SMART GRID, SMART RULES OR SMART CONTEXT?

A COMPARATIVE CASE STUDY OF SMART GRID IMPLEMENTATION IN THREE (EXPERIMENTAL) COMMUNITY ENERGY PROJECTS

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TU Delft

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A comparative case study of smart grid implementation in three (experimental) community energy projects

By

Mees Dekkers

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SUMMARY

Introduction

The Paris Agreement aims to limit global temperature rise and achieve climate neutrality by 2050. The UN's Sustainable Development Goal 7 emphasizes access to affordable, sustainable energy, which smart grids are vital in. These grids adapt to user behavior and connect various components. Smart grids address the challenges of integrating renewable energy, but socio-technical complexities require a multidisciplinary approach. Institutions play a pivotal role in smart grid development, but there's a lack of focus on their significance. Stakeholders, technology, and institutions form a complex interplay, making the implementation of smart grids intricate. Research on smart grids largely focuses on technical aspects, but a holistic approach that considers social, economic, environmental, and institutional dimensions is essential. The research aims to bridge this gap by improving energy system design using the Institutional Analysis & Development (IAD) framework within the multidisciplinary context of the Netherlands' electricity/energy system. Therefore, the main research question of this thesis research is: "*What are the impacts of institutional rules on the development and implementation of smart grids in the Netherlands at community level?*"

Research Approach

The research approach chosen is the comparative case study method, focusing on smart grid technology integration initiatives in the Netherlands. The Institutional Analysis and Development (IAD) framework is used as a tool for analyzing complex socio-technical systems, particularly in energy transitions and smart grids. Case selection criteria include similarity of context, energy community categorization, presence of smart grid technology, local energy cooperative involvement, and exemption under the Experimentation Decree. This resulted in the analysis of three cases: Schoonschip Amsterdam, GridFlex Heeten and Groene Mient The Hague. Data collection involves literature study and semi-structured interviews, with 14 interviews conducted to gather information from a range of experts and project stakeholders. Deductive coding is applied to interview transcripts using a pre-defined codebook derived from the IAD framework and related concepts. Comparative case analysis is used to analyze the cases individually and through cross-case analysis using the IAD framework and the ASI (Actors, System & Institutions) diagram, aiming to understand the interrelations of technology, actors, and institutions in smart grid projects.

Main Findings

The Dutch electricity system transitioned to a competitive liberalized market, with smart grids and energy systems gaining importance for sustainable practices. The shift towards decentralized energy production, facilitated by smart grids, requires technological advancements and institutional changes at EU, national, and local levels, as reflected in emerging energy communities.

Nowadays implementing local smart grid technology in the Netherlands involves factors such as obtaining exemptions, conducting feasibility studies, and engaging legal entities like homeowners' associations and energy cooperatives. Analyzed cases highlight the significance of pre-exemption feasibility studies and the role of technological requirements, stakeholders like the Distribution System Operator (DSO), and energy

management systems in successful implementation. The evolving electricity system adds complexity to the process, emphasizing the need for careful planning and stakeholder involvement for effective smart grid integration.

The most important results show that each case is unique. Each project's key institutional rules and their impact on the action situation are examined. In Schoonschip, boundary, position, choice, and payoff rules played a pivotal role. GridFlex highlighted the significance of position, choice, information, and scope rules, with differing outcomes from the project's inception. Groene Mient showcased the influence of boundary, position, choice, payoff, and scope rules, alongside changing goal attainment. These case studies, informed by the IAD framework, unveil complexities in decision-making and governance within sustainable smart grid initiatives. Ultimately, the findings from this research provide insights into the necessary adaptations required in the Netherlands to successfully implement smart grid energy systems and mitigate climate change.

In short, the successful implementation of smart electricity grids necessitates a comprehensive consideration of technology, institutions, and stakeholders, as indicated by the ASI-diagram. Analyzing these interactions offers vital insights into the intricate dynamics of such initiatives. The cases examined within the IAD-framework reveal the substantial impact of biophysical conditions, community attributes, goal attainment, and rules-in-use on smart grid outcomes in the Netherlands. This understanding underscores the significance of addressing these factors for effective local smart grid development.

Recommendations

Most important implications for further research apply to the various types of rules governing smart electricity grids that are changing. Notably, the positions of actors within these grids are particularly affected by evolving and uncertain legislation. Therefore, there is a need for increased scientific research focused on understanding the roles and positions of actors involved in smart electricity grids at the local level. Next to that encourage interdisciplinary research for comprehensive insights into smart grid complexities, considering institutions, actors, and technology. Develop integrated decision-making frameworks, merging IAD and ASI, aiding policy and planning. Conduct more empirical case studies using IAD and ASI, unveiling challenges, opportunities, and generalizable insights. Significant policy recommendations: Obtain financial support, define clear policy roles, accommodate local smart energy systems, promote positive framing, standardize data exchange, and facilitate umbrella (energy cooperative) organizations to overcome lack of cohesion in local smart electricity grid projects.

ACKNOWLEDGEMENTS

With this thesis I set my final accomplishment of my Master's degree in Complex Systems Engineering & Management at the faculty of Technology, Policy and Management as part of the Delft University of Technology. This part I would like to thank and express my gratitude to all the people helped, advised and supported me throughout the extensive and challenging process of my master thesis.

In my journey to get this academic degree, I want to express my sincere thanks to my respected thesis supervisors: Dr. Thomas Hoppe as my daily first supervisor, Dr. ir. Rutger van Bergem as my second supervisor and lastly Dr. Amineh Ghorbani as my Chairman of my thesis committee. Their ongoing support and scholarly perspectives have played a pivotal role in shaping the direction of this research.

I deeply appreciate the unending support and encouragement from my friends (the mossen) and family, whose belief in my abilities has been a constant source of inspiration. Their presence has fortified my resolve and enriched my scholarly journey. I extend my thanks to my fellow scholars for their intellectual exchanges and many helpful coffee breaks.

This work stands as a tribute to the collaborative efforts of those who have contributed to its realization.

With many thanks,

Mees Dekkers
August 20th, 2023

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

SG - Smart Grid
STS – Socio-Technical Systems
IAD – Institutional Analysis & Development
cVPP – Community Virtual Power Plant
STS – Socio-Technical Sytems
DSO - Distribution System Operator
IPIN - Innovation Programme for Smart Grids
EU CEP – Clean Energy Package
REDII – Renewable Energy Directive
IEMD – Internal Electricity Market Directive
SSA – Schoonschip Amsterdam
HOA – Homeowners association
VPP – Virtual power plant
GFH – GridFlex Heeten
EMS – Energy management System
USEF - Universal Smart Energy Framework
GMDH – Groene Mient Den Haag (The Hague)
SoS – Sterk op Stroom
SCP – Smart Community Platform
EC – Energy Community
CEC – Citizens Energy Community
REC – Renewable Energy Community
RvO – Rijksdienst voor Ondernemend Nederland
ACM – Autoriteit Consument en Markt
PV – Program Responsible Party
GDPR – General Data Protection Regulation
IoT - Internet of Things
MLOEA – Meer leveranciers op één aansluiting (English: More (energy) suppliers on one connection)

1. INTRODUCTION

This chapter provides an overview of the research conducted, starting with a problem introduction that highlights the importance of addressing a specific issue within the field. It then proceeds with a literature review, which identifies the existing knowledge gap in the literature and sets the foundation for the research question. The research question, guiding the study, is formulated to address this gap. The chapter also outlines the chosen research approach and methodology employed to answer the research question. Additionally, it establishes a link to the study program, illustrating how the research contributes to the broader field. Finally, the structure of the thesis is presented, giving a brief outline of the chapters and their respective contents.

1.1. PROBLEM INTRODUCTION

The aim of the Paris Agreement is to make global temperature rise less than two degrees Celsius by 2050, and therefore achieve climate neutrality with greenhouse gas emissions (UNFCCC, 2015). Next to that the United Nations have their seventeen Sustainable Development Goals. Of special importance is Goal 7: "To ensure access to affordable, reliable, sustainable and modern energy for all" (UN DESA, 2015). To achieve these goals the world needs a shift to enormous amounts of energy derived from different sources than current conventional ones, i.e., fossil fuels. The most promising sources are variable renewable energy sources like solar PV and wind. These variable renewables are one of the key factors to reach a decarbonized power sector (Sinsel, Riemke & Hoffmann, 2020). Contemporary electricity systems become ever more complex, decentralized and unstable, because with the rising number of renewables it brings lots of variability into the (electricity) system. Therefore, research on solutions to relieve the grid are needed. A possible way to cope with the intermittency problems of renewable sustainable energy sources could be to reinforce the electricity grid with thicker and more cables (Battaglini, Komendantova, Brtnik & Patt, 2012) or other possibilities, e.g., congestion management. According to Sinsel et al. (2020) flexibility technologies have more prospective options than grid extension. Lammers and Heldeweg (2016, p. 1) argue for a more sustainable solution, the implementation of smart grid energy system technology: "to balance the energy supply and demand by increasing the flexibility of the electricity grid through the use of information and communication technology (ICT) and real-time remote control, e.g., with smart appliances and electric vehicles." Which is also argued by Tuballa and Abundo (2016) who state that smart grid technology gives an answer to the needed shift to more sustainable and renewable technologies like distributed generation and microgrids.

Smart grids consist of electricity networks that can adapt and connect the behavior and actions of its users in an intelligent manner (Yu, Cecati, Dillon & Simões, 2011). According to Ma, Chen, Huang, & Meng (2013, p. 36) a smart grid system "integrates electrical grids and communication infrastructures and forms an intelligent electricity network working with all connected components to deliver sustainable electricity supplies." A visualization of a smart grid is presented in Figure 1.

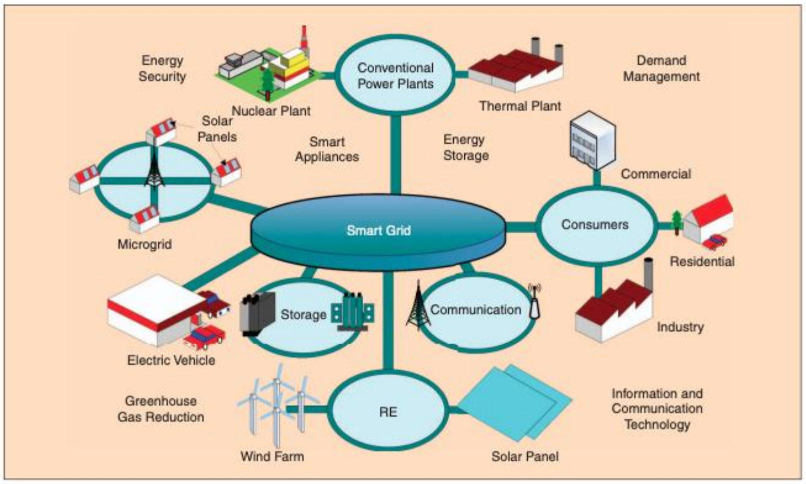

Figure 1 The concept of a smart grid (Yu et al., 2011)

Currently, smart grid systems are predominantly subjected to technical analysis in a mono-disciplinary manner (Norouzi, Hoppe, Elizondo & Bauer, 2022). Smart grid systems need to be analyzed from a multidisciplinary perspective that considers their complex socio-technical aspects (Norouzi et al., 2022). This holistic approach goes beyond purely technical analysis and includes social, economic, environmental and institutional dimensions. It enables better decision-making and planning for the design, implementation, and operation of smart grid systems.Next to the technical aspects of smart grids for the realization the institutional part is of high importance, since smart grids are highly complex systems (Goulden, Bedwell, Rennick-Egglestone, Rodden & Spence, 2014). Wolsink (2012) states that the development of smart grid systems has a lack of focus broader than just technology. Wolsink (2012) argues that there is an enormous gap with regards to the understanding of the need for institutional change required to establish smart grids. Lammers & Arentsen (2016) acknowledge this for the case of the Netherlands. Which also is stated by Lammers & Arentsen (2017, p. 1): “Despite the assumed high sustainability potential, the implementation of smart energy systems is still predominantly rhetoric instead of practiced.” This amounts to the main focus of this thesis research, which will be further elaborated in section 1.3: *there is a regulatory disconnection between regulation and innovation, e.g., within the field of smart grid energy systems*. Therefore, to make optimal use of the potential of smart grid technology, policy and institutional factors have to be considered and analyzed thoroughly within the system design of smart grids.

1.2. LITERATURE REVIEW

In this chapter the academic knowledge gap will be identified. Based on this gap, the main research question of this thesis will be determined. In section 1.2.1 the literature review process will be delineated with the most important academic papers that are core to the later identified knowledge gap(s). The next section (1.2.2) the core concepts will be explained.

1.2.1 LITERATURE REVIEW PROCESS

The main database that is used for chapter two's literature review is Google Scholar and to some extent also Scopus. A part of the information is found by snow-balling in the scientific articles found in those databases. In Table 1 the main articles found for the literature review are visible, which are found by the following keywords used.

KEYWORDS used: 'smart grid AND 'literature review', 'smart grid' AND 'electricity grid', 'smart grid' AND 'policy', 'institutions' AND 'smart grid*' AND 'Netherlands'.

Table 1 Scientific literature used as a basis for the knowledge gap

#	Source	Title
1	Lammers & Hoppe (2019)	Watt rules? Assessing decision-making practices on smart energy systems in Dutch city districts
2	Norouzi et al. (2022)	A review of socio-technical barriers to Smart Microgrid development
3	Lammers & Heldeweg (2016)	Smart design rules for smart grids: analysing local smart grid development through an empirico-legal institutional lens
4	Wolsink (2012)	The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources
5	Van Summeren et al. (2022)	Together we're smart! Flemish and Dutch energy communities' replication strategies in smart grid experiments
6	Milchram et al. (2020)	Designing for justice in electricity systems: A comparison of smart grid experiments in the Netherlands
7	Van Summeren et al. (2020)	Community energy meets smart grids: Reviewing goals, structure, and roles in Virtual Power Plants in Ireland, Belgium and the Netherlands
8	Lammers & Diestelmeier (2017)	Experimenting with Law and Governance for Decentralized Electricity Systems: Adjusting Regulation to Reality?
9	Lammers (2018) (PhD thesis)	Rules for Watt? Designing Appropriate Governance Arrangements for the Introduction of Smart Grids
10	Lammers & Hoppe (2018)	Analysing the Institutional Setting of Local Renewable Energy Planning and Implementation in the EU: A Systematic Literature Review
11	Lammers & Arentsen (2016)	Polycentrisme in lokale besluitvorming over duurzame energie: de casus slimme netten
12	Lammers & Arentsen (2017)	Rethinking Participation in Smart Energy System Planning
13	Milchram et al. (2019)	Understanding the role of values in institutional change: the case of the energy transition

1.2.2 CORE CONCEPTS

The technical and institutional settings are changing. There is an increasing need to coordinate energy, resource and spatial planning. The smart grid terminology is inconsistent and vague. All of these aforementioned problems make the implementation of smart grid energy systems complex for the stakeholders involved, especially the local ones (Lammers & Heldeweg, 2016). "Since Smart (Micro) Grids can be applied or adopted differently according to regional requirements, there is a need for context-based analysis to study the inter-dynamics between institutions, technology and actors." (Norouzi et al., 2022, p. 14).

Technology

Different kinds of technical definitions of smart grids:

- Colak: "Smart grids can be defined as self-sufficient systems, which allows integration of any type and any scale generation sources to the grid that reduces the workforce targeting sustainable, reliable, safe and quality electricity to all consumers." (Colak, 2016, p. 30).
- ETP SmartGrids: "Electricity networks that can intelligently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies." (ETP SmartGrids, 2010).

But as Wolsink (2012) stated that the technology is not the only bottleneck for smart electricity grids nowadays. Due to the scope of this thesis, I cannot delve deeply into the technological infrastructures of Smart Grids. Moreover, there is a clear knowledge gap, but not in the technology because that is sufficiently developed and analyzed. It is just not optimally used. The 'why' of the suboptimal use of smart grids lies more within the stakeholder and institutional aspects than the technology. Hence, in this research the focus will not be on technology, but on the institutional aspects.

Stakeholders

The problem(s) within smart grids development and its related coherence is stated by the International Energy Agency in their report about the roadmap of smart grids: "The physical and institutional complexity of electricity systems makes it unlikely that the market alone will implement smart grids on the scale that is needed. Governments, the private sector, and consumer and environmental advocacy groups must work together to define electricity system needs and determine smart grid solutions." (IEA, 2011, p. 5).

The social and institutional aspects of implementing a new energy system, such as a smart grid, are at least as important as the technical aspects (Wolsink, 2012). The roles and responsibilities of the various stakeholders involved in generating and using power would change completely, as consumers could be prosumers and the flow of electricity becomes two ways. Additionally, the inclusion of significant amounts of decentralized renewable energy sources may give rise to entirely new industry players. There is a lack of attention to the social acceptance of smart grids within the existing literature on the topic, which tends to focus primarily on the technical aspects of these systems (Wolsink, 2012). As a result, the concerns and perspectives of all stakeholders involved in the implementation of a smart grid are not adequately addressed. The process of modernizing the energy system involves collaboration among various stakeholders, including policymakers, technology providers, distribution system operators (DSOs), and various types of end users (Lammers & Hoppe, 2019).

Thus, the smart grid stakeholder field is very complex, but for the sake of this research: there are some structural problems in the stakeholder infrastructure, such as new division of responsibilities. The introduction of smart grids in the Netherlands is challenged by a complex multi-stakeholder configuration, and by 'rules of the game' (institutional conditions) which are essential for the cooperation between stakeholders but perceived to be outdated (Lammers & Hoppe, 2019). However, I am of the conviction, just as Wolsink (2012) describes, that institutional problems within the socio-technological systems are of more importance, because when these are adequately addressed, stakeholder problems will probably dissolve (Yanfika, Listiana, Mutolib & Rahmat, 2019). This is because stakeholders are part of a grander institutional analysis. That is why I will focus on institutional factors.

Institutions

On top of a general technical system design of smart electricity grids, the policy and institutional side have to be aligned with the technology. The current design of the electricity network is for a centralized and top- down system (Koirala & Hakvoort, 2017). The liberalization of the EU's electricity markets led to a lack of clear legislation defining the roles and responsibilities of stakeholders in local energy planning and implementation, which has made it difficult to make decisions regarding the adoption of renewable energy technologies (Lammers & Hoppe, 2018). Battaglini, Lilliestam, Haas & Patt (2009, p. 916) argue that with regards to policy uncertainties in Europe, “At present, there is considerable uncertainty about the future energy and climate policy of Europe. Further research into the potentially suitable range of policy instruments, the costs, benefits and risks of different instruments is necessary.” Milchram, Künneke, Doorn, Van de Kaa & Hillerbrand (2020, p. 4) have conducted research which considered multiple smart grid experiments in the Netherlands, in which the authors hold that: “In the Dutch energy transition, smart grids are attributed a special importance as an alternative to electricity network expansion.” Energy policies within Europe that facilitate smart grids are increasing, such as Electricity Directive 2009/752/EC, which states that EU member states have to implement smart metering in 80% of households by 2020 (Tuballa & Abundo, 2016). To adapt smart metering/smart grid system (energy) storage needs to increase and it is a prominent local flexibility option, but it lacks proper institutions to handle it (Milchram et al., 2020). The Distribution System Operator (DSO) is prohibited to own and/or operate storage, it is more for the producer and consumer of energy that is currently allowed to do something with storage (capacity) (Milchram et al., 2020). Therefore, as reported by Milchram et al. (2020, p. 12): “Policymakers should adjust regulation so that DSOs can benefit from storage owned by market parties for grid-stabilizing services.” Lastly, according to Koirala & Hakvoort (2017) institutional settings for smart grids, such as grid access, regulation, support incentives and (local) balancing need to adapt to the changing (technical) energy landscape.

1.3 KNOWLEDGE GAP & RESEARCH QUESTIONS

This part will be about the academic knowledge gap identified during the literature review, which is a result of the (still) ‘missing’ part in the literature. Thereafter, the main research question and sub questions will be obtained from the knowledge gap and the aim of this research.

The techno-institutional settings of the energy field change constantly in many ways (Heldeweg & Lammers, 2015). Wolsink (2012) expects a problematic situation as most existing rules of the game are largely geared towards supporting the centralized power supply system are inadequate for effectively establishing, running, and managing microgrids within a larger, integrated smart grid. An example here to illustrate this: The Dutch Experimentation Decree (constit. level) - exemptions Art. 16 Dutch Electricity Act: ‘only DSOs for grid operation’ (Elektriciteitswet 1998, wetten.nl, n.d.) is an example of an institutional factor that hinders the development of smart grid energy system(s) in the Netherlands. This Experimentation Decree will have a central role in this research, as to some extent it influences experimental projects’ degrees of freedom within the existing legislation, which is core in this thesis. All three projects analyzed have this Experimentation Decree experimental status.

The Netherlands is known for allocating a significant amount of public funding towards smart grid demonstration projects in the European Union. For instance, the country conducted twelve pilot projects as part of the ‘Innovation Programme for Smart Grids’ (IPIN) between 2011 and 2016. Despite this, the adoption of smart energy grids has not yet reached widespread implementation (Lammers & Hoppe, 2019). Many of the initiatives for introducing smart energy systems in Dutch city districts were initiated by local governments or distribution system operators, and therefore had a top-down character. This, combined with the multi-actor setting and the absence of clear guidelines for decision-making, has presented challenges for the implementation of these systems (Lammers & Hoppe, 2019).

“Furthermore, it can be concluded that future research and policy-making should pay attention to the creation and adequate orchestration of ‘rules of the game’ in decision-making processes on smart energy system planning.” (Lammers & Hoppe, 2019, p. 244). Norouzi et al. (2022) recommend that future research examines the impact and influence of supranational institutions and intergovernmental agreements in addressing and overcoming the barriers to smart grid research and development through international cooperation initiatives. “Additional research is needed to further explore the institutional and other contextual barriers, ways in which these barriers can be addressed in different national contexts, their impacts on community Virtual Power Plant (cVPP) designs and its upscaling potential.” (van Summeren, Wieczorek, Bombaerts & Verbong, 2020, p. 13) cVPP is considered as a form of smart grid.

With this the research problem can be formulated as follows: Within the field of smart grids (at pilot projects) in the Netherlands there is a lack of knowledge beyond technology. There is a regulatory disconnection between regulation and innovation, i.e., the ‘rules of the game’ do not match the technology. Therefore, the aim of this research proposal is to improve the energy related (institutional) system design for smart grid (innovation) development in the Netherlands with respect to especially the low/medium voltage electricity grid, which considers the multidisciplinary aspects of the electricity/energy system in the Netherlands.

Therefore, the Knowledge gap(s) found are: Lammers (2018) concluded in her PhD dissertation that conducting empirical research on a larger number of smart grid projects in local settings, and studying the extent and nature of causal relationships in decision-making, is strongly recommended for projects in the Netherlands and other countries. Which led her to advice for further research: In order to further test the findings from Lammers & Hoppe (2019) about the payoff, choice, and position rules and examine any other factors that may impact the implementation of smart energy systems, it is recommended to study and compare additional smart energy system projects at the city district level in the Netherlands and in other countries. These actions for future research are acknowledged by Lammers (2018, p. 179): “The findings of Chapter 4 (of Lammers’ dissertation) demonstrate that institutional conditions are foremost responsible for enabling and disabling decision-making processes on smart energy infrastructure introduction, while external events, generally speaking, had less influence on the decision-making process.”

So, to conclude this section, this thesis will attempt to shed light on the following Main Research Question:

What are the impacts of institutional rules on the development and implementation of smart grids in the Netherlands at community level?

Hence, in order to answer this, the following sub-questions (SRQ) are drafted:

- **SRQ1:** What constitutes the institutional environment of smart grids?
- **SRQ2:** How is smart grid technology implemented in local experimental community energy projects?
- **SRQ3:** How does context (institutions, technology and stakeholders) influence the development of smart grids in the Netherlands?

1.4 RESEARCH APPROACH

In this master thesis research, the chosen research approach that best fits the purpose is the comparative case study approach. Scientifically, comparative case studies involve examining multiple situations to generate knowledge that can be applied more broadly to understand the reasons behind the success or failure of specific policies or programs (Goodrick, 2014). These studies emphasize comparisons made within and between different contexts over a period of time. Comparative case studies are opted for when it is not feasible to use an experimental design or when it is necessary to comprehend and explain how factors specific to a particular context influence the effectiveness of policy or program initiatives (Goodrick, 2014). This information is valuable in designing interventions to achieve desired outcomes. By analyzing and synthesizing the patterns, similarities, and differences among two or more examples that share a similar focus or objective, comparative case studies provide insights. The approach is valuable in the development and exploration of theories, as well as the testing of hypotheses (Kaarbo & Beasley, 1999). This method allows for the exploration of similarities and differences across cases, enabling researchers to identify patterns, trends, and underlying mechanisms. This thesis research will contain a total of three cases that will be analyzed within themselves and later cross-cases. The chosen cases will consist of experimental projects that make use of the implementation of smart grid technologies, and they will be further described in chapter 3.

1.5 LINK TO STUDY PROGRAM

Smart grids can be seen as complex socio-technical system (STS) (Wolsink, 2012, p. 224): “A smart grid is a socio-technical network characterized by the active management of both information and energy flows, in order to control practices of distributed generation, storage, consumption and flexible demand.” Complex STS are large-scale systems with complexity, because of a variety of social, institutional and technical aspects and are core in the MSc CoSEM program. “Complex socio-technical systems generally consist of elements/functions, including technologies, humans, and organizations.” (Salehi, Veitch & Smith, 2020, p. 119). It also includes many stakeholders from different parts of society whose actions are guided by the institutions in place, e.g., rules and regulations. Those different aspects of an STS like smart grids will be further elaborated in the next chapter. Therefore, the aim of this research proposal is to improve the energy related system design for the use of smart grids. This will be done by analyzing the embeddedness of the smart grid system in an institutional setting, which considers the multidisciplinary aspects of the electricity/energy system in the Netherlands, by means of the Institutional Analysis & Development (IAD) framework taught in the course SEN1131 Institutional Economics for Designing in Socio-technical Systems.

1.6 STRUCTURE OF THE THESIS

The structure of the rest of this thesis will follow a normal scientific outline. Firstly, after the introduction section 2 will be about the theoretical framework (the IAD-framework) used in this research. Secondly, section 3 explains the methodology with techniques used to gather and process data. Thereafter, in section 4 a first brief exploration of the current status of smart grids in the Netherlands will be discussed. In section 5, 6 and 7, which will be the main focus, the case studies will be executed, with a total of three cases. Then in section 8 the cases will be compared in a cross-case analysis. Section 9, the main additional information from the data gathering via interviews with experts is outlined. Lastly, to summarize and answer all the (main) research question the conclusion is drafted in section 10 with a discussion section as well.

2. THEORETICAL FRAMEWORK

This chapter is intended to the outline the theoretical purpose of this research and what will be the basis of the main (theoretical) frameworks used. Here institutions are conceptualized and how they could be interdependent in different conceptual models/frameworks used.

2.1 INSTITUTIONS

"Institutions are human-constructed constraints or opportunities within which individual choices take place and which shape the consequences of their choices." (McGinnis, 2011, p. 170). Institutions are also a set of rules that structure social interactions which are important for the functioning of complex socio-technical systems, e.g., smart grids (Koster & Anderies, 2013). Energy transitions are dependent of social and technologically innovative expansion. Therefore, the institutional environment of smart grids has to be clear, since it contains social, economic, technological and institutional aspects. That is why in this section the (theoretical) institutional environment of the smart grid will be explored and elaborated.

2.2 INSTITUTIONAL ANALYSIS & DEVELOPMENT FRAMEWORK

Institutional analysis relates to finding coordination issues at stake and trying to design an institutional artifact. Considering this the Institutional Analysis and Development (IAD)-framework can be used, which can be seen in Figure 2. "The IAD-framework is intended to contain the most general set of variables that an institutional analyst may want to use to examine a diversity of institutional settings." (Ostrom, 2010, p. 646). Also, the IAD-framework can distinguish multiple relevant coordination problems related to the action situation, which is the core element of the framework. Next to this, the IAD-framework is designed to facilitate a comprehensive analysis and in-depth understanding of public institutions (McGinnis, 2011). The selection of the IAD-framework, as opposed to alternative theoretical frameworks or theories, was primarily based on its ability to disaggregate complex action situations into their individual elements. This facilitates the analysis of institutional arrangements and enables effective comparisons between them (Lammers, 2018).

The study by Lammers & Hoppe (2018) reveals a scarcity of scholarly literature pertaining to institutional frameworks in renewable energy planning and implementation. Predominantly, the existing research concentrates on specific case studies. Nevertheless, the authors discern recurrent patterns and obstacles in the literature. These encompass the requirement for effective coordination and collaboration among diverse government tiers and stakeholders, the significance of policy and regulatory frameworks that facilitate local renewable energy initiatives, and the influence of public participation and social acceptance on the attainment of project success. Therefore, in this (thesis) research the IAD-framework is a well-substantiated framework that can facilitate the research.

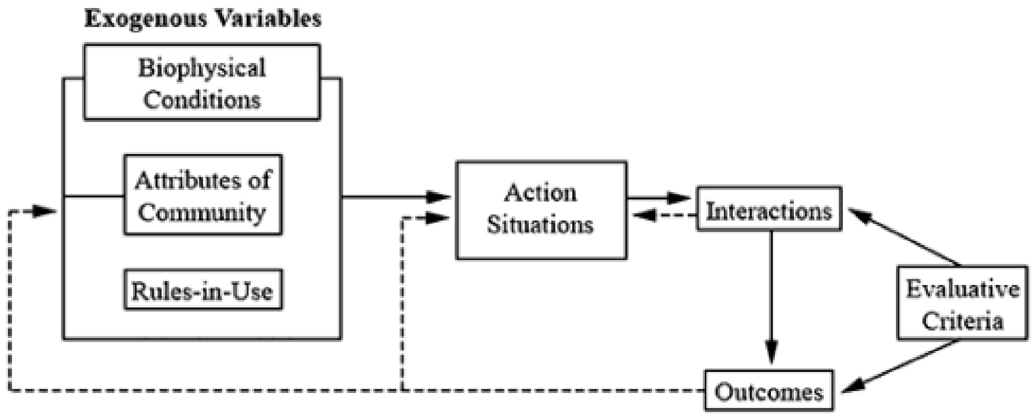

Figure 2 IAD-Framework (McGinnis, 2011)

The definitions of the different aspects of the IAD-framework are based on from Milchram, Märker, Schlör, Künneke, van de Kaa (2019):

- Biophysical/Material Conditions: The physical environment that impacts the possible actions that are taken in a given action situation, such as the use of existing infrastructure or technology.
- Attributes of Community: Socio-economic characteristics of the participants' community.
- Rules-in-use (generic rules that apply to stakeholders): Formal laws and regulations (examples of institutions), that govern and limit the behavior of participants.
- Action Situation (core of framework): The social context in which interactions occur, participants make individual decisions on their actions based on the available information, costs, benefits, and potential outcomes.
    - Actions
    - Actors (Stakeholders)/Participants: Individual actors or groups, e.g., governmental and non-governmental bodies or firms, that play a role in the action situation.
- Interactions: Procedural aspects of the interactions among participants in an action situation.
- Outcomes: The results of the interactions, which can include new institutions, knowledge, or operational outcomes, such as the adoption of new technologies.
- Evaluative Criteria: The criteria used to evaluate the interactions and outcomes, e.g., sustainability, distributional equity, or economic efficiency.

This research focuses particularly on the institutional part of a system as the 'rules of the game'. Milchram et al. (2019, p. 3) acknowledge this: "Within the IAD framework, institutions are defined as political, social, and legal "rules of the game" that incentivize (enable or restrict) actor behavior in situations which require coordination among two or more individuals or groups." The network infrastructural system herein is the electricity system and ICT-systems for smart grids. Formal rules, in the framework called 'rules-in-use', have a special importance due to the fact that energy system(s) are considered as a crucial issue of national governance and security (Milchram et al., 2019).

About the utilization of the IAD-framework in scientific literature it is said that normally its application focuses more on the traditional common pool resources study, but nowadays the framework is growing in the field of research into energy transitions (Lammers & Hoppe, 2019). Milchram et al. (2019)

also argue for this as they state that because the framework constitutes of many elements coming together in a generic approach to analyze public policies, the academic world addresses the framework to a wide variety of subject in the energy field.

One of the important challenges for researchers within the field of (institutional) climate adaptation is of bringing forth the specificities therein, by complementing the knowledge on social interactions and (in)formal rules-in-use in light of the biophysical conditions and interactions, which lacks (scientific) information currently (Roggero, Bisaro & Villamayor-Thomas, 2018).

For smart grid energy systems focus more on stakeholder interactions and conditions of the environment of the smart grid project: “The analysis has identified a gap concerning biophysical conditions and physical interactions.” (Roggero et al., 2018, p. 444). To fill these gaps one can either focus on a full coverage of the IAD-framework elements or going in depth on the single elements of the framework (Roggero et al., 2018).

The technical and institutional settings are changing. There is an increasing need to coordinate energy, resource and spatial planning. The smart grid terminology is inconsistent and vague. All these problems make the implementation of smart grid energy systems complex for the stakeholders involved, especially the local ones (Lammers & Heldeweg, 2016). The existing institutional framework is adding more complexity to the system especially because of regulatory disconnection. “To decrease this complexity, both the governance of collective action and the related legal regimes have to be addressed.” (Lammers & Heldeweg, 2016, p. 2). Hoppe and Van Bueren (2015, p. 8) state with their proposed research agenda: “addressing institutional conditions in multi-stakeholder configurations, looking into positions, ownership, institutional rules and policies”, which is acknowledged by this research.

One of the strengths of the IAD framework is the insight it gives into the effect the institutions in place, or the so-called rules in use, have on the action situation. It can help determine the optimal policy surrounding the smart grid system and help cement the best institutions. The research by Xenias, Axon, Whitmarsh, Connor, Balta-Ozkan & Spence (2015) shows that policy instability is the most important factor in unwillingness to invest. The IAD-framework can help the developers, i.e., policy makers and smart grid developers, to understand the system so that the best policy can be decided, which supplies the policy stability. This means that the IAD-framework is indeed a valuable tool in remedying the most important hurdle of the smart grid system.

2.2.1 ACTION SITUATION SPECIFICATION & IT’S RULES-IN-USE

The IAD framework is a meta-theoretical instrument that enables academics to analyze the institutional context in which decision-making occurs rather than an explanatory theory that specifies (assumed causal) links between variables (Lammers & Hoppe, 2019). The article written by Heldeweg & Lammers (2015) showed that IAD-framework could be a useful tool to help reduce complexity in local decision-making processes on smart grid implementation. All pertinent elements of the institutional context inside an action circumstance are designated by rules that are currently in use. (McGinnis, 2011). Ostrom (2011) specifies the effect of the rules-in-use as external variables on the internal structure of the action situation more in depth in Figure 3, which will be one of the core elements of this research.

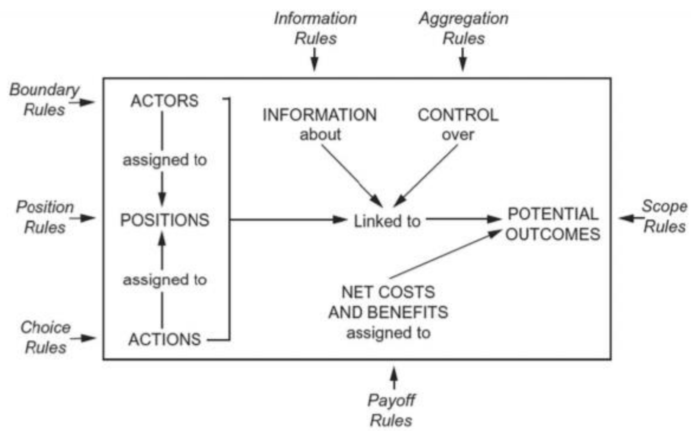

Figure 3 Specification of the effect of rules-in-use on the internal structure of the action situation (Ostrom, 2011)

Heldeweg & Lammers (2019) define the IAD framework as a conceptual instrument used to examine the impact of rules/regulations on a specific (action situation) situation. So, it is a useful tool for the type of research done in this thesis, where the 7 categories of rules-in-use will be the main focus. A detailed description of the rules as drawn by Lammers & Hoppe (2019), which is also used in the codebook (Appendix B) used in this research.

- **Boundary rules** (affect stakeholders/actors): “Specify the number of actors that participate in the local energy planning project (e.g., municipal policy officer etc.), and how those actors join and leave the decision-making process.” (Lammers & Hoppe, 2019, p. 245).
- **Position rules** (affect positions): “Specify the set op positions actors hold in the local energy planning process (e.g., project leader, network manager).” (Lammers & Hoppe, 2019, p. 245).
- **Choice rules** (affect actions): “Specify the set of actions that can (could have), may or must not (have) been taken place at specific points in time, e.g., deriving from informal agreements or from policy instruments, laws or regulations.” (Lammers & Hoppe, 2019, p. 245).
- **Information rules** (affect information): “Specify the amount and type of information available to participants (e.g., about the technology, policies, meetings, or costs- and benefits) and how this information is used and shared (e.g., boundary spanning). (Lammers & Hoppe, 2019, p. 245).
- **Aggregation rules** (affect control): “Specify how decisions are made, e.g., by an individual actor, or in collaboration with others (e.g., coalitions, co-creation).” (Lammers & Hoppe, 2019, p. 245).
- **Payoff rules** (affect net costs and benefits): “Specify the costs and benefits that derive from particular actions and outcomes, e.g., costs of project, pack-back time, distribution of costs and benefits among actors.” (Lammers & Hoppe, 2019, p. 245).
- **Scope rules** (affect potential outcomes): “Specify the set of possible outcomes, as well as jurisdiction and state of outcomes, e.g., geographic region and events affected, temporary or final status of the outcome.” (Lammers & Hoppe, 2019, p. 245).

2.3 ASI-DIAGRAM CONCEPT

In complex socio-technical systems it is all about the collaboration and interactions between the technical system, the actors/stakeholders, and the institutions. These interactions shape the behavior and dynamics of the system as a whole. In technological systems, there is a need for "rules of the game" that guide and organize the actions of individuals. These rules can be formal laws, like those governing corporations or competition, or they can be informal norms and attitudes within a specific industry. Institutions or institutional arrangements are essentially a set of guidelines that regulate the interactions between parties involved in a technological system (Koppenjan & Groenewegen, 2005).

A general visualization of this is presented in the Actors, System & Institutions diagram (ASI) in Figure 4 and will be further specified and applied to smart grids in chapter 4. This diagram is useful to generally analyze (policy analysis) complex socio-technical systems, e.g., smart grids (Enserink, Bots, van Daalen, Hermans, Kortmann, Koppenjan, Kwakkel, Ruijgh-van der Ploeg, Slinger & Thissen, 2022). This diagram is based on the visualization of Koppenjan & Groenewegen (2005) where they position institutional design in the relation between technological, institutional and process (stakeholder) design.

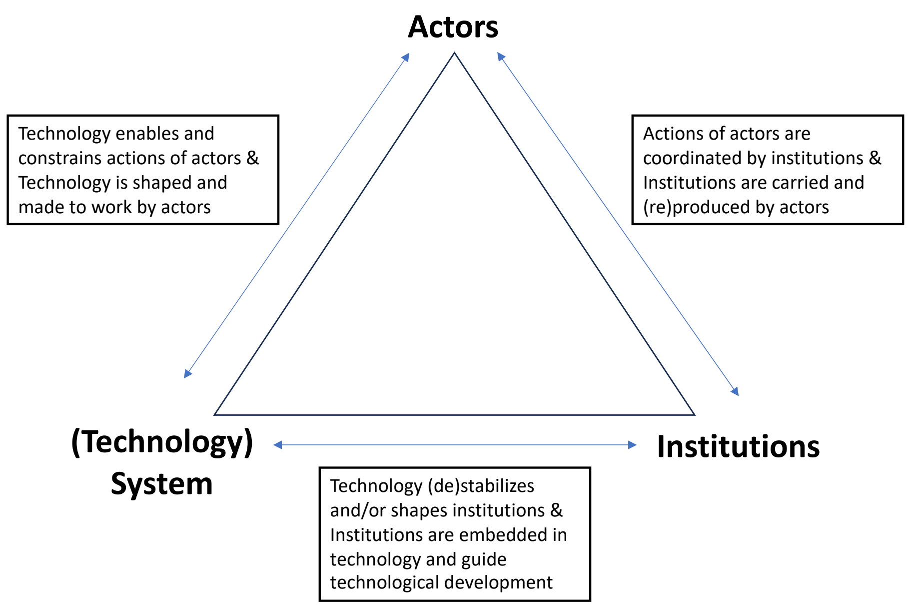

Figure 4 General ASI-diagram adopted/based on (Koppenjan & Groenewegen, 2005)

The interactions between actors, the technology system, and institutions are complex and dynamic, requiring careful analysis to understand the interdependencies and feedback mechanisms that drive system behavior and outcomes in (complex) socio-technical systems. This thesis tries to get a hand on the interactions of institutions and the other two aspects of the diagram.

3. METHODOLOGY

In this chapter the steps taken to conduct this research, combined with the applied methods, will be explored and explained. Every section of this chapter outlines the implemented actions (procedures), utilized techniques and instruments, and the methodology employed for data collection and management. The selection of the appropriate cases will also be substantiated. For additional details on coding, please refer to Appendix B that elaborates the codebook.

3.1 RESEARCH APPROACH

In this master's thesis research, the chosen research approach is the comparative case study method. Comparative case studies involve examining multiple scenarios to derive widely applicable insights, providing a comprehensive understanding of the factors influencing the success or failure of specific policies or programs (Goodrick, 2014). They are preferred when experimental design is impractical or when context-specific elements need comprehensive exploration (Goodrick, 2014). Such insights are crucial for designing effective interventions. Comparative case studies analyze and summarize patterns, similarities, and differences among cases with comparable objectives. They are guided by a theoretical framework that shapes research, aids hypothesis development, and informs interpretation of findings. Contrary to a common misconception, the case study approach values practical knowledge alongside theoretical insights, enriching theory (Flyvbjerg, 2006). This approach aids theory development, hypothesis testing, and exploration of underlying mechanisms (Kaarbo & Beasley, 1999). It uncovers commonalities and disparities across cases, revealing patterns and tendencies. This thesis research examines three distinct cases individually and through cross-case analysis, focusing on experimental smart grid technology integration initiatives. Further details are provided in the subsequent section(s).

3.2 CASE SELECTION

This master thesis research adopts a comparative case study approach, which is chosen for its suitability in understanding the success or failure of policies or programs. Comparative case studies involve analyzing multiple situations within and between different contexts over time. The theoretical framework discussed in chapter 2 sets the foundation for the subsequent steps in the research process. The next step involves selecting appropriate cases in the Netherlands to gain a deeper understanding of the subject. To determine the suitability of a case for this research, specific selection criteria are employed:

- According to the IAD-framework the **context of the projects** has to be **similar** to a certain extent in order to be able to be compared, i.e., the external variables have to be pretty much the same and constant.
- The case has to able to be categorized as an **Energy Community** according to the European Union definition, which will be further explained in chapter 4.
- A **smart electricity grid** has to be in place or planned to be in place in the near future. This can include smart meters up until smart assets depending on the case.
- It has to be in a **residential area** on a local level with an energy cooperative/energy working group consisting of residents or closely related people.

- The cases need to have an **Exemption** of parts of the Electricity Act 1998 under the **Experimentation Decree**, which also will be elaborated in chapter 4.
- The **chronology** of the cases and its **status of the exemption** matters as well to get a concise coherent mix of cases. In order to get the most insightful set of knowledge one case should be finished, one ongoing project and a future project with regards to the exemption under the Experimentation Decree.
- Given the **time limitations** inherent to the master's thesis, the analysis and comparison will focus on only three cases. These cases will be selected based on the research objective, with the intention of showcasing divergent outcomes.

Therefore, this thesis will focus on cases of experimental projects implementing smart grid technologies. An overview of possible projects can be found on the Netherlands Enterprise Agency website (in Dutch: Rijksdienst voor Ondernemend Nederland (RvO)) (2017a). In total 18 projects got an Exemption under the Experimentation Decree. Considering all these criteria the following three projects are chosen to be analyzed in this research: *Schoonschip Amsterdam, GridFlex Heeten and Groene Mient The Hague.*

3.3 DATA COLLECTION

The primary objective is to provide an overview of the methods used for data collection that are appropriate for addressing the sub-research questions outlined in chapter 1. Each method is briefly described and justified in relation to its relevance. These selected methods will serve as the foundation and input for applying the Institutional Analysis and Development framework, which aims to provide a comprehensive answer to the main research question.

Literature study (desk research)

In the preliminary stages, it is imperative to establish a robust theoretical foundation concerning the institutional framework underpinning this investigation, as well as its intricate interrelation with technology and the spectrum of stakeholders involved. The initial phase of data acquisition for this study entailed an exhaustive examination of extant literature. A portion of the crucial information was obtained through an analysis of academic and grey literature, which made it possible to compile pre-existing sources from a variety of sectors (Lawrence, Houghton, Thomas & Weldon, 2014).

Document analysis assumes a systematic and structured methodology wherein documents are rigorously perused and critically assessed. Document analysis requires data to be reviewed and interpreted in order to elicit meaning, gain insight, and create empirical knowledge, just like other analytical methods in qualitative research (Bowen, 2009). Therefore, document analysis is a supporting method for the literature study using grey literature get the needed knowledge for the context of the selected cases in this research.

Semi-structured interviews

To obtain additional crucial information for especially the case (studies) interviews are needed. For this purpose, fourteen in-depth interviews were held with a variety of people, from field/academic experts to people living at the analyzed projects. According to Döringer (2021) (expert) interviews are an excellent qualitative research method that is widely used with the aim to acquire knowledge about an action within the field you are interested in. Meuser & Nagel (2009, p. 17) say that expert interviews “as a method it appears to be ‘quick, easy, and safe’ in its application, and it promises to be of good practical value.” The interviews were semi-structured which benefitted from being adaptable (Rabionet, 2011).

Microsoft Teams is used as the main technology for conducting and recording most of the interviews. Some of the interviews have been in person and recorded only with audio. In total fourteen interviews have been conducted for the knowledge of this research. The interview transcripts are made as a summary of the interview manually by the researcher. All the interviews have been taken approximately one hour of conducting the interview with an additional few hours per interview for transcribing. In accordance with the approved Data Management Plan form the Human Research Ethics Committee, the interview transcripts and potential recordings were saved during the research on the TU Delft One Drive. An anonymized overview of the interviewees can be found in Appendix A where variety of interviewees can be seen, from case related people to field and academic expert. Furthermore, in Appendix A a brief description of the overall topics of the related questions and the interview consent form the interviewees needed to sign prior to the interview can be found.

3.4 DATA ANALYSIS

Data analysis is an integral part of quantitative and qualitative research. In this paragraph the data analysis is explained for this research. Firstly, the used institutional rules are explained and its influence on the outcomes of the case studies, which are core in the IAD-framework. Secondly, data treatment is discussed as deductive coding using a qualitative data tool.

3.4.1 OPERATIONALIZATION

In the context of smart grid research aligned with the IAD-framework, crucial outcomes (Milchram et al., 2019) arise from interactions, encompassing novel institutions, knowledge, and operational results like the integration of smart grid-ready assets (flexibility options), sustainability, and energy-economic efficiency. Evaluative criteria encompass interaction and outcome assessment. Additionally, goal attainment, comparing initial project aims with realized outcomes during the analysis timeframe, is pivotal (Lammers & Hoppe, 2019). This operationalization captures the multifaceted dimensions of smart grids within the IAD-framework, including their transformative impacts and evaluation parameters.

In measuring outcomes pertaining to smart grid projects, a comprehensive operationalization involves distinct indicators aligned with key dimensions. For implementation of smart grid ready assets (flexibility possibilities), quantification encompasses asset integration rate, dynamic load balancing effectiveness, and demand response participation. Sustainability is gauged through reduction in carbon emissions, renewable energy utilization, and grid resilience enhancement. Energy and economic efficiency involve metrics like peak shaving, cost savings, and energy loss reduction. Evaluating goal attainment necessitates comparing predefined project objectives against actual achievements. This holistic framework enables a nuanced assessment of smart grid project outcomes, capturing their technical, environmental, and socioeconomic implications. This assessment will be done for each case individually in chapter 5, 6 and 7.

3.4.2 DATA TREATMENT: CODING

Qualitative data coding is done to analyze the interview transcripts methodically. The practice of coding qualitative data based on pre-existing beliefs or notions is known as deductive data coding (Fereday & Muir-Cochrane, 2006). It entails putting a pre-made coding scheme derived from pre-existing theoretical frameworks or research questions to use on the data. ATLAS.ti is a well-known qualitative data analysis program that makes coding and analysis easier (Friese, Soratto, & Pires, 2018), therefore it is used in this thesis research. Two main reasons for deductive data coding:

- Theory-driven analysis: Deductive coding aligns with a theory-driven approach to qualitative data analysis. It enables researchers to examine how well existing theories or concepts apply to their data and explore any variations or discrepancies that may emerge. By applying pre-existing codes, researchers can evaluate the relevance, applicability, or modification needed in established theories (Fereday & Muir-Cochrane, 2006).
- Conceptual frameworks: Deductive coding often involves using pre-established conceptual frameworks as a basis for coding. These frameworks can stem from various sources, such as prior research, established theories, or relevant literature. By aligning the data with these frameworks, researchers can explore how well the data fits within or challenges the existing concepts, enhancing the rigor and reliability of the analysis (Fereday & Muir-Cochrane, 2006).

The pre-defined codes that have been applied to the interviews transcribed for this research can be found in Appendix B (Codebook) in Table **12** Codebook used with Atlas.tiTable 12. This codebook is partly adopted from Lammers & Hoppe (2019) and Milchram et al. (2019). These codes have been used for the three case analysis to be able to compare them.

3.5 COMPARATIVE CASE ANALYSIS

After three extensive within case analyses a comprehensive cross case analysis will be done, by means of the parts of the IAD-framework. Next, to gain insights in the interrelations of technology, actors and institutions, as described in section 2.3, Table 11 shows these relations with regards to its influence (+/-) to the cases. The concepts are mainly based on the ASI-diagram and its usefulness which has a scientific foundation (Enserink et al., 2022; Koppenjan & Groenewegen, 2005). The goal attainment of each case is added to this in section 8.2 as this is an important outcome and evaluative criterion of the cases for the research.

4. SMART GRIDS IN THE NETHERLANDS

The implementation of a smart grid in the Netherlands has the potential to revolutionize the country's energy system by enhancing efficiency and reducing carbon emissions. However, the successful implementation of such a system requires an understanding of the institutional arrangements that govern the behavior of actors involved in the process. This chapter tries give an overview of the institutional environment in which the implementation of a smart grid in the Netherlands take place.

4.1 THE CONVENTIONAL DUTCH ELECTRICITY SYSTEM

The liberalized Dutch electricity system, implemented in the late 1990s, with the Electricity Act (1998) and the Gas Act (2000) significantly changed the Dutch energy world by allowing customers to choose their own energy supplier and aimed to introduce competition and efficiency in the electricity market (Tanrisever, Derinkuyu & Jongen, 2015). It involved separating generation, transmission, distribution, and supply functions. In 2007 came the legal obligation to completely separate grid management and energy production and supply (Independent Grid Management Act). Market mechanisms such as power exchanges and bilateral contracts were established, allowing for competition among market participants. Regulatory authorities were put in place to ensure fair competition and protect consumer interests. The system promoted innovation, renewable energy deployment, and the development of smart grid technologies. However, challenges such as market concentration and price volatility emerged, requiring effective regulation (Tanrisever et al., 2015). Overall, the liberalized Dutch electricity system transformed the market, creating a competitive environment that aimed to benefit consumers and promote sustainable energy practices.

Transition of the old electricity system to the new one, driven by climate change considerations, involves the integration of smart grids. Smart grids play a crucial role in facilitating the efficient integration of renewable energy sources and optimizing energy consumption (Colak, 2016). They enable real-time monitoring, automation, and demand-response capabilities, allowing for the effective management of energy supply and demand. The transition to smart grids requires not only upgrading infrastructure but also implementing advanced communication and information technologies. Additionally, stakeholder engagement and collaboration are essential to ensure a smooth transition, as the involvement of energy companies, policymakers, regulators, and local communities is vital in driving the adoption of smart grid technologies and supporting the transition to a cleaner and more sustainable energy system (Kern & Howlett, 2009). Therefore, in the next section a first exploration of the current Dutch smart grid field will be executed.

(Interviewee #10) The current congestion problems in the electricity grid stem from excessive government subsidies leading to a large influx of new projects, particularly in the west. As a result, projects began shifting to the east, which lacks adequate grid capacity due to land scarcity, high land prices, and reduced production capacity. Grid managers pass on the costs of this grid shortage to customers through increased grid tariffs, causing them to bear the financial burden of the subsidy-induced problems.

4.2 SMART GRIDS IN THE NETHERLANDS: A FIRST EXPLORATION

A smart grid can be considered as a complex socio-technical system (Wolsink, 2012) and "smart grid innovation is currently still not considered a mainstream technology in the energy transition, and there is little attention to the role of end-users." (Norouzi, Hoppe, Kamp, Manktelow & Bauer, 2023, p. 1). In this section the (current) status of smart grids in the Netherlands will be briefly explored with the help of an ASI-diagram that is adapted to the main framework (IAD) of this thesis research and based on Koppenjan & Groenewegen (2005) as can be seen in Figure 5.

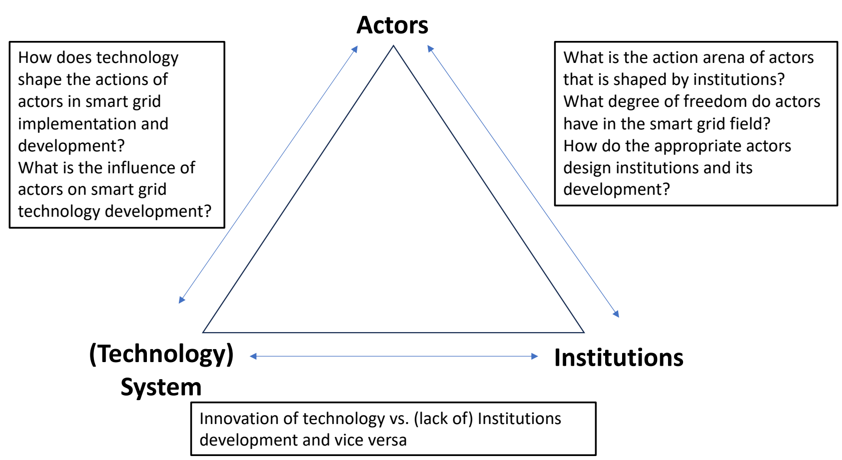

Figure 5 Smart Grid ASI Diagram

This diagram consists of the following parts: (Technology) System, Institutions, Actors (stakeholders). The main purpose of this diagram is to get a hand on the understanding of the interaction between each part of the diagram. The related questions stem from the Institutional Analysis and Development framework, which is described in section 2 of this research.

Firstly, the interaction between the technical system and actors raises the questions of how does technology shape the actions of actors in smart grid implementation and development? And what is the influence of actors on smart grid technology development?

Secondly, the interaction of the actors and the institutions is an important notion to understand, grasping the questions what is the action arena of actors shaped by institutions? What degrees of freedom do actors have in the smart grid field? And how do the appropriate actors design institutions and its development?

Lastly, the interaction of the technical system and the institutions in place has to be understood. What is the development of innovation of technology vs. (a lack of) institutions and vice versa? This diagram will be applied to the cases in section 5, 6, 7 and 8 of this (thesis) research.

The need to understand the interactions between all these aspects are also clearly argued for by Heldeweg & Lammers (2019) as they explain that local smart energy systems are complex and require the integration of various stakeholders, including energy providers, consumers, regulators, and policymakers. In order to develop effective institutional arrangements for these systems, it is necessary to take into account both legal and institutional factors.

4.2.1 SMART GRID PREDECESSOR(S)

The Netherlands is known for allocating a significant amount of public funding towards smart grid demonstration projects in the European Union. For instance, the country conducted twelve pilot projects as part of the 'Innovation Program for Smart Grids' (short IPIN) between 2011 and 2016, which is a Dutch predecessor of Smart(er) Grid projects. The urgency surrounding the need for flexibility in the electricity system, as highlighted by IPIN, was initially recognized but eventually lost (interviewee #9). The economic value of flexibility is crucial for smart grids to gain significance, as otherwise, gas turbines become the default solution. The recent gas crisis has brought about a renewed sense of urgency, but predicting and addressing future urgencies requires focused innovation programs with sufficient financial and organizational support. A change in the cabinet diminished the urgency of the previous IPIN initiative. The interviewee (#9) anticipates that only when blackouts occur, people will realize the lack of innovation and investment in the electricity grid, prompting a greater focus on smart grid potential.

4.2.2 SMART GRID DEVELOPMENT IN THE NETHERLANDS

Adapted from Norouzi et al. (2023, p. 1): *Diagnosis of the implementation of smart grid innovation in the Netherlands and corrective actions.* Acknowledged by interviewee #12.

"**(innovation-oriented analysis) Weakly fulfilled functions:** Knowledge diffusion, creation of legitimacy and market formation

(transformational-oriented analysis) Observed transformational failures: Policy coordination failures as the lack of coordination across various policy levels which can lead to incoherence in policy implementation of deviation of strategies.

→ Leads to:

- Despite policy support there is neither market formation nor creation of legitimacy.
- Insufficient knowledge exchange between end-users and entrepreneurs.
- The lack of platforms for learning about smart grids.
- The absence of powerful actors in creating a strong network."

Adapted from Norouzi et al. (2022, p. 1): *Review on Socio-Technical Barriers of Smart (micro)Grid Development.* Acknowledged by interviewee #12.

"**Regulatory and policy barriers:** market structure, market performance barriers, cybersecurity & privacy issues, investment barriers, incentives for consumers, conflicting incentives between renewable energy sources, traditional generators and network operators.

Social acceptance and institutional barriers: acceptance at multiple levels in society, acceptance of SGs and community energy, ownership and involvement, institutional economic barriers and complexity of decision making.

Technical barriers: smart devices and requirements, need for frameworks to reduce complexity in design and need for assessment.

Conclusion: Although technical requirements can be improved by alternative solutions, smart (micro)grids mostly suffer from lack of incentives from actors to invest, unregulated interaction of actors in the emerging market, institutional lock-in, and social acceptance of smart (micro)grids."

4.3 ENERGY COMMUNITIES

Energy communities, also known as energy cooperatives or energy collectives, are emerging as a sustainable and community-driven approach to energy production and consumption. The need for energy communities to take an important role in the development of smart grids especially in the Netherlands poses great potential (Diestelmeier & Swens, 2021), therefore, in this section the concept and importance of energy communities will be briefly described and discussed.

“One approach to realize decentralized energy solutions is through a (citizen) energy community where the members control the community to provide environmental, economic, or social benefits to the community or the local area.” Reijnders, van der Laan & Dijkstra, 2020, p. 138).

Van Summeren, Wieczorek & Verbong (2021) note that energy communities can mobilize ICT to change how technology functions, strengthen collaboration to increase collective agency, and support their efforts to create, disrupt, or maintain institutions. Energy Communities will obtain a great importance in the future energy system. It may be required to build a framework for supporting energy communities, especially in light of the fact that energy communities are expected to serve a wider role than the traditional operations (production, supply, and distribution) (Swens & Diestelmeier, 2022).

Swens & Diestelemeier (2022) make a legal distinction between Renewable Energy Community (REC) and Citizens Energy Community (CEC)[1] as described in the new European Clean Energy Package (CEP), with its corresponding Renewable Energy Directive II (REDII) and Internal Electricity Market Directive (IEMD). This distinction is inspired by the different goals in RED II and IEMD: “The differences between REC and CEC are inherent to the leading goals associated with the RED II and IEMD that define REC and CEC, respectively. The IEMD generally focuses on completing the internal energy market, with the new paradigm of the consumer/citizen at its center, while the objective of the RED II is to promote renewable energy generation.” (Tarpani, Piselli, Fabiani, Pigliautile, Kingma, Pioppi & Pisello, 2022, p. 3). Energy communities have to provide environmental, economic, or social community benefits for its shareholders

1 ***Renewable Energy Community (REC)*** under the Directive on the promotion of renewable energy sources: Directive (EU) 2018/2001 article 2(16) (derived from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG)
(16) ‘renewable energy community’ means a legal entity:
(a)which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity;
(b) the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities;
(c)the primary purpose of which is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits;

Citizen Energy Community (CEC) under the Directive on common rules for the internal market for electricity: Directive (EU) 2019/944/… article 2(11) (derived from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019L0944)
(11) ‘citizen energy community’ means a legal entity that:
(a)is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises;
(b)has for its primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and
(c)**may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders**;

or members or for the local areas where it operates, rather than financial profits, (Electricity Directive, Article 2.11b; Renewable Energy Directive, Article 2.16c.)

“The framework of energy communities reflects the need to find an alternative solution for better organizing and governing energy systems while finally delivering a stable network where long-distance and local energy production compensate for each other.” (Tarpani, Eelke Kingma et al., 2022)

Energy communities according to Reijnders et al. (2020, p. 139):

- “According to the European Commission, a **Citizen Energy Community** is citizen energy community’ means a legal entity that: “(a) is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises; (b) has for its primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and (c) may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders; [Article 2 of the Electricity Directive].
- In the same directive the European Commission also speaks about **Renewable Energy Communities**. These can generally be seen as a subset of citizen energy communities, as the members of renewable energy communities need to be located in the proximity of renewable energy projects owned and developed by the community. This indicates that there are more stringent requirements to become a renewable energy community.”

All the cases in this research are considered as Citizen Energy Communities and to some extent also Renewable Energy Communities.
Interviewee #8 stated that: The ‘new’ concept of Energy Communities within the EU Directives (CEP, REDII and IEMD) creates possibilities for member states, because the definition is not straight forward, and each member state can define an Energy Community itself.

4.4 EXPERIMENTATION DECREE

The Experiments Electricity Act 2015-2018 (in Dutch: Experimenten Elektriciteitswet 2015-2018) (hereafter called (Exemption under the) Experimentation Decree) was a regulatory framework implemented in the Netherlands to encourage innovative and experimental approaches in the electricity sector (RvO, 2017b). The experiments aim to explore new business models, technologies, and market arrangements to support the transition towards a more sustainable and flexible energy system. Under this framework, selected projects are granted exemptions from certain provisions of the Electricity Act 1998, allowing them to test and demonstrate new concepts. These exemptions provide flexibility in areas such as market participation, grid connection, tariffs, and balancing responsibilities. The experiments cover various aspects of the electricity sector, including decentralized energy production, demand response, energy storage, and peer-to-peer energy trading. The goal is to gather insights and practical experience to inform future policy and regulatory decisions. By enabling these experiments, the Dutch government aimed to foster innovation, promote renewable energy integration, and explore the potential of emerging technologies and business models. The knowledge gained from the experiments was expected to contribute to the development of a more sustainable, reliable, and cost-effective energy system in the Netherlands.

According to the Experimentation Decree, homeowners' associations or cooperatives can set up two types of projects based on the size of their connected customer base (Swens & Diestelmeier, 2022). The first type, called 'project grids' are limited to 500 connected customers, have one connection to the public distribution system, and are located within a specific geographic area (Experimentation Decree Article 1) (Ministry of Economic Affairs, 2015). Owners of project grids can construct, own, and operate their local grid. The second type, called 'large experiments', can have a maximum of 10,000 connected customers and are not limited to a specific site. They can operate virtually within the service area of a DSO. However, in the case of 'large experiments', the asset management of the grid remains the responsibility of the DSO (Experimentation Decree Article 2) (Ministry of Economic Affairs, 2015; interviewee #2; interviewee #4; interