districts would not be very high. Therefore, he suggested shifting the focus from energy trading to batteries. Accordingly, a neighbourhood or residential battery could store excess energy, which could be used for a residential area during peak time.

> "[..] "Personally, I don't believe in P2P that very much. I believe it becomes relevant for business." (interviewee 1)

"[..] I agree with interviewee 1, small prosumers have very little market power, right. You have five or six solar panels, so that is very little. But if you aggregate those over neighborhoods, right. Then I believe this might work." (interviewee 3)

In contrast, the majority of interviewees did see a future where P2P energy trading would be facilitated and integrated. Similar to interviewee 1, they elaborated on the notion of aggregating or bundling DERs. Accordingly, this will result in bundling the demand and supply of the prosumers. Therefore, interviewee 3 determined that the form of a future P2P energy trading market would be community-based. Interviewees 4, 5, 6, 7, and 10 all agreed with the assessment of interviewee 3. Additionally, interviewee 4 referred to the draft proposed Energy Act and suggested creating an energy community. Since, this would enable a community to participate in trading energy with the market. Therefore, creating an energy community is defined as a boundary condition for P2P energy trading.

"[..] the introduction of energy communities provides communities with a state aparte and energy communities get their own position in the energy system" (interviewee 4)

The addition of energy communities in the proposed Energy Act generates a new market player in the energy market. Also, it makes the energy market more dynamic and diverse. This is recognised by the majority of the interviewee. According to The Dutch Minister of Economic Affairs and Climate Policy (2020b), energy communities can enable higher participation in the energy transition, more investments in the energy transition and generate multiple energy choices for consumers. While conversely, the majority of the interviewees reasoned from a regulatory, economic and congestion viewpoint. Interviewees 4, 9 and 12 agree with the assessment of The Dutch Minister of Economic Affairs and Climate Policy (2020b).

7.5.2 The social aspects

However, the interviewees stressed the importance of defining a goal before creating an energy community. Therefore, interviewee 1 argued that the municipality should first determine the premise of energy trading for Prinsenland and Het Lage Land. Since in his assessment, facilitating energy trading to prevent congestion would not be effective. This notion was shared by the majority of the interviewees. Consequently, interviewees 1, 6, 7 and 14 discuss goals related to energy, enhancing integration of DERs, creating environmental awareness and behaviour and creating climate-neutral districts. Whereas interviewees 10 and 12 discuss social goals, such as inclusion and social equity. Interviewee 2 also discusses the importance of defining a goal and determines that creating Smart Energy solutions, such as P2P energy trading, could have great implications. Particularly, if the municipality does not understand what they are facilitating or handing over to a company. Therefore, this study defines determining a goal and focus of energy trading as the first boundary condition for energy trading. Subsequently, interviewee 10 explains that the municipality could then focus on instruments (social-led and policy-led instruments) to achieve their goal.

"[..] "You need someone who takes care of energy management and links it to the objectives of the Energy Community for Rotterdam." (interviewee 14)

According to interviewee 12, the energy transition changes the narrative of energy, subsequently bringing it back into the social and collective domain. He assessed that the cooperative sector, energy communities and local energy initiatives are key for ensuring that energy becomes something "for the people by the people". Additionally, interviewees 4, 5, 6, 7, 10 and 12 argue that energy communities can be placed perfectly in society and residential area's to enable participation. Interviewee 6 added that end-users are increasingly participating in local energy initiatives. He reasons that end-users have obtained an interest in sustainability and have a sense of urgency due to the Climate Agreement. Interviewee 4 concurred and added that local initiatives are becoming a social trend. Since people rather deal with someone that they know than with someone they do not know. Additionally, interviewee 5 explains that end-users should be informed, in a simple language, what the advantages and disadvantages are of an energy community. Since explaining the complexity of energy trading will fend away participants. Some interviewees acknowledge this, however, the majority of the interviewees assess that creating an energy community could turn out to be a challenging task.

"[..] You and I, as households, really don't care about whatever lies beyond the socket." (interviewee 4)

"[..] Within the energy sector, we find these things very interesting. But the interest of customers.. Energy remains a no-interest product! So, not a low-interest product but a no-interest product. So, it will always be very difficult to fill those kinds of initiatives." (interviewee 9)

Interviewee 5 explains that energy is often not regarded as a priority. Therefore end-users do not bother themselves with matters related to energy. Therefore, interviewee 1 refers to energy as just a commodity, while interviewee 9 refers to energy as no-interest. Interviewees 10, 11 and 12 disagree with the notion that energy is a no-interest product. Interviewee 12 emphasises that people will not categorise energy as "just" a commodity when reasoning from the occurring energy transition and social transition. However, most of the interviewees assessed that enabling participation in an energy community will prove to be complicated. Interviewee 6 explains that creating and organising an energy community will provide users flexibility, transparency and low-threshold access to the electricity market. However, interviewee 5 argues that this does not persuade residents to become a part of the energy community. Since he assess that environmental awareness and behaviour of end-users is not (yet) high enough, that it will enables participation. Therefore, the interviewees determine that an energy community should generate benefits for the participant. Some interviewees focus on monetary benefits. However, interviewees 1 and 10 wondered whether substantial profits could be made in energy trading. Moreover, interviewee 1 assesses that a small group of residents will be persuaded to participate in the energy community within a community, which he refers to as the niche. Therefore, the mass, the majority of the residents will not participate in the energy community. He explains that the nature of energy, energy being a commodity, will not motivate the majority of the residents to pursue better energy requirements since energy trading does not provide real monetary profit. Thus, they will not participate in social energy initiatives. Accordingly, he explains that the majority of the residents in Prinsenland and Het Lage Land will not participate in this particular social activity. Thus they will be excluded in creating shared prosperity. Therefore, the interviewees (unknowingly) discussed the concept of inclusion and specifically social inclusion, smart participation and citizenship. The majority of the interviewees recognised that this could happen in a community. Interviewees 3, 10, 12 and 13 argue that this refers to inclusion, thereby reaffirming the importance of inclusion. Therefore, interviewees 3, 10 and 12 discuss linkage opportunities, which refers to linking energy transition-related projects to projects for the benefit of a community, such as creating a playground for kids. Thus, linkage opportunities enable win-win situations for both the municipality and the residents in the community. This refers to creating social cohesion and thereby ensuring shared prosperity. According to interviewee 10, the municipality should identify the needs and challenges of their citizens related to energy. The identified needs should then be incorporated in the design. Since, this allows for creating a service based on real needs. Also, she explains that the municipality should focus on generating feedback for their residents. The feedback could then be used in the development of P2P energy trading, or any SEs.

"[..] I think, the problem will be that the residents will not be interested. Energy is a commodity! Are they really going to put a lot of effort in participating, just to save 10-20 Euro's a year?" (interviewee 1)

"[..] I can imagine that the advantages of participating together, within a community. But I'm afraid, you will soon see that the less poor, the rich people use this faster and better than the other people. Not because there is a difference in education. But because they have other problems, substantial problems! Practically, they have other things on their minds, than energy!" (interviewee 5)

Additionally, interviewees 1 and 5 discussed economic inclusion and explained that some residents might not have the finances to participate in the energy market. Therefore, participant 10 emphasises the importance of creating an inclusive energy community. Furthermore, the interviewees discuss energy poverty, which refers to end-users spending approximately 10% of their income on their energy consumption. Accordingly, they assess that this is a real problem and could cause serious problems in the future. Therefore, some interviewees empathise that the municipality should actively integrate inclusion in their design. Interviewee 10 argues that the municipality should integrate inclusion in the design of a community and subsequently in the design of P2P energy trading. She explains that the municipality should identify the needs and challenges of their citizens related to P2P energy trading or any other SEs, and create a design that actively aims to combat the challenges and needs identified. She also explains that generating feedback from the residents and community can enable inclusion. Since, the feedback could then be used in the development of P2P energy trading, or any SEs. This could result in adjustments in activities in terms of inclusion. Therefore, she explains that the municipality should determine their current activities in terms of inclusion. Interviewee 12 concurs and adds that the municipality should assist the end-users in transitioning from their energy supplier to the energy community. Interviewee 10 strongly rejects the assessment of certain interviewees, such as interviewee 1. She also assesses that new residential buildings without material inequities, no difference in social housing and 'normal' housing, could enable economic inclusion. Furthermore, interviewee 11 explained that the majority of the residents in Prinsenland and Het Lage Land are apprehensive of the energy transition. However, they want to be a part of this process. He adds that the current municipality-resident relation does not allow for participation. This is related to political inclusion. Therefore, an additional boundary condition is identified. Namely, the municipality should include the concept of inclusion in the design of P2P energy trading.

"[..] I think the challenge will be, within a community, that certain people have stronger shoulders. Therefore, these people would be able to utilize this. I think, this requires a certain willingness to ensure inclusion. It may be a challenge to achieve it, but I think this is really a fundamental goal! Especially on such a level!" (interviewee 10)

7.5.3 The supporting technologies

According to interviewees 4 and 5, another premise of an energy trading market is a good energy management system and demand-side management. Subsequently, interviewee 6 argues that the notion of P2P energy trading relies on controlling, forecasting, steering and having insight into the energy supply and demand. Currently, energy suppliers relieve end-users from the burden of understanding the energy market. Whereas, in a P2P energy trading system, prosumers will need insight into their demand and supply because this is key for a good energy management and demand-side management. Therefore, the majority of interviewees advocated for the use of smart metering devices in the energy communities. Interviewee 10 assessed that integrating smart metering devices could enable transparency in the energy communities by giving the community a better insight into their energy demand. However, interviewees 1, 9 and 10 all explained that some smart metering devices do not work sufficiently to be called smart. In addition, interviewee 10 determined that the definition of smart metering devices in the Energy Act is not (yet) comprehensive. The definition does not explain who can read the data on these devices, which can have profound implications for privacy within the energy market. However, integrating smart metering devices is key for energy trading. Therefore, integrating adequate smart metering devices is defined as a boundary condition.

"[..] You need smart meters, working smart meters, so not some of those smart meters that have been rolled out. Those devices do not offer any insight into what people actually generate and consume. So you will need smart meters that meet a certain standards." (interviewee 10)

Furthermore, the interviewees discussed different technologies and resources for energy trading. Interviewee 5 discussed a good working application. He reasons that an application informing participants of their accumulated profits and contribute to the energy market could enable participation. This could also trigger other residents to participate. Interviewee 1 agrees with this and describes an automated system for transparency. He defined the system as gamification. Accordingly, he explains that his company utilises gamification. However, in his observation, gamification only enables active participation in the first few months. Therefore, he assessed that consumers often soon lost interest in applications. Furthermore, the interviewees discuss the implications of a second measuring device. According to, interviewee 5 this allows for a second energy supplier. Therefore, end-users could choose to enter into an energy community and also have an energy supplier. However, interviewee 10 assess that sufficient and good smart metering devices should allow for this. The interviewee also determined that a second measuring device are expensive, around 500-800 Euro. Therefore, interviewee 5 determines that second measuring devices have enormous implications for inclusion in the energy market. Furthermore, interviewees 3, 9 and 10 discussed pricing mechanisms for P2P energy trading and asses that there should be a fair price mechanism for energy trading. Accordingly, they determine that such a mechanism does not exist. Interviewees 3 elaborated on his P2P energy trading pricing mechanisms research, whereby he uses game theory, optimisation, algorithms, and AI technologies. Blockchain was also discussed as a technology for energy trading. However, the interviewees revealed the, as of yet, immature nature of Blockchain. Interviewee 4 explained that Blockchain is not integrated into an important regulatory process, a data system, in the energy market. Therefore, Blockchain does not communicate with this data system. He explained that other companies use Blockchain to record transactions. Those companies access their platform to access the regulatory data system. Additionally, he explains that Blockchain is a sensitive matter in the energy system. This is related to the notoriously high energy consumption of Blockchain. However, interviewee 6 assessed that this would decrease in the coming years. Furthermore, interviewee 5 explained that the use of Blockchain in a Smart Energy platform surprisingly enabled privacy issues. However, interviewee 8 assesses that the decentralised nature of Blockchain will become important in the future energy markets and emphasises that it will become a promising tool. Moreover, interviewee 3 discusses an ICT infrastructure and or a virtual market. However, the interviewees emphasised that this should not be the concern of the municipality. Interviewees 10 and 12 again emphasised that the municipality should first define a goal for energy trading, which could be social or environmental but should include the concept of inclusion. Subsequently, interviewee 4 adds that with a well-defined goal, the municipality could then "shop" the functionalities/technologies needed for the goal.

"[..] I think you should look at the technology from a neutral perspective!" (interviewee 6)

"[..] I would like to make an appeal: Do not reinvent the wheel that everyone is currently inventing! So the question you are asking, is being asked by different companies. So don't develop it all yourself. I think those companies will form a consortium of companies/parties that can and will take care of that part of the new ecosystem. Then you will be able to shop all those functionality. The most important aspect for the municipality is to create a community. Additionally, enable a place where all the stakeholders can gather and make sure that there is something of a legal body there. Because that is easier. " (interviewee 4)

7.5.4 The key actors

In addition to determining the demand, it is also important to determine the supply of DERs. Given the unpredictable nature of DERs, interviewee 4 discusses energy management and thereby focuses on forecasting energy production. He finds this to be an important aspect of energy trading since forecasting end-users demand is often not as difficult as forecasting supply. Therefore, he advises the municipality to integrate a forecaster within the energy trading system. Conversely, the majority of interviewees emphasise integrating an aggregator. Accordingly, aggregators have been recognised and defined in the Energy Act. Aggregators have two objectives. First, an aggregator bundles and subsequently sell energy generated by end-users. Second, an aggregator sells flexibility based on demand response. Demand response refers to adjusting an end-users electricity consumption concerning the normal or existing consumption pattern to free up flexibility. The aggregator can then sell the flexibility to an actor that is experience congestion. Ergo, an aggregator can receive balancing responsibilities in the energy market and also assist in congestion management. Therefore, the introduction of an aggregator in the Energy Act enables a new design for energy trading. Whereby an aggregator oversees a community energy supply and demand and determines the production capabilities for the prosumer. Also, the aggregator trade according to the communities preference and rules. Therefore, integrating an aggregator is defined as a boundary condition. Furthermore, interviewee 5 adds that an aggregator can only perform this and his job description, as determined in the Energy Act, if a community has different energy profiles. Therefore, this is also defined as a boundary condition.

"[..] So you would need different combinations, households, offices, factories and maybe also a tram depot. You name it. All of which have a different user profile, and then you can play with supply and demand as an aggregator." (interviewee 5)

However, the Energy Act does not explicitly mention whether aggregators will have access to the data of smart metering devices. According to participant 9, an energy supplier can communicate with Stedin for the smart metering data. This enables energy suppliers to determine the energy production and demand for a residential area. In addition, interviewee 6 empathises that participants should be provided with the same ease and simplicity as they currently have with their energy supplier. Therefore, interviewees 5, 6, 7 and 9 discussed combining an energy supplier with an aggregator within an energy trading system design. They assessed that this could ensure the participant's trust the system. In addition, the resident can access the energy suppliers platform or application for information on their energy consumption. However, interviewee 12 has some objections to adding an energy supplier. According to him, energy suppliers can use energy trading to create a business model that resembles the business model of Uber and Airbnb. This would disrupt the envisioned social and local aspects of trading. Therefore, he discusses community energy cooperatives participating in facilitating P2P energy trading.

"[..] If you really want to shape to that energy transition in a way, in an honest way, in a way that actually adds value. So, not only for the world, but also for the people. Because in the end, the energy transition will need to be carried by the people. Then I think, the cooperative way of organizing is a really good way to go. I think the energy transition isn't just a transition from dirty to clean. But also from centralized to decentralized. And also from only market and privatization to the society!" (interviewee 12)

Furthermore, interviewee 14 questions whether only integrate an aggregator would be sufficient for the energy management of a community. Therefore, he discusses the wholesale energy market, the market's volatile nature, and the volatile nature of the energy prices. Interviewee 6 recognises and agrees with the assessment of interviewee 14. Additionally, interviewee 14 elaborates on the financial risks of energy trading. Also, he stresses the importance of integrating an actor that could cover and manage the financial risks. Therefore, he also discusses introducing an energy supplier or trading company, such as Nuon Energy Trade and Eneco Energy trade. He subsequently determines that additional actors are needed within a future P2P energy market, such as forecasters, trading companies, or energy suppliers with knowledge on trading. Therefore, he concurs with the assessment of interviewee 4 and argues for integrating a forecaster for energy production and also integrating a trading company that covers the financial risks. Accordingly, interviewee 14 discusses the importance of transparency and openness in energy trading systems. He explains that transparency and openness ensure support for P2P energy trading. Accordingly, he asses that the social and local aspects will not be disrupted through the integration of energy suppliers, as long as the system is transparent and open. Therefore, integrating a forecaster and a company for the financial aspects of energy trading are also boundary conditions.

"[..] Let's say, energy trading. So I foresee a future where customers and customers with assets, so end-users with and without DERs, can exchange energy with each other. I can certainly see that happening. But you want something in between, so between the end-users and the wholesale market." (interviewee 14)

7.5.5 The legal aspects

Furthermore, the interviewees were asked about the legal conditions of energy trading. Therefore, the interviewees discussed instruments that enable energy trading. Interviewee 1 argues that all the instrumentation for energy trading is available. According to him, B2B energy trading is allowed by the national government and does not require a supply for trading. Additionally, B2B energy trading has different regulations regarding taxes that prevent double taxation. Conversely, other interviewees determine that no policy instruments support P2P energy trading, since Article 2.2.15 prohibits energy trading for households. Interviewee 10 explained that, due to the past negative experience, it is doubtful that individual energy trading will be allowed in the Netherlands. She also discussed instruments that resembled energy trading and determined that those instruments had all been changed or terminated. According to her, those instruments only allowed for more renewable energy in the total energy mix. It did not allow for sharing energy between people who invested in renewable energy. In addition, she determined that those instruments did not allow for inclusion since it was only accessible to people who had the finance. Which, according to some of the interviewees, was an additional reason for removing those instruments. However, the proposed Energy Act is still a draft version. Therefore, interviewee 10 explained that the Dutch government needs to form a new cabinet because the current cabinet has a demissionary status. Additionally, the Act needs to pass the council of states, the house of Representatives and the Senate. After which, the proposed Energy Act could have had some substantial changes. Terms could be removed, changed or added, and therefore, instruments for energy trading could be affected.

7.6 The boundary conditions for a Community-Market energy trading system

The analysis of the findings in the interviews has generated a design for a local inclusive P2P energy trading system, which will be referred to as the Community-Market energy trading system. This section will provide an overview of the boundary conditions identified from analysing the findings in the interviews. Table 7.1 presents the boundary conditions for a Community-Market energy trading system. The table contains nine boundary conditions. The boundary conditions are allocated into three categories: social, technical, and law and regulation, which refers to a term adopted in the proposed Energy Act. The sequence of the table refers to the governance requirement that first needs to be adapted. Figure 7.4 present a visualisation of the Community-Market energy trading system.

The analysis and study provided in-depth knowledge on energy trading. The interviewees elaborated on the national energy law and provided insight on the boundary conditions for a future energy trading design. Therefore, the interviewees determined that the municipality should focus on determining a goal for P2P energy trading. The interviewees argued that this should be the municipality first concern. Additionally, the interviewees explained that an individual prosumer would obtain any benefits for energy trading. The discussed benefits were related to grid stabilisation and monetary incentives. Therefore, they explained that bundling and aggregating the DERs would benefit the end-user and the national energy system. Hence, creating an energy community is defined as a second boundary condition. Furthermore, the social implications of energy trading and a community were defined to be important. Therefore, the interviewees acknowledged the importance of inclusion, and they recommended including the concept of inclusion in the design of a local P2P energy trading system. Some interviewees determined that inclusion should be actively included because this could enable smart participation, shared prosperity, social cohesion and makes the system transparent. Therefore, conceptualising inclusion is defined as the third boundary condition. This study defines conceptualising inclusion as:

linking the dimensions of inclusion to the values of community

For the energy management system, adequate smart metering devices have to be integrated into the community. This is defined as the fourth boundary condition. Furthermore, both the current and proposed Energy Act prohibit end-users for supply energy. Subsequently, it prohibits energy trading. Therefore, the integration of an aggregator with ACM was advised. An aggregator can trade for the end-users in the energy community. Additionally, the aggregator can ensure benefits for the end-users and the energy system. Also, the aggregator can trade according to the communities preference and rules. Integrating an aggregator is subsequently defined as the fifth boundary condition. However, to do so, an aggregator would need different user profiles, which is defined as the sixth boundary condition. Furthermore, the interviewees explained the importance of a forecaster and an actor that could take care of the financial aspects of trading. Therefore, integrating these actors, respectively, is defined as the seventh and eighth boundary conditions. Lastly, the interviewees did not elaborate on the technologies for the energy trading system. The interviewees determined that the municipality should first focus on determining a goal for energy trading and then 'shop' the functionalities for the energy trading system. Table 7.1 presents the boundary conditions of the energy trading system.

Number	**Category**	**Boundary condition**
1	Social	Determine the goal and focus of energy trading
2	Social, Law and regulation	Create an energy community
3	Social	Conceptualizing inclusion and include it in the design
4	Technical, Law and regulation	Integrate adequate smart metering devices
5	Technical, Law and regulation	Integrate an aggregator with an ACM license
6	Technical	Create an energy community with different energy profiles
7	Technical	Integrate a forecaster
8	Technical	Integrate an actor for the financial risks
9	Technical	"Shop" the technologies needed for well-defined (goal included) energy trading system

Table 7.1: Boundary conditions for the proposed design of P2P energy trading market

The qualitative research determined a design for energy trading. The design is community-based, and interviewee 5 defines this as Peer-to-Community-to-Market-to-Community-Peer. Where peers indirectly supply energy to each other within the energy community. Practically, a peer sells or buys energy from the community. The aggregator ensures that the energy community, the participants within the community, are foreseen of energy. After which, the aggregator trades the community's surplus or deficient energy with the market. Therefore, the energy community creates an energy portfolio, which encompasses the energy surplus or deficient of the community. The portfolio can then be used for energy trading on the market. Interviewees 3, 4, 5, 6, 7 and 10 all recognised that Peer-to-Community-to-Market-to-Community-Peer, referred to as Community-Market energy trading, has the most potential and is the most promising energy trading design for Prinsenland and Het Lage Land. Additionally, this design was discussed with interviewee 14, reaffirming the importance of integrating a forecaster and an actor for the financial aspect. Also, the design was discussed with the supervisor of this thesis in the municipality of Rotterdam. Thus, the design has been validated.

The literature study, section 2.6 defined three energy trading markets, the coordinated market, decentralised market and community market. The interviewees determined that bundling DERs would provide the most benefits for both the prosumer and the national energy system. Accordingly, the integration of a decentralised and coordinated energy trading market was rejected. Even though the Community-Market energy trading is community-based, this design differs from the community energy trading market determined in section 2.6. The literature study determined that a community energy trading market includes a community manager. The function of the community manager is to influence the prosumers to participate in the trading market indirectly. This is done through informing the prosumers of certain pricing signals (Tushar et al., 2020). Within the Community-Market energy trading system, the aggregator assumes this function. However, an aggregator's function also includes managing and controlling the amount of energy that can be traded in the community. According to Tushar et al. (2020), a centralised energy trading market includes a centralised coordinator. A centralised coordinator has direct control over the number of energy prosumers who can trade. Therefore, the function of an aggregator is more similar to the function of a centralised coordinator. Like the centralised coordinator, the aggregator can connect with the main grid and the wholesale market. The revenue generated from trading is then distributed eventually among the prosumers. The distinguishing elements of the Community-Market energy trading system are a forecaster and an actor for the financial risks on the wholesale market. More importantly, a Community-Market Energy trading market incorporates the concept of inclusion to provide benefits for every participant. Figure 7.4 present a visualisation of the Community-Market energy trading system.

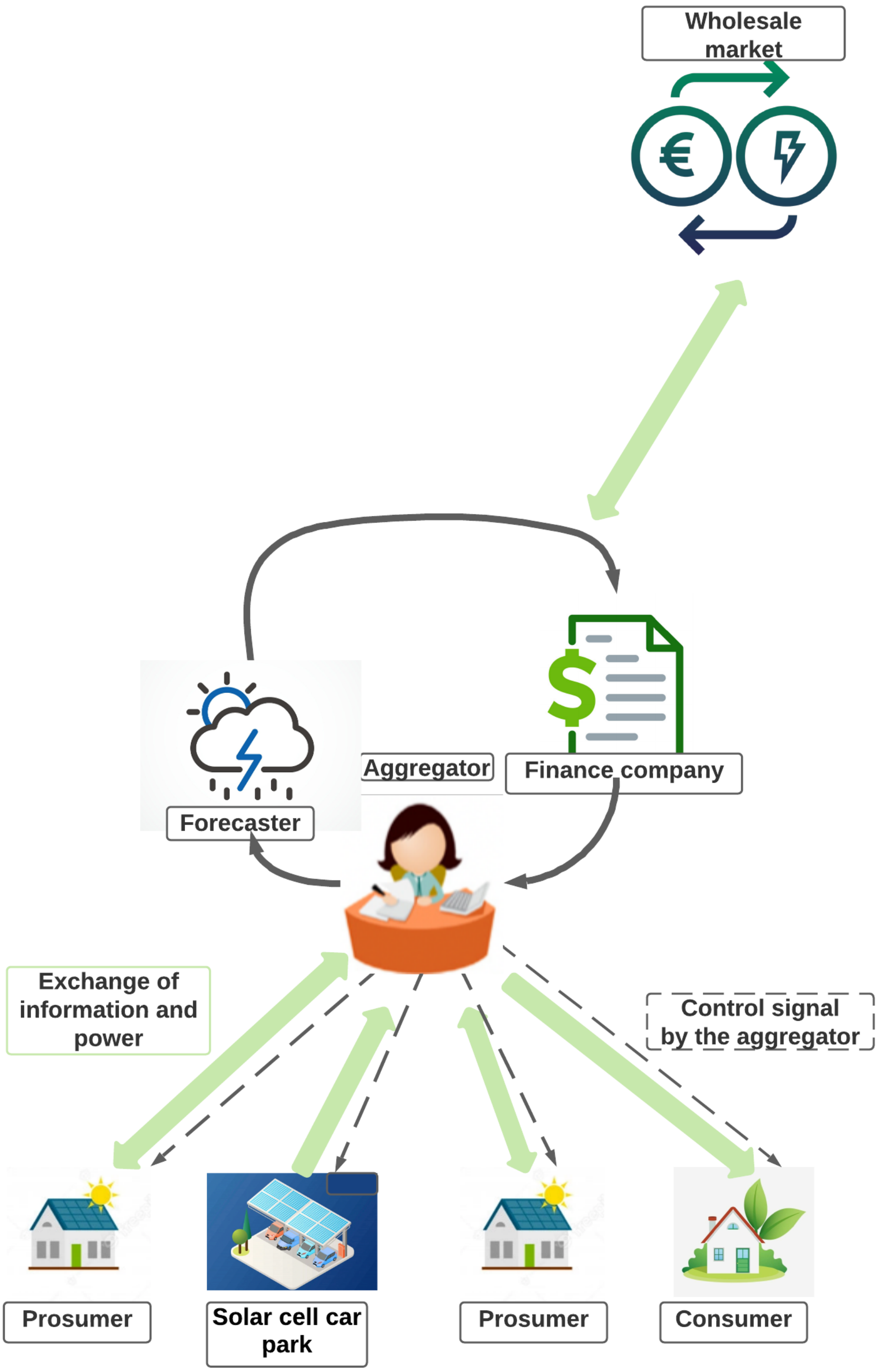

Figure 7.4: Visualisation of the Community-Market energy trading market, own image derived from interview data

7.7 Conclusion

The empirical research generated an abundance of knowledge abundance on the national energy system, the proposed Energy Act and the design of an inclusive local P2P energy trading system. Therefore, this chapter mapped the stakeholder landscape and determined the inter dynamics of the stakeholders in the Rotterdam energy system. In contrast, the previous chapter identified the stakeholders the literature deemed important for P2P energy trading. This chapter focus on the stakeholders relevant to the Rotterdam energy system. Therefore, this study determined that several stakeholders identified from the literature were not relevant for the case study of Rotterdam, such as energy producers, ESCOs. However, this study identified two additional stakeholders that the academia did not define, a forecaster and a trading company. Accordingly, the stakeholders crucial in the case of Rotterdam are active in different elements of the system interacting with different technologies and resources that are also interrelated, which reaffirms the complexity of facilitating a local P2P energy trading system. The opportunities and design of a local inclusive P2P energy trading system rely on the national market and regulatory bodies. Therefore, the interviewees elaborated on the proposed Energy Act. Accordingly, they argued that the proposed Energy Act, which aims to put the end-users at the centre of the energy system, could have adopted more progressive EU directives to satisfy this objective. The interviewees also discuses the apprehensiveness of the national government to actively include progressive directives and subsequently regulate them. Therefore, this study determines that while the proposed Energy Act has great objectives, the path to achieving these objectives is still vague. Since it does not include comprehensive directives that better serve the objective. Nonetheless, this study was able to identify and determine nine boundary conditions and created a design for an inclusive local P2P energy trading system, referred to as Community-Market energy trading. Accordingly, the Community-Market energy trading system is based on the community P2P energy trading form market identified in section 2.6. The boundary conditions are presented in table 7.1 and categorised in three aspects, technical, legal and social aspects. This study determines that the social aspects of the Community-Market energy trading system are crucial for the integration. Therefore, this study determines that the municipality should conceptualise the concept of inclusion and include it in the design. Accordingly, this is defined as a boundary condition. Therefore, this study determines that the municipality should identify the needs and challenges of their citizens related to P2P energy trading, or any other SEs, and create a design that actively aims to combat the challenges and needs identified. Additionally, this study determines that generating feedback from the residents and community can enable conceptualising inclusion. Since the feedback could then be used to develop inclusive local P2P energy trading or any SEs, this could also result in adjustments in activities in terms of inclusion. Therefore, the municipality should first assess their current activities in terms of inclusion. Lastly, linking opportunities was discussed by the interviewees. The interviewees elaborated on linking opportunities and explained that linking opportunities and conceptualising inclusion could increase residents' participation and contribute to inclusive shared prosperity.

Chapter 8: Results: theoretical reflection

Chapter 3 elaborated on the theoretical framework of Borrás and Edler (2014) to generate a better understanding of governance of change in ST&I systems. The framework was subsequently extended and modified to analyse and determine how change can be induced in the national energy system to facilitate a Community-Market energy trading system. This chapter will apply the extended framework to empirical research to examine the governance requirements for the municipality of Rotterdam. Therefore, this chapter will relate to the sub-question:

Sub-question 4: What are the governance requirements of the city of Rotterdam that will enable a P2P energy trading market in terms of agents and opportunity structures, instrumentation and legitimacy?

First, section 8.1, 8.2, 8.3 will, respectively, elaborate and analyse the empirical knowledge generated on the three pillars of governance of change. Section 8.4 will elaborate on the concept of inclusion in energy trading.

Lastly, section 8.5 will reflect on the theoretical framework of the analysis and empirical results. Furthermore, this section will discuss the governance requirements defined for the municipality of Rotterdam.

8.1 The first pillar: The relation between opportunity structures and capable agents

The first pillar of the framework focuses on agents capable of triggering, directing and inhibiting change in the system by utilising opportunities structures. Practically, this pillar involves "who" and "what" can induce change to facilitate a Community-Market energy trading system. Therefore, this pillar analyses, based on the interviews, whether the stakeholders identified in section 7.2 can induce change in the energy market to create Community-Market energy trading, as presented in section 7.6, in Prinsenland and Het Lage Land.

According to interviewees 5 and 10, the EU regulation related to energy, which aims to reverse climate change, has created opportunity structures in the Dutch energy system. According to interviewees 4, 6 and 7, these opportunity structures have been acknowledged by the DSOs.

"[..]The shareholders of Liander said, many years ago, the energy transition is coming! The scenarios and the rate of these scenarios are still unknown.[...] Therefore, they assigned us to create solutions that can facilitate the different scenarios. After which, the DSO can determine the legal implications of the solutions. Furthermore, we can determine whether the market will facilitate this or whether it falls under the DSO responsibility. And if we are unable to find any solutions, we can at least start the conversation! (interviewee 4)

Interviewee 2 explained that DSOs had access to the Experiments Electricity Act, enabling DSOs to deviate from the traditional Electricity Act. Therefore, interviewees 6 and 9 explained that the DSOs utilised different advancements in ICT, such as platformization, which resulted in new openings and opportunities for the energy market. An example of this is Liander, a DSO, creating a platform for B2B energy trading to prevent grid congestion. The qualitative research indicated the importance of DSOs in the system. Since DSOs foresaw an opportunity in the national energy system and utilised the opportunity by designing a new business model. This was confirmed in the qualitative research by interviewee 5. The interviewee determined that DSOs are primary agents of change. Additionally, interviewees 5 and 6 explained that congestion management could force the DSOs into participating in energy trading projects. Furthermore, most interviewees stated that DSO's have resources, monetary resources, expertise, time and influence to create and facilitate the energy trading design. Interviewee 9 added that DSOs are in charge of the data provided by smart metering devices. Therefore, the DSOs have interpretative abilities in the form of communicative and coordinating energy devices that promote change in the energy systems and enable energy trading. Currently, Stedin has developed a pilot for an energy trading system similar to the Community-Market energy trading design. The pilot was created with the use of the Experiment Electricity Act. However, interviewees 2, 4, 5, 6 and 9 stated that the Experiments Act would be terminated. According to interviewee 9, the Dutch government did this to force DSOs to focus on facilitating an energy market. Therefore, DSOs will be unable to create a new pilot for energy trading. Accordingly, interviewees 6 and 7 emphasise that DSOs will primarily concern themselves with facilitating a reliable energy market as a neutral party. Subsequently, they argued that DSOs would upgrade the grid rather than induce change and possibly force end-users into a system. This reveals a passive approach to inducing change. However, DSOs operate the grid and have resources that are instrumental for the development, and therefore DSOs are determined the be important for the development of energy trading.

Subsequently, this is related to the apprehensiveness of the national government. The proposed Energy Act enables engaging citizens in the energy system and energy transition. However, it does put them at the centre of the energy system since it does not allow for progressive Smart Energy solutions. Accordingly, the national government has terminated the Experiment Electricity Act. Thus, prohibiting DSOs and municipalities to induce change for the progressive project.

Furthermore, the interviewees discussed energy suppliers and also defined them as agents capable of change. Interviewee 10 assessed that the national government is prone to promote energy trading through an energy supplier than through individual peers. Whereas other interviewees assessed that energy suppliers could induce energy trading by supporting the Community-Market design. The interviewees assessed that this would also enable additional trust in the system. However, interviewee 14 argued that energy suppliers should have a more substantial role within the Community-Market energy trading system. Therefore, he elaborated on the national energy system and the volatile nature of the energy prices. Accordingly, he determined that an additional actor would be needed to manage the financial risks and explained that energy suppliers could assume this role. The interviewee also explained that some energy suppliers have already introduced energy trading in their business model by providing B2B energy trading. Therefore, energy suppliers can also be identified as capable agents within the ST&I system. Both interviewees 9 and 14 determined that energy suppliers have the capability to do so since energy suppliers have the resources, knowledge and expertise to induce change in an energy system. Interviewee 14 explained that energy suppliers have utilised an opportunity structure in the energy system and thereby created a new business model. Interviewee 9 conversely determined that DSOs first need to provide them with smart metering data. Accordingly, he assessed that this would enable energy suppliers to effectively induce change in the energy market. Therefore, he implies that the ability of energy suppliers to induce energy trading relies on the DSOs, while interviewee 14 assess that energy suppliers could do this without the DSOs. Interviewee 12 empathises that energy suppliers will most likely create energy trading based on a sharing economy business model. Subsequently, he explained that these energy trading designs will not focus on the local aspect of energy trading and will also have negative implications for the concept of inclusion. Also, he assesses that energy suppliers could form an enormous force against energy trading. However, interviewee 14 disagrees with this notion. He explains that the energy transition is of the utmost importance, and energy suppliers are eager to help. Additionally, he explains that energy suppliers are a community of energy experts with enormous resources to induce change. Therefore, energy suppliers are capable agents to induce energy trading for Prinsenland and Het Lage Land.

In addition, interviewee 12 assessed whether the local energy cooperative could be capable agents to induce energy trading in the Dutch energy system. The interviewee determined that local energy cooperatives should be involved in energy trading. Local energy cooperatives are best positioned to safeguard the public interest. However, interviewee 11 explained that currently, Prinsenland and Het Lage Land's energy cooperative are primarily focused on generating energy. Therefore, Alex Energie is focused on integrating DERs, assisting residents with energy consumption and helping them isolate houses. To do so, Alex Energie plans on visiting residents at their houses to enable participation and assist where needed. Therefore, Alex Energie uses their resources, time and expertise to induce change related to the energy transition. These resources will also be essential to induce change and facilitate energy trading. Since, local energy cooperatives aim to safeguard the public interest and use their resource for this, they will be critical agents for the development of energy trading.

"[..] The ownership should be left to the residents and also organise that way. Which will result into bringing the added value, the usefulness/effectiveness and the returns directly to the residents. I think, the big risk is, it will become a shareholder game. And then, as far as I'm concerned, you will create the totally derailed Uber examples. Where only the shareholder really benefits and no longer the users. So I'm not saying that the market can't play a role in this, but safeguarding the public interest is super important. And when you leave it to the market, chances of that happening then are not that great. Now and then I think, maybe this is an assignment for us as the cooperative sector, to play a role in that." (interviewee 12)

Additionally, the interviewees determined that the municipality of Rotterdam would be an important capable agent to induce energy trading. Borrás and Edler (2014) define social institutions as regulations, normative rules and worldviews and explains that social institutions can shape the production and use of technologies. Accordingly, opportunity structures result from the embeddedness of a particular new technology/knowledge into a set of specific social institutions. The majority of the interviewees determined that municipally could enable this by focusing on social institutes. Therefore, interviewee 6 discusses regulations, such as building standards for residential areas.

"[..] What is the role of the municipality in this and in the energy transition at all? In The Netherlands, we have privatised everything in regards to energy. So municipalities, so actually governments and public players are not allowed to generate energy! They can't because that would be competition policy distortion." (interviewee 10)

"[..] The municipality has powerful resources to enforce something on a large scale. The municipality has a long haul!" (interviewee 6)

The interviewees also determined that the municipality should primarily concerned themselves with defining a goal and then identifying the capable agents who can achieve the goal for them. Borrás and Edler (2014) emphasised that opportunity might be normatively/ethically problematic and socially contested. For this reason, interviewee 10 cautions municipalities within these socio-technical systems, such as energy systems. She emphasises that municipalities should always prioritise their residents. Additionally, interviewees 2, 5, 10 and 12 concur and assess inducing a change in the energy system can also include a social change. Accordingly, inducing and creating a social change that occurs at the expense of their residents has immense negative implications for all involved parties. This is also related to legitimacy, the third pillar. Furthermore, interviewee 6 discusses the long haul of a municipality. With this, he refers to the resources of the municipality. The vast majority of interviewees concluded that the municipality has the resources and interpretative abilities to enable energy trading. The resources of the municipality include monetary incentives, time, expertise, influence and credibility. Additionally, interviewee 13 explains that municipalities are assigned, by the national government, to direction and manage the energy transition. Therefore, the municipality of Rotterdam is in charge of the integration of any Smart Energy solutions. Also, the municipality has created subsidiaries for Smart Energy solutions and is currently inducing change through the EU funded project RUGGEDISED. Moreover, this demonstrates the ability of the national government and EU to induce change, which in the Prinsenland and Het Lage land case is done through the municipality. However, most of the interviewees questioned whether the municipality should devote all their resources to energy trading. Some interviewees advise focusing on certain parts of energy trading, such as integrating DERs for all citizens. Thus, making DERs inclusive. They also discuss focusing on integrating smart metering devices and batteries.

"So let's go back for a while, because P2P trading is quite an ambition. I think it is quite an ambition. I would like to see us, together with PV Netherlands, I would like to see us enable it. For many reasons. However, at the same time it is also a big step! From 0 to 100 in two seconds! How do we ensure that we take small steps? So you could start with integrating solar panels on communal roofs or flats, for example. Then use the solar panels to balance the residents energy bill. That's 1! And 2 would be, provide the residents with more insight. That already is a big task[..]" (interviewee 6)

Lastly, the Dutch government has been identified as an important capable agent to induce change in the energy system. However, every interviewee determined that the Dutch government is solely focused on creating instruments, specifically policy-led instruments. This will be elaborated on in the next section.

8.2 The second pillar: The instrumentation through which intentional definitions of collective solutions are put into practice

The second pillar of the framework is concerned with the specific ways by which agents induce change in the socio-technical system and are able to design and give direction to that change, which is also referred to as instruments used in the governance of change. Borrás and Edler (2014) explains that traditional instruments include state-led policy and social instruments. However, they suggest going beyond studying the effectiveness of policy instruments or social instruments and suggest governance instruments that focuses on a broad range of mechanisms for social action.

The qualitative research revealed that most interviewees focused on policy instrumentation as governance instruments. Subsequently, the interviewees discussed the state-led policy instruments within the current energy system. The interviewees explained that the energy system is experiencing much change due to the EU directives. The EU directives regarding energy initiated a new Energy Act.

"[..] The SDE+ initiative gave consumers a tax advantage. However, this initiative only enhanced the amount of solar energy in the total energy mix. It did not enable the owners of the solar panels to trade energy with each other." (interviewee 10)

The proposed Energy Act is an important policy instrument that aims to induce change in the national energy system. According to interviewee 10, the previous policy instruments focused on achieving a specific goal, which was to enhance the integration of DERs. She explained that this enables consumers to integrate DERs on their roofs and around their houses. In addition, it enabled groups of prosumers to create and or invest in solar parks and wind farms. In return, the prosumers would get a tax benefit for their investments in DERs. However, the government was not focused on the ownership of DERs. Additionally, interviewees 10 and 12 both explained that the policy instruments took a large portion of tax revenue. Hence these instruments will be terminated. In contrast, the proposed Energy Act aims to achieve a climate-neutral economy and society, enhance the integration of DERs and engaging end-users in the energy system. However, the interviews questioned whether the proposed Energy Act could achieve this goal. However, the proposed Energy Act does enable the Community-Market energy trading market, but the interviews assessed that the national government is hesitant in introducing progressive directives and thus hesitant in creating policy instruments that could induce change. While every agent in the energy system will use the proposed Energy Act, it does not create opportunities to genuinely influence and change the system. Therefore, the proposed Energy Act does engage citizens in the energy transition, but it does not genuinely induce Smart Energy solutions. Therefore, the lacks certain progressive directives that were included in the EU directives. Furthermore, the national government has terminated the Experiment Electricity Act. This prohibits DSOs and municipalities to induce progressive projects and thus induce change in the national energy system. According to Borrás and Edler (2014) the second pillar is related to who is designing, shaping and using the instruments. The interviewees determined that the Dutch government is responsible for designing the policy instruments. Every agent uses these instruments in the energy system. However, the proposed Energy Act does not genuinely influence change in the system.

The interviewees determined that the municipality of Rotterdam could also influence and design some of those instruments. According to interviewees 1, 10 and 12, the municipality can influence the selection of the policy instruments since the municipality can lobby for certain changes in the Act. Accordingly, they referred to the lobbying power of the municipality as societal-led policies. However, interviewee 2 explained that these lobbying power are limited. However limited these powers may be, lobbying can influence the selection and the shape of the policy instruments designed by the national government for the energy market. Furthermore, the qualitative research revealed that the energy transition is the main focus in the national energy market. Therefore, the interviewees wonder how the transition will occur and what will be needed for it to occur correctly. The majority of the interviewees assessed that human behaviour would determine the course of the energy transition. Whereby, some interviewees asses that state-led policy instruments will have the most significant influence. More specifically, state-led policies with monetary incentives. In the case of Rotterdam, the interviewees primarily focused on designing subsidiaries as an instrument. Additionally, interviewee 6 discussed instruments that enable "future proof" houses. Thus, creating an instrument for sharpening the requirements in the building decree and setting several conditions on the construction of new buildings, such as integrating smart metering devices, heat pumps and communications standards in buildings. These instruments could also influence behaviour. Therefore, interviewee 12 also discussed instruments the municipality could create and focused on the collectives and neighbourhoods. For facilitating energy trading, interviewee 10 emphasises that the municipality should assess the technologies and assess the influence of the technology on their residents. Since opportunities such as energy trading and the energy transition might be normatively problematic and socially contested (Borrás & Edler, 2014). Therefore, the interviewee determines that the municipality should enable mobilising input and feedback on energy trading technologies in early design stages and then use the feedback for re-designing the technologies. However, the interviewees all agree that the municipality should be a natural actor in the design of energy trading. This might refer to the municipality not actively creating the instruments discussed. However, interviewee 13 explains that the Dutch government placed the municipalities in charge of their district's energy transition, including the municipality of Rotterdam. This enables the municipality of Rotterdam to regulate the course of the energy transition and thereby the Smart Energy solutions developed in Rotterdam. In response to this, the municipality created the Rotterdam Climate Agreement and Smart Energy system subsidy. Also, Rotterdam is a part of a Smart City project funded by the European Union called RUGGEDISED. However, the municipality had defined its self as a facilitator within the energy trading market. Therefore, other actors such as energy coaches, energy collective arise as the societal actors for energy trading because they can argue for the public value of the change. Therefore, policy-led instruments designed by the national government, which is influence by the EU, combined with the social-led instruments and the lobbying power of the municipality, could change the policy-led instrument, thus could induce change. Additionally, energy coaches and community energy corporations focusing on preserving public value can prevent normatively problematic designs for the municipality.

> "[..] And the municipality could for example, collaborate with their residents in the neighbourhoods, so the existing neighbourhoods, for the benefit of new neighbourhood development, determine what the smart meters or the technologies or the systems should have for those people? And when does it serve these people? That seems to me, an appropriate role for a municipality." (interviewee 10)

Interviewee 9 elaborated on the instruments of DSOs. He explained that DSOs, including Stedin, are in charge of the smart metering data. However, in his observation, DSOs do not share the smart metering data. Therefore, he concludes that DSOs, including Stedin, prohibiting the development of P2P energy trading. Conversely, interviewees 6 and 7 elaborated on a project Stedin has initiated through the Experiment Electricity Act. The project also focuses on community-based energy trading. However, the Experiment Electricity Act has been terminated, thus prohibiting DSOs for inducing change. Accordingly, the interviewees emphasised that Stedin's main objective is to facilitate the energy market. Therefore, it can be concluded that the national government's decision to terminate the Experiment Electricity Act prevented Stedin from inducing change in the energy system and developing future energy trading systems. However, they explained that Stedin would assist by reinforcing the grids in Rotterdam.

The interviewees defined Stedin and the cooperative sector, Energie van Rotterdam en Alex Energie, as capable agents that can induce change. The interviewees also determined that Energie van Rotterdam and Alex Energie influence the ways by which agents induce change in ST&I systems. Interviewees 11 and 12 explained that the cooperative sector's main concern is to assist residents with their energy demands. Therefore, the cooperative sector is using their human resources and knowledge, their resource, to influence the behaviours of residents. Also, they assist the residents by creating energy initiatives in their neighbourhoods, such as collective sunroofs. Accordingly, interviewee 12 elaborated on the additional benefit of including the cooperative sector in the development of energy trading. He assessed that they could ensure that public interest is safeguarded in the development of energy trading. Whereas interviewee 11 indicated they would focus on assisting the residents with their energy. Therefore, Energie van Rotterdam envisions a more significant role in the development of energy trading. Conversely, Alex Energie focuses on supporting residents and producing energy. Nonetheless, both parties focus on creating societal-led policies, mainly instruments that influence behaviour. The instruments of the cooperative sector aim to empower residents in the energy transition and enhance their decision-making capabilities.

8.3 The third pillar: The sources and hindrances of legitimacy in the process of governing change

The concept of legitimacy refers to the 'why' ST&I systems are or are not accepted and why the process of governing change is or is not accepted. The interviews elaborated on input legitimacy to determine whether facilitating Community-Market energy trading and its governance will be legitimate. Since output legitimacy can only be determined after a change has occurred in ST&I systems, the interviewees did not discuss output legitimacy (Borrás & Edler, 2014). According to (Borrás & Edler, 2014), systems are legitimate if the process by which the decisions were made were also supported.

Practically, input legitimacy refers to the popular support that a particular social community grants a specific set of political institutions to conduct collective problem-solving for that community (Borrás & Edler, 2014). Interviewee 10 explained that municipalities, including the municipality of Rotterdam, often have difficulties generating support from their residents. According to the respondent, residents often distrust the municipality, which stems from a particular time in history and has valid reasoning. The interviewee did not specify the history of this distrust nor the reasoning for this distrust. Interviewee 1 explained that communities in Prinsenland and Het Lage Land, include communities of vulnerable consumers. Accordingly, he explains that those communities do not always welcome the municipality's proposals for the neighbourhoods and residents. Therefore, some interviewees determined that generating input legitimacy for energy trading might be a difficult task. Interviewee 10 acknowledges this and assess that the municipality should involve the community to generate input legitimacy. Conversely, interviewee 11 explains that the municipality is,currently, proposing designs for the Next Generation Prinsenland and Het Lage Land. However, the municipality does not really allow citizens to participate in the design and explains that this could lead to residents distrusting the output.

"[..] In South Rotterdam, they are investing in the heat network. I think, the connection fees are 1500 euros, but with a subsidy of something like 13,000 per home. If this were to be the case in every district, this will be, of course, perhaps, very tough. But I think it has landed with people who are a bit interested in it. They know that something is coming our way and that something will cost a lot of money. However, the question is, are we all going... are we going to pay for companies who will only benefit form it? Or are we going to benefit from it? Is it really sustainable for us? So say, trust is a very important aspect, I think!" (interviewee 11)

The statement of interviewee 11 refers to the fact that input and output dimensions of legitimacy cannot be disconnected from each other in the process of governing change in a system. Output legitimacy refers to the support given to a system due to its real capacity to solve collective problems. Accordingly, output legitimacy is characterised through mechanisms of participation and representation. The qualitative research revealed that many interviewees did not expect the resident of Prinsenland and Het Lage Land to participate in energy trading. Therefore, interviewees explained that energy was a commodity, a no-interest product and difficult to understand. While all of these statements might be true, the qualitative research revealed that currently, the municipality of Rotterdam might not have the basis for input legitimacy. This could potentially de-legitimise any changes in the system, including the development of energy trading.

Therefore, the interviewees discussed different strategies to enable input legitimacy. Interviewees 2, 4 and 5 discuss being transparent and explaining, in simple language, what the gains would be and thus focusing on creating trust. This also refers to raising awareness about P2P energy trading among Prinsenland and Het Lage Land citizens, thereby empowering them to participate in the decision-making processes. Interviewees 10 and 11 determine that the municipality should actively engage their residents by going door to door. This also enables input and feedback to design the technologies, systems and proposals from all interested parties. Interviewees 4, 5, 6, 9, 10, 11 and 12 discuss engaging capable agents, such as energy suppliers and the cooperative sector. Interviewees 1, 3, 5, 6 and 7 discuss focusing on the local and community aspect of the design. They assess that the residents can and would motivate each other to participate. Interviewees 10, 11 and 12 discuss creating community incentives such as community gardens. Conversely, some interviewees argue that monetary incentives might legitimise energy trading.

8.4 Inclusion in energy trading

In section 2.2 and 2.7 elaborated on the concept of inclusion, its five dimensions and inclusive P2P energy trading. Inclusion aims to provide citizens with solutions that are really beneficial and applicable to their actual lives, whereby every citizen can participate in the solution and subsequently enjoy the benefits. Therefore, inclusion is related to the support and participation of citizens. Accordingly, chapter 3 integrated inclusion in the third pillar of governance of change. However, inclusion is also defined as a boundary condition for Community-Market energy trading. This section will elaborate specifically on inclusion.

The qualitative research revealed that approximately half of the interviewees were familiar with the term inclusion. This is due to the energy transition and the envisioned effects of this transition. The effects of the energy transition are a high priority in the energy sector. One of the expected effects is energy poverty. Interviewee 10 explains that energy poverty occurs when households spend approximately 10% of their income on their energy consumption. She argued that the energy transition could have enormous implications for these people. Additionally, she assesses that the energy transition will be costly, and energy poverty could affect a large group of citizens. Therefore, the interviewee discussed the majority of the interviews related inclusion to combating energy poverty.

Other interviewees related and refer to inclusion as participation within the energy sector. Only three interviewees described inclusion as Liang et al. (2021) defined it. Therefore, the qualitative research revealed that the interpretation of the concept does not quite match how it is defined. Additionally, the interviewees, except interviewee 10, were not familiar with the five dimensions of inclusion. However, the interviewees all recognised the problems associated with inclusion. Therefore, the interviewees identify problems regarding housing, accessibility, public infrastructure, social equity, (social) participation, quality of life, environmental awareness and behaviour, migration and demographic issues, access to information, shared prosperity, and resident-municipality relation. These problems are related to all of the five dimensions of inclusion.

The interviewees acknowledged that the municipality efforts to facilitate energy trading are related to human-induced climate problems and aim to prevent humans from carrying on in their current mode of production and consumption. Since they all determined that this would compromise the needs and interests of future generations, this refers to environmental inclusion. Problems related to spatial inclusion involves equal access to public infrastructure. Public infrastructure includes power and energy infrastructure. Therefore, it also includes DERs. The interviewees discussed that certain residents have access to information that enables them to invest in DERs. Which also allows them to receive a tax benefit. In contrast, the other residents do not have this privilege. Additionally, the interviewees determined that those residents pay, through their taxes, for the benefits of the residents who can invest. The majority of interviewees attributed this problem to social inclusion, namely the accessibility of DERs. Since social inclusion relates to increasing equal development opportunities and access for everyone and attending to social members' needs. The interviewees, to some extent, acknowledge that residents do not always have equal access to social resources, such as employment and information. However, some interviewees determine that this is because energy is regarded to be a no-interest product. Residents do not want to include themselves and participate in the development of new energy systems. Therefore, these residents are unable to share in rising prosperity, which relates to economic inclusion. Subsequently, interviewees 3, 6, 7, 10, 11 and 14 advised the municipality to focus on creating programs that enable the integration of DERs for all their residents. Subsequently, the interviewees focus on creating inclusive DERs instruments. Also, interviewee 10 discusses integrating smart devices for their residents. Since, this would give them insight into their energy demand, which might empower them to participate in decision-making processes related to energy, such as P2P energy trading.

Lastly, the empirical research revealed problems related to the relationship between the municipality and residents. Whereby interviewee 1 discusses the migration background of the resident, interviewee 10 discusses a distrust due to events in history, and interviewee 11 discusses the municipality not allowing citizens to participate in the developments of the district.

The results of the case study described a Community-Market energy trading system. The interviewees all discussed the importance of inclusion within this design. Moreover, interviewee 12 emphasised that the difference between residents within a community will be more noticeable and have significant implications on the concept of inclusion. Accordingly, creating an energy community relies on the participation of all the residents in the district. Therefore, the concept of inclusion was added as a boundary condition. This case study revealed that with respect to inclusion, certain dimensions are crucial: social inclusion, economic inclusion and political inclusion. Specifically, access to information, accessibility and affordability of DERs, environmental awareness and behaviour, social participation, shared prosperity, and resident-municipality relation.

8.5 Reflecting on the framework

This chapter applied the theoretical framework of Borrás and Edler (2014) to the results of the case study Prinsenland and Het Lage Land. Therefore, the theoretical framework of Borrás and Edler (2014) explored and examined the regularities associated with the governance of change. The framework enabled the identification of capable agents that could induce change to facilitate Community-Market energy trading. Also, the framework identified the policy instruments and social instruments for Community-Market energy trading. Additionally, the framework focused on the concept of legitimacy for Community-Market energy trading. The interviews result revealed that the capable agents identified did not have any intentions to prevent change from happening, including the national government. However, it did reveal that the most capable agents were reluctant to induce change to facilitate Community-Market energy trading. This is related to the national government reluctantness to integrate progressive EU directives and their choice to terminate the Experiment Electricity Act. Even though the state policy instruments allow Community-Market energy trading, the interviewees questioned the readiness of society and the national government to contribute to the process. Subsequently, the interviews discussed social instruments and determined that instruments should be created that focus on environmental awareness and behaviour to influence behaviour and enable rule development and implementation (Borrás & Edler, 2014). Since this could increase the readiness of the citizens, which is also related to legitimacy. Accordingly, the interviewees discussed distrust and participation. Therefore, the case study revealed that the municipality might not have the basis for input legitimacy. As discussed in section 3.6, facilitating Community-Market energy trading, will require the interactions of the various capable agents and governance instruments. Therefore, the key questions of Borrás and Edler (2014) were modified and extend to also generate knowledge on inclusion and the role of a facilitator. The case study revealed the apprehensiveness of local energy cooperatives to corporate and include big energy suppliers in the development of Community-Market energy trading. However, both capable agents will be needed to induce change. Also, the case study revealed that the policy instruments, the proposed Energy Act, could better interact with social instruments. Therefore, the interviewees discussed focusing on social instruments, such as housing requirements and subsidies, to influence behaviour and enable rule development and implementation. For the concept of inclusion, the case study determined that social inclusion, economic inclusion and political inclusion are crucial objectives that the municipality should concern itself with regarding the Community-Market Energy system. Therefore, interviewees discussed determining the needs and requirements of the residents, which could be linked to the development and design of Community-Energy trading. Furthermore, they discussed projects for the citizens, such as playgrounds. Reflecting the theoretical framework to the case study results reveals that it enabled examining and determining the capable agents and instruments that could induce change. Also, it generated knowledge on legitimacy and inclusion, which could be used to generate support and enable a citizen-focused approach for the development of a Community-Energy trading system.

8.6 Conclusion

This chapter applied the theoretical framework to the results of the case study Prinsenland and Het Lage Land. Therefore, this chapter defined the governance requirements, the regularities associated with the governance of change to facilitate Community-Market energy trading. In terms of capable agents and opportunity structure, this study identified DSOs, energy suppliers and local energy cooperatives. DSOs and energy suppliers have utilised different opportunity structures for energy trading. Accordingly, Liander and Eneco have created B2B energy trading systems, and Stedin has facilitated an energy trading system. This makes them essential for inducing change and facilitating a Community-Market energy trading system. Additionally, community energy corporations and cooperatives were identified as capable agents because they can ensure public value and concern themselves with the needs of residents. This study determines that the proposed Energy Act is a crucial state-led policy instrument in terms of instruments. Accordingly, the Act enables Community-Market energy trading. However, this study finds that social instruments will be needed to enhance the readiness of the residents for Community-Market energy trading. This is related to the fact that the use of technologies takes place in a social context defined by social institutions, such as regulation. The interviewees discuss housing requirements and subsidies to influence behaviour and enable rule development and implementation to induce Community-Market energy trading. Therefore, this study determines that social instruments could be instrumental for energy trading. Additionally, the framework focused on understanding the concept of legitimacy for Community-Market energy trading. Accordingly, the main finding of legitimacy was related to the municipality-resident relationship, which was revealed to be less than optimal. This has implications for input legitimacy since residents could disapprove of the Community-Energy trading. Furthermore, inclusion was discussed, which affirmed the importance of all five dimensions—specifically, social inclusion, economic inclusion and political inclusion.

Chapter 9: Results: Recommendations generated from case study

This chapter will present the empirical data gathered from the interviewees on the future directions for the municipality of Rotterdam. Hence, this chapter will present the recommendations provided by interviewees. Therefore, this chapter will relate to the sub-question:

Sub-question 5: What are the future directions for Rotterdam to enable an inclusive P2P energy trading market?

9.1 Recommendations

The interviewees explained and reaffirmed the complexity P2P energy trading. Accordingly, the interviewees had opposing views regarding P2P energy trading. Therefore, their recommendations are organised into three categories: recommendations for energy trading, recommendations for other Smart Energy solutions, and recommendations for additional research.

9.1.1 Recommendations for energy trading

The interviewees who elaborated on energy trading recommendations discussed initiating pilots, energy trading platforms, and B2B energy trading.

Interviewee 12 discusses creating energy trading platforms and explained that the municipality should focus on the role of facilitator. Accordingly, he recommended that the municipality identified stakeholders, capable agents and argue for the involvement of the cooperative sector. He advised the municipality to cooperate with the DSOs and energy companies and cautions the municipality for large energy suppliers. Since, in his opinion, this could enable sharing economy, such as Uber. Therefore, he recommends that the municipality create a pilot for energy trading and create incentives for this. These incentives include monetary and social instruments, such as creating playgrounds for linking opportunities.

Interviewee 8 also recommended initiating a pilot for a community-based energy trading system. Therefore, he advises doing an economic feasibility study. He explains that the municipality could integrate community-based energy trading within a residential area. At the same time, the municipality should set an equal comparison residential area. Thus, a residential area without the integration of community-based energy trading. He assessed that this would enable the municipality to compare "apples with apples". Whereby they could define the difference in the infrastructure in terms of investment. He explains that enables the municipality to determine whether the integration of energy trading makes sense from an economic perspective. Instrumental for the economic feasibility study is monitoring and cross verifying the pilots. Therefore, he expects that the economic feasibility study will reveal that trading can deliver substantial economic benefits. Moreover, he determines that this will incentives the national government, DSOs and TSO, in terms of savings in infrastructure. According to him, the physical infrastructure needs much investment to allow the integration of DERs because the benefit of participating in energy transition and energy trading is shared across all the parties, including the national government, DSOs and TSOs. The study will incentivise them to invest in energy trading. Interviewee 5 also reaches the same recommendation. He explains that DSOs are obligated, through the proposed Energy Act, to participate in congestion management. Therefore, he both assess that integrating and coordinating Smart Energy solutions will enable congestion management. Therefore, the DSOs will have to participate and invest in these solutions. However, interviewees 6 and 7 both empathise that the DSOs main objective is to facilitate the energy market as a neutral party.

Lastly, interviewee 13 discusses using the assets of the municipality for energy trading. Therefore, he refers to integrate B2B energy trading for the municipality. He determines that B2B energy trading could make Rotterdam the frontrunner in Smart Energy solutions.

9.1.2 Recommendation for other Smart Energy solutions

The majority of the interviewees determined that the municipality should focus on determining the problem or define an energy-related objective for Prinsenland and Het Lage Land. Then determine whether energy trading would meet this objective. Accordingly, interviewee 1 assessed that the problem of Prinsenland and Het Lage Land is related to the objective of the districts to become all-electric. He elaborates on this by explaining that all-electric districts generate surplus energy during the day. Subsequently, he assesses that the demand will be low during the day. Conversely, the energy demand will be high during the evening, but the DERs will not generate enough to meet the demand. Therefore, he finds energy trading not a viable solution for the municipality. Subsequently, he discusses batteries and assesses that the municipality should focus on integrating neighbourhood batteries since a battery could store the excess energy produced during the day, which the residents could then use in the evening hours.

Interviewee 10 concurs and also advises the municipality to initiate and engage in a dialogue with their residents. She expects that this will enhance the municipalities knowledge of the needs of the residents in Prinsenland and Het Lage Land. She determines that this would reveal the residents' concerns, problems and needs related to energy. Accordingly, she empathises that the municipality should focus on designing Smart Energy solutions for the problems and needs identified. Whereas interviewee 11 argues that the municipality should include the residents in the design. Furthermore, interviewee 10 argues that the municipality should aim for inclusion when developing these Smart Energy solutions. Since in her assessment, a project that does not aim for inclusion often leads to less inclusion. Therefore, she discusses linking opportunities and concludes that this could have great implications for input legitimacy and inclusion. Additionally, she and interviewee 11 recommended that the municipality focus on governance instruments for the inclusive integration of DERs. Interviewee 10 discusses the integration of adequate smart metering devices for all citizens. Since this provides the residents with insight into their energy consumption.

Interviewees 6 and 7 concur with the recommendation of interviewee 10. Therefore, they explain and reaffirm that integrating DERs and smart metering devices are building blocks for energy trading, as discussed in section 2.5. For the integration of DERs, they elaborate on community solar roofs and solar panels on residential buildings. Additionally, they discuss balancing the energy production of these DERs within the community and the residents in the particular building. Furthermore, they discuss integrating a predictable and controllable feature in the community, such as batteries or electric cars. These DERs can store and supply energy to the citizens. However, they caution the municipality and emphasise that trading is complicated. Additionally, they assess that the integration of P2P energy trading will be too ambitious.

9.1.3 Recommendations for additional research

Lastly, interviewee 4 suggests that the municipality use this research, which he refers to as preliminary exploration, to initiate a market consultation. Thus, using this research to determine the goal, the obstacles and necessities for developing the energy trading market. By conceptualising and operationalising this, the municipality could consult the market for solutions. Again, he and interviewee 14 stress that the municipality should shop the functionalities by approaching capable agents. They both assess that (eventually) a consortium will arise, consistent of parties that could take care of the development of the P2P energy system. Additionally, he advises the municipality to look into a consortium called TROEF Sharing Energy. TROEF Sharing Energy aims to accelerate the energy transition by developing a new energy ecosystem. The consortium TROEF consist of different capable agents, such as Stedin, Entrance and BAM. These agents aim to collaborate and establish new energy systems, such as energy trading. Besides the technical aspects, he also discussed the importance of focusing on energy regulations. Therefore, the majority of respondents assessed that municipality should use their lobbying powers for state-led policies. While also creating societal-led policies for energy trading.

9.1.4 Conclusion

This chapter presented the recommendations of the interviewees. The interviewees emphasised the complex nature of P2P energy trading. Therefore, some recommendations focus on P2P energy trading, while others focus on other Smart Energy solutions and inclusive DERs. Additionally, one interviewee recommended additional research. Accordingly, the recommendation based on the case study, my recommendations, will be presented in the next chapter.

Chapter 10: Conclusions and Discussion

This final chapter completes this study with the research conclusion, where the main findings will be revisited, and the research questions will be answered. First, this chapter will start by presenting the answer to each sub-question. This is followed by the answer to the main research question. Secondly, the main finding of this research in the broader context of existing literature will be discussed. This is followed by a discussion of the limitations of this research and the academic and societal relevance. Furthermore, the recommendations of this study for further research and policymakers, mainly the municipality of Rotterdam, will be provided. Lastly, a reflection of the study program MOT concerning this study is presented.

10.1 Conclusion: answer to the research questions

The research objective of this study is to investigate the boundary conditions for the governance of an energy market that facilitates P2P energy trading. Following this research objective, the main research question is described as follows:

How and under what conditions can the city of Rotterdam govern and facilitates P2P energy trading within the inclusive Smart City concept?

From the main research question, five sub-research questions were formulated. Each sub-research contributed input to answer the main research question. In the following paragraphs, a comprehensive answer is provided for each sub-question.

1. **What is the current state of inclusive local P2P energy trading market?**

   As rapid urbanisation confronts cities with new challenges and obstacles, cities turn to the Smart City concept to alleviate them. P2P energy trading has been defined as a Smart Energy solution within the Smart City concept. The literature study elaborated on the technical, theoretical, social, market and regulation aspects of P2P energy trading. Accordingly, the literature study revealed that within the literature, researches primarily focus on the technical and theoretical aspects of energy trading. The social aspects of P2P energy trading have not been sufficiently studied. Researchers that focus on the social aspects often only focus on the potential benefits such as grid stabilisation and monetary incentives. In comparison, some researchers elaborate and focus on inclusion by discussing digital exclusion, inclusive technology and valuable consumers. However, the concepts were defined as negative externalities of energy trading, and they did not elaborate on concepts and terms enabling inclusive local P2P energy trading. Therefore, the literature study determined that limited research has been done on inclusive local P2P energy trading. The interviews revealed that currently, local P2P energy trading markets do not exist. Hence, currently, inclusive local P2P energy trading markets also do not exist.

2. **Who are the stakeholders involved with P2P energy trading market for locally self-generated sustainable green energy?**

   The literature study identified several stakeholders that were divided into five categories: end-users, energy market, virtual market, regulating parties and intermediates. From the empirical research, it can be concluded that the end-users, energy market, regulated parties and virtual market are the most important stakeholders for P2P energy trading. The stakeholders in the virtual market are essential for the energy management system, whereby the technology providers are responsible for developing smart metering devices. The end-users are also determined to be essential stakeholders since energy trading relies on their participation. Additionally, the end-users are responsible for the demand within the energy trading market. The stakeholders in the energy market are essential for the demand side management and the financial aspect of trading. Lastly, the regulatory parties are crucial for P2P energy trading because these stakeholders have substantial decision-making powers for energy trading. The empirical research also identified two additional stakeholders, forecasters and trading companies. The academia did not identify these stakeholders. However, for the development of local P2P energy trading systems in Rotterdam, these stakeholders are crucial. The unpredictable nature of DERs makes forecasters essential for supply-side management. Trading companies are essential for covering financial risks due to the volatile nature of the market the energy prices.

3. **What are the boundary conditions that enable an inclusive P2P energy trading market for locally self-generated sustainable green energy?**

   This study produced an extensive literature study on the supporting elements of P2P energy trading. However, the literature does not define any boundary conditions. Since the opportunities and design of a local inclusive P2P energy trading market rely on the national market and regulatory bodies, this study analysed the proposed Energy Act. Additionally, the empirical research provided insight into a new and viable future energy trading market. Therefore, this study proposes an energy trading design for Rotterdam, referred to as Community-Market energy trading. This study determined nine boundary conditions for the Community-Market energy trading market; 1) determine the goal and focus of energy trading, 2) create an energy community, 3) conceptualising inclusion and include it in the design, 4) integrate adequate smart metering devices, 5) integrate an aggregator with an ACM license, 6) create an energy community with different energy profiles, 7) integrate a forecaster, 8) integrate an actor for the financial risks, and lastly, 9) "shop" the technologies needed for well-defined energy trading system.

4. **What are the governance requirements of the city of Rotterdam that enable an inclusive P2P energy trading market in terms of agents and opportunity structures, instrumentation and legitimacy?**

   This case study determined that an energy trading market is a complex socio-technical system. The complexity of the system is reflected through the many different decision-making actors in the social and physical layers. Therefore, the introduction of a Community-Market energy trading market will also be complex. Therefore, this study determined how a system can be changed to facilitate Community-Market energy trading. The governance requirements related to the agents and opportunity structures, instrumentation and legitimacy were defined. This case study determined that the capable agents appear in the energy market and the regulating parties. Practically, energy suppliers and DSOs have utilised different opportunity structures for energy trading. Liander and Eneco have created B2B energy trading systems, making them forerunners in developing energy trading systems. Stedin has also induced change to facilitate a community energy market. Therefore, these agents have resources, knowledge and financial resources for the development of energy trading. Community energy corporations and cooperatives are also determined to be capable agents since their main objective is to initiate energy-related initiatives, whereby they aim to ensure public value for citizens. Thus, they are applying their resources, mainly human resources, to reach the communities.

   In terms of instrumentation, this study determines that the national government is responsible for the state-led policy instruments. However, the EU has some influence on the state-led policy instrument. Community energy corporations and cooperatives primarily focus on creating social-led instruments. Additionally, the municipality of Rotterdam was defined as an important agent for governance instruments because municipalities can influence the state-led and create social-led instruments to achieve specific goals such as the development of energy trading. Whereas the social-led instrument aims to influence behaviour and enable rule development and implementation. Therefore, the municipality can concretise the opportunity structures.

Lastly, the concept of legitimacy is placed at the heart of governing energy trading. Legitimacy is related to the readiness of societies to contribute to different processes and comply with directions taken by the municipality. Therefore, this study determined that currently, the municipality relationship with its citizens might not allow for support of the development of energy trading. Without the residents support, developments initiated by the municipality will not be accepted. Therefore, the municipalities should focus on generating support when developing the Community-Market energy trading system.

5. **What are the future directions for Rotterdam to enable an inclusive P2P energy trading market?**

   This empirical research defined multiple future directions for the municipality of Rotterdam. Some experts recommended focusing on P2P energy trading by focusing on B2B energy trading, initiating pilots and creating a trading platform. In contrast, other discussed recommended integrating other Smart Energy solutions, inclusive DERs and smart metering devices. Additionally, an expert recommended additional research and looking into TROEF Sharing Energy consortium. This is a consortium consists of multiple capable agents. By joining the consortium, the municipality could open the dialogue for Community-Market energy trading for their citizens.

The main research question can now be answered after addressing the sub-research questions and gathering all necessary information.

How and under what conditions can the city of Rotterdam govern and facilitates P2P energy trading within the inclusive Smart City concept?

This study determines that a fair amount of changes is currently occurring in the Dutch energy market. These changes are related to the energy transition. An important change in the national energy market is the integration of the proposed Energy Act. This Act includes terms that have substantial implications and subsequently introduced and supported the Community-Market energy trading system. The Community-Market energy trading design relies on a community approach. Accordingly, an energy community needs to be created to coordinate the DERs of the residents in the community. Additionally, an aggregator is introduced for the trading processes in the energy community. Therefore, both the trading process and information communication are done through the aggregator in a centralised fashion. Since the design relies on the terms introduced in the proposed Energy Act, the design can be introduced and facilitated when the proposed Energy Act is accepted. However, the process of accepting the proposed Energy Act could take some time, and during which terms can be changed, removed and added.

The boundary conditions for the Community-Market energy system includes determining a goal and focus for Community-Market energy trading. Therefore, the municipality could focus on this boundary condition while it awaits the integration of the proposed Energy Act. Additionally, the municipality should aim to include the concept of inclusion in the design and integration of P2P energy trading. This study determined that all five dimensions are important. Specifically, access to information, accessibility and affordability of DERs, environmental awareness and behaviour, social participation, shared prosperity, and resident-municipality relation. Furthermore, the supporting elements of energy trading include the integration of DERs and adequate smart metering devices. Accordingly, this study suggests focusing on the inclusive integration of these supporting elements. This provides every resident with the opportunity to integrate DERs and have better insight into their energy demand and supply. Accordingly, with the integration of the supporting elements of P2P energy trading, a well-defined goal and an energy community. The municipality could then focus on the governance requirements in terms of agents and opportunity structures, instrumentation and legitimacy.

The capable agents for the Community-Market energy system include the DSOs, energy suppliers, trading companies and the cooperative sector. By involving these capable agents, the municipality is also initiating a market consultation for Community-Market energy trading. This study determined that the cooperative sector views related to energy could substantially differ from the views of (large) energy suppliers, which could result in some tensions and should be properly governed by the municipality. In terms of instrumentation, policy instruments are created by the national government. The community energy initiatives and collectives primarily create social instruments in Rotterdam. The municipality of Rotterdam could create social instruments that focus on the environmental awareness and behaviour of its citizens. Additionally, social instruments that aim to influence behaviour and draw on the infrastructure of the agents for rule development and implementation, such as housing requirements and inclusive subsidies. Lastly, in terms of legitimacy, this is essential for governance of change to induce P2P energy trading is legitimacy. However, this study determines that the municipality's relation with its citizens might not allow for support, which de-legitimises the Community-Market energy trading. This is also related to political inclusion. Accordingly, this study determines that legitimacy and inclusion are closely related. Therefore, for Community-Market energy trading, inclusion and legitimacy are deemed fundamental. This reaffirms the importance of the five dimensions of inclusion for the municipality of Rotterdam. Practically the municipality could focus on social inclusion, economic inclusion and political inclusion by assessing the needs and challenges of the residents related to energy and subsequently incorporating the development and design of a Community-Market energy trading system. This refers to conceptualising inclusion and allows for creating services based on the real needs of residents, which enables participation, real profits, and support.

10.2 Discussion

This section will elaborate on the main findings generated on energy trading in the context of existing literature. Additionally, as with any other scientific research, this research has its limitations. These limitations are related to the research methodology and resources available. Therefore, this section will also address the limitations future researchers need to take into consideration. Furthermore, the recommendations of this study for further research and policymakers, mainly the municipality of Rotterdam, will be provided. Lastly, this section will academic and societal relevance and reflect on this research in the context of the MOT program.

10.2.1 Academic Discussion

The present study investigated P2P energy trading, a Smart Energy solution that emerged from the Smart City concept. Within the Smart City concept, researchers have acknowledged the need to deviate from the techno-driven and profit-driven approach to a citizen-focused approach (Liang et al., 2021);(Lee et al., 2020). However, researchers in the P2P energy trading field have not acknowledged the need for this transition. Previous studies on P2P energy trading, see for instance Tushar et al. (2021);Sousa et al. (2019), have created a body of work for the theoretical and technical requirements of P2P energy trading. Accordingly, this study identifies a lack of knowledge on the social aspects of P2P energy trading. Additionally, the majority of researchers discussing social aspects focus on creating monetary benefits within P2P energy trading, which they refer to as social welfare (Zhou et al., 2020). However, this supports a profit-driven approach, whereby the needs of the citizens is not included. Therefore, this study also revealed the need for a citizen-driven approach in P2P energy trading, and subsequently, the need for inclusive P2P energy trading. Researchers elaborating on inclusive P2P energy trading mainly discuss vulnerable consumers, inclusive technology, and digital exclusion(Reis et al., 2020);Wilkins et al. (2020). Whereas the research of Liang et al. (2021) elaborates on inclusion and defines five dimensions. The literature on inclusive P2P energy trading does not elaborate on the five dimensions nor include the five dimensions. Therefore, the body of knowledge on inclusive P2P energy trading is limited, revealing a knowledge gap on inclusive P2P energy trading. Also, there is a knowledge gap on including the concept of inclusion in the development of P2P energy trading.

However, previous studies on P2P energy trading identified three market forms for P2P energy trading: centralised, decentralised and community-based energy trading markets (Parag & Sovacool, 2016);(Tushar et al., 2021). The researchers elaborated on the market form by demonstrating their effectiveness of energy trading and thereby focused on the architecture, technologies, testing, security and scalability of the architecture (Soto et al., 2020). However, the academic literature does not provide knowledge, specifically, for the Dutch energy system. Since the main premise of energy trading is prohibited in The Netherlands because it forbids supplying energy without an energy supply permit. The current academia in The Netherlands does not focus on P2P energy trading. This study investigated the national market and regulatory bodies, the proposed Energy Act, to create a design for an inclusive P2P energy trading market, the Community-Market energy trading. Accordingly, this trading design relies on a community-based energy trading form but uses a centralised form of communication and trading. Therefore, this study confirms the findings of (Parag & Sovacool, 2016);(Tushar et al., 2021) and adds a new market form that combines centralised and community-based energy trading market forms. Additionally, this research contributed to the national P2P energy trading literature by providing a market form that could be implemented specifically for The Netherlands.

This research also addresses the reported lack of knowledge on inclusive P2P energy trading. Therefore, this study identified the theoretical framework of Borrás and Edler (2014) to understand governance of change. This study modified the key questioned proposed by Borrás and Edler (2014), to understand inducing change for a P2P energy trading system. Accordingly, this study extended the framework and determined that the concept of inclusion and legitimacy are closely related. According to Borrás and Edler (2014), input legitimacy refers to the support that a social community grants a political system to provide collective problem-solving for them. It is also seen as a form of participation. Accordingly, inclusion refers to providing collective problem-solving by utilising a citizen-focused approach that aims to provide real solutions that citizens support and participate in to provide real benefits to enhance their quality of life (Mohamed & Manaf, 2020). Therefore, this study contributed by extending the framework of Borrás and Edler (2014) and revealing a relation between inclusion and legitimacy. Most of the interviewees were not familiar with inclusion since they referred to it as energy poverty, transparency within the energy system, and participation. When discussing inclusion, the experts understood the importance of the concept. Accordingly, the interviewees argued that the negative externalities of energy trading would be enhanced in communities. Whereas, Koirala and Hakvoort (2017) elaborated on communities and explained that citizens within a community share a sense of place, identity and have the same values. This study determines that this notion is false and will have negative implications for both the concept of inclusion and legitimacy. This study emphasises that within a community, citizens have different concerns, values, problems and opportunities. The presumption that these citizens have the same value will result in collective problem-solving that does not apply to the different citizens. Thus it will have negative implications on participation, support and will lead to exclusion. Accordingly, this reveals the gap between the academic world and the non-academic world. Subsequently, this study determined that inclusion should be conceptualised and linked to the development of P2P energy trading. Practically, inclusion can be included in P2P energy trading by assessing the needs and challenges of the residents related to energy and subsequently incorporate it into the development and design of energy trading.

Additionally, this research determined focused on the governance requirements for energy trading. Researchers in the Dutch energy system has not research P2P energy trading. This enables a knowledge gap on governance requirements. According to Tushar et al. (2021), future researchers should concern themselves with determining and prioritising the stakeholders of the energy trading market. Therefore, this study utilised the theoretical framework of Borrás and Edler

(2014) to provide guidelines to understand governance of change, which could be used to induce change and facilitate P2P energy trading markets. To this end, this study contributes to this knowledge gap by providing knowledge on the governance requirements in terms of agents of opportunity structures, instrumentation and legitimacy for inducing a P2P energy system. More specifically, providing and presenting a concrete image of the stakeholders in Dutch energy systems can utilise policy-making and decision-making activities to induce P2P energy trading.

10.3 Limitations

The first limitation of this research is related to the selection of the interviewees, which influences the external validity of the research results. According to Yin (2014), external validity refers to the generalizability of the result. The literature study in this research describes the Smart City concept, converges to Smart Energy solutions, and elaborates on the different aspects of P2P energy trading. Both the general stakeholder analysis and the literature review reflects on other cultural and geographical contexts. However, the empirical study focuses on P2P energy trading in The Netherlands, specifically the Prinsenland and Het Lage Land districts in Rotterdam. Therefore, recommendations of this study are also targeted at the municipality of Rotterdam. However, since the Community-Energy trading market is based on the national Energy Act, it can be applied by other Dutch municipalities and practitioners. Therefore, the generalizability of the empirical study to other geographical contexts, apart from The Nederlands, is limited. Additionally, political and cultural contexts are additionally limited to Rotterdam. However, since this study applied the framework of Borrás and Edler (2014) to the empirical research, this improved the studies external validity.

Also, this study did not manage to interview all stakeholders in the Dutch energy trading system. For instance, the energy coaches of Rotterdam who assist the citizens of Rotterdam with their energy consumption, and PowerPeers, an energy supplier that used to facilitate P2P energy trading, were not interviewed. Therefore, this influences the representativeness of this study. Ultimately, this research conducted 14 interviews, the data generated from the interviews were analysed by creating codes. These data collection tools also have their limitations since they require a high degree of interpretation from the researcher. Bhattacherjee (2012) refers to this as interpretivism, which is determined to be a limitation of qualitative (case) studies. Given the subjective nature of qualitative data collection and the interpretation process, this research could be subject to bias. This limitation can be related to the lack of coding verification since the data derived from the interview was only coded by the researcher. Also, the themes derived for the codes were not verified. At the same time, the derivation of the themes was based on the research question. The research question was verified.

10.3.1 Academic and Societal Relevance

This study has value for both academics and practitioners and therefore has societal relevance and academic relevance. The literature study identified an abundance of theoretical and technical knowledge on P2P energy trading. However, it also revealed a knowledge gap on the social, market and regulation aspects of P2P energy trading. For the knowledge gap on the social aspects of P2P energy trading, this study contributed by elaborating on inclusion within communities and providing guidelines on how to incorporate inclusion in the design of P2P energy trading. Therefore, this study introduced the term conceptualise inclusion, which refers to linking the dimensions of inclusion to the values of the community. Practically, the municipalities should identify the needs and challenges of citizens related to P2P energy trading to create a design that actively aims to combat the challenges and needs. Thus, linking the development of P2P energy trading to the citizens living in the city.

Additionally, academic literature on P2P energy trading does not elaborate on P2P energy trading market form for specific countries, including The Netherlands. Therefore, this enabled a knowledge gap for the market and regulation aspects of P2P energy trading for The Netherlands. Therefore, this study analysed the existing and proposed Energy Act to identify an inclusive P2P energy trading market, the Community-Market energy trading system. An energy trading that combines centralised and community-based energy. Thus a community-based energy trading system where both the trading process and information communication are done through the aggregator in a centralised fashion. This study contributed to the knowledge gap by creating a design that could be integrated into the Dutch energy system. Accordingly, this study identified nine boundary conditions. Whereby defining an overall goal and conceptualising inclusion in the development of energy trading are determined to be fundamental for the development. Accordingly, this study contributed to the knowledge gap on the concept of inclusion in P2P energy trading systems by providing a design for inclusive trading. Furthermore, this study used and modified the theoretical framework of Borrás and Edler (2014) to understand governance of change. Therefore, this study contributed to the literature by extending the framework to understand the regularities associated with the governance of change, that could induce and facilitate a Community-Market energy trading. Accordingly, this study and the extended framework identified a relationship between the concept of inclusion and legitimacy. Also, governance requirements on the integration of P2P energy trading have not been discussed by academics. Since governance requirements are related to specific regulatory bodies, which the literature does not discuss, this study contributes to this knowledge gap by determining governance requirements for the Community-Market energy trading system. For this, this study used the extended framework to governance requirement in terms of capable agents and opportunity structures and instruments to induce change for a Community-Market energy trading. Accordingly, this study determined governance requirements for the concept of legitimacy. Therefore, this study also provides practitioners, namely municipalities, with the governance requirement to induce change and facilitate Community-Market energy trading. Thus, the main academic contributions of this study are 1) the design of Community-Market energy trading, 2) the nine boundary conditions for Community-Market energy trading, 3) how inclusion can be included in the development of energy trading, specifically for the municipality of Rotterdam, 4) the governance requirements in terms of capable agents, instruments, legitimacy for the development of Community-Market energy trading, specifically for the municipality of Rotterdam, 5) the extended framework and lastly, 6) the identification of a relationship between inclusion and legitimacy.

The societal relevance is contributing to and in the citizen-driven smart city approach. These approaches enable a future-proof and inclusive energy trading market. Also, the recommendations of this study provided guidelines and offered clear measures for the development of inclusive energy trading markets.

10.4 Recommendations

Based on the findings of this research, recommendations can be made towards the municipality of Rotterdam regarding energy trading. These recommendations are for the researcher herself.

This study designed an inclusive local energy trading system, the Community-Market energy system, based on the proposed Energy Act. However, the proposed Energy Act is still in a draft version. Therefore, it could take some time before the proposed Energy Act is accepted, during which energy terms essential for the design could be changed or removed. Accordingly, new terms can be integrated. Therefore, this study recommends that the municipality await the definitive version of the Energy Act. However, this study determines that the municipality could focus on energy trading using their assets. Thus this study recommends initiating B2B energy trading. B2B energy trading has different regulations than P2P energy trading. B2B energy trading does not require an energy supply permit, and the taxes are less complex for B2B energy trading. Therefore, the municipality of Rotterdam has different assets that could be used for B2B energy trading, such as the pumping station, solar parking lots and Ahoy Rotterdam. While using these assets for energy trading, the municipality can adequately assess the value of Community-Market energy trading.

Concurrently, the municipality should focus on formulating a goal for facilitating Community-Market energy trading. This could also be done by enhancing their own knowledge on energy trading by facilitating Business-to-Business energy trading. Since a well-defined goal for energy trading enables the municipality to concretise the 'real' opportunity structures for Prinsenland and Het Lage Land. While focusing on B2B energy trading, the municipality should not lose sight of their citizens. Therefore, the municipality should also assess the needs and challenges of their citizens related to Smart Energy solutions. Then they should assess the activities and instruments they currently use in terms of inclusion and adjust the activities and instruments if the feedback recommends this. Accordingly, this will allow for the residents' participation and enable them to contribute to inclusive shared prosperity.

Furthermore, this study determines that facilitating inclusive energy trading relies on the inclusive integration of DERs and smart metering devices. Therefore, the municipality should create an inclusive, integrated community energy system, thus focusing on creating social-led instruments. This could be done by working with community energy corporations and cooperatives. These agents have the human resources and aim to safeguard the public interest, and this would be instrumental since the course of the energy transition relies on human behaviour. Additionally, the municipality should investigate creating instruments that enable inclusive integration of DERs and smart metering devices. This could be done by opening the dialogue with community energy initiatives and collectives. When these elements are integrated for every resident in Prinsenland and Het Lage Land, the municipality could assess whether Community-Market energy trading will be of value for their citizens with the knowledge generated from Business-to-Business energy trading.

Inclusive local P2P energy trading could make the city of Rotterdam smart. Therefore, it can combat the challenges of rapid urbanisation and enable the transformation to a climate-neutral energy system. However, inclusive P2P energy trading relies on multiple elements, including inclusive DERs, which should be the municipality first concern. Also, this research determines that inclusive local P2P energy trading should be regarded as a tool. Therefore, the municipality should investigate other Smart Energy solutions. Also, the municipality should investigate neighbourhood batteries because this could also be beneficial for Prinsenland and Het Lage Land.

Lastly, the municipality can and should look into TROEF Sharing Energy consortium. The consortium consists of multiple capable agents. By joining the consortium, the municipality could open the dialogue for Community-Market energy trading for their citizens.

10.4.1 Recommendations for Future Research

Based on the findings of this research, recommendations for future research would be to focus on the concept of legitimacy and inclusion for energy trading or other Smart Energy solutions. Future research should coordinate the participation of local stakeholders and allow them to determine their challenges and needs related to energy. Therefore, the local stakeholders can contribute to inclusive developments in their community. Also, this research determined that the integration of smart energy devices are essential for the development of an energy trading market. However, this research also identified problems related to the functionality of smart meting devices. Also, it is unclear which actor is responsible for the data of these devices. Furthermore, can this data be used for energy trading due to privacy concerns? Therefore, a recommendation for future research is to determine the needs of residents related to smart metering devices. Whereby the researcher should also concern themselves with identifying an adequate smart metering device and the data ecosystem of these devices. Also, this research created the Community-Market energy trading for Rotterdam. An energy trading system that combines centralised and community-based energy. Thus a community-based energy trading system where both the trading process and information communication are done through the aggregator in a centralised fashion. The design is derived for the analysis of the proposed Energy Act. Future researchers could verify whether this design could also be integrated into other countries for local use. Thus, researchers could determine whether other countries' market and regulatory bodies will support Community-Market energy trading. Accordingly, future researchers could determine whether this design could be integrated into different cities within The Nederlands. Thus, research whether the design is generalisable. Lastly, a recommendation for future research is to determine how the municipality of Rotterdam can utilise their assets for Business-to-Business energy trading.

10.4.2 Reflection on the link with MOT program

This thesis is conducted in the context of the Master program in Management of Technology (MoT). The study program aims to create an understanding of how technology is explored to design and develop innovations and services that benefit both the consumer and the organisation developing it. Therefore, this research is in line with the study program since this thesis involves how to design, develop and manage a service. In this case, the Smart Energy solution, energy trading, to achieve benefits for residents. Also, this research provided knowledge to bridge the gap between technology and society, whereby the components of management and technology are deemed essential.

This research has a technology component, and the identification of boundary conditions enable the management aspects. Therefore, there is a relation and link present between this research and the courses given within the MOT program. Courses such as Leadership and Technology Management, Technology Dynamics and Technology Strategy and Entrepreneurship provided knowledge on the relationship between society and technology, the influence of societal values on technology and how these values can be managed. My elective courses include the course Values of ICT. This course and the courses Social and Scientific Value provided knowledge on how ICT systems can be built to promote, protect and preserve various values related to humans. Additionally, the courses Research Methods and Preparation for the Master Thesis provided knowledge and skills to conduct academic research.

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Appendices

Appendix A: Theoretical framework of Borrás and Edler (2014)

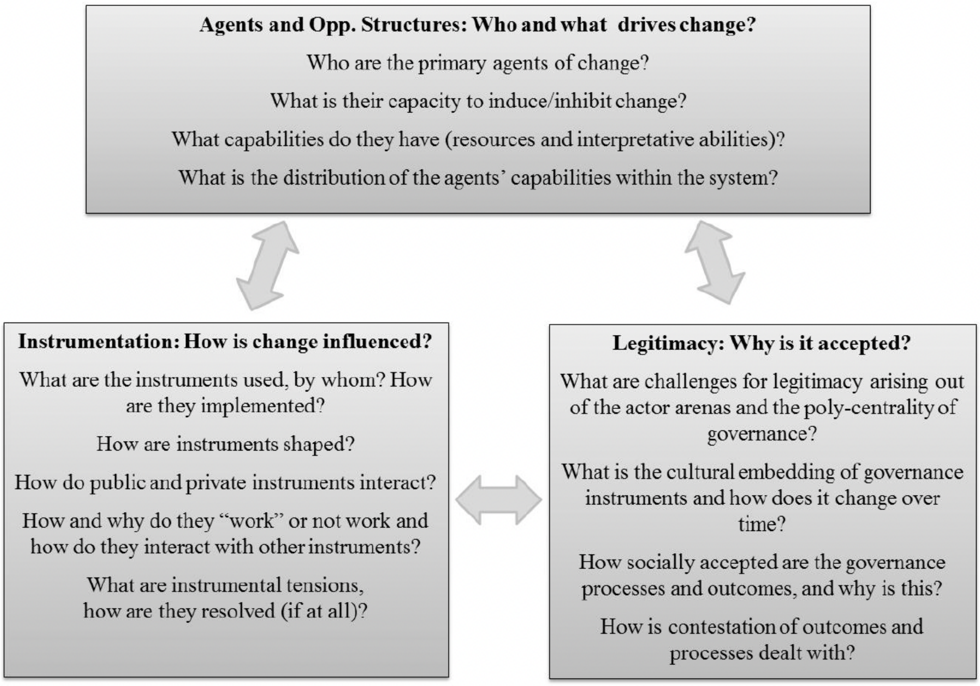

Figure A.1: The conceptual framework, including the key analytical questions, for governance of change in ST&I, figure adapted from (Borrás & Edler, 2014)

Appendix B: Interview guide

Vragenlijst over P2P energy trading voor de Next Generation Prinsenland en Het Lage Land

Deze vragenlijst heeft als doel inzicht te verkrijgen in de belangrijkste aspecten rondom P2P trading in Rotterdam.

1. Kunt u kort omschrijven wat uw functie is?
2. Indien van toepassing, kunt u een korte omschrijving geven van het project waar u bij betrokken bent?

   Technische aspecten:

3. Wie zijn volgens u de primaire stakeholders die betrokken moeten zijn in de ontwikkeling van P2P energy trading?
4. Welke resources en/of technologieën zijn er volgens u nodig voor de ontwikkeling van P2P energy trading?
5. Wat vindt u het belangrijkste technische element voor P2P energy trading?
6. Wat zijn mogelijke strategieën voor de gemeente Rotterdam om samenwerkingen mogelijk te maken tussen potentiele partijen, waaronder primaire stakeholders, die willen deelnemen aan P2P energy trading?

   Wet en regelgeving:

7. Welke beleidsinstrumenten worden momenteel ingezet om P2P energy trading te stimuleren?
8. Welke beleidsinstrumenten zijn er volgens u in de nabije toekomst nodig om P2P energy trading te faciliteren?
9. Hoe kan de gemeente Rotterdam en/of andere stakeholders ervoor zorgen dat de benodigde beleidsinstrumenten voor P2P energy trading worden gecreëerd?
10. Alleen de benodigde beleidsinstrumenten of ook andere factoren (in brede zin) die een gunstige invloed kunnen hebben op het creëren van gunstiger markcondities voor lokale P2P energy trading in R'dam?

    Sociale condities:

11. Wat zijn volgens u de uitdagingen wat betreft sociale legitimiteit en draagvlak voor P2P trading?
12. Wat verstaat u onder inclusie? En wat denkt u dat de uitdagingen (en risico's) van inclusie m.b.t. implementatie van P2P trading zijn?
13. Hoe verwacht u dat P2P trading tot meer en of minder inclusie zal leiden?
14. Verwacht u dat bepaalde P2P technologieën tot meer inclusie zullen leiden?
15. Wat zijn volgens u de belangrijkste factoren die P2P-marktontwikkeling gunstig beïnvloeden?
16. Heeft u nog suggesties met betrekking tot het benaderen van andere (praktijk-) experts voor meer relevante informatie? Of eventuele relevante documenten?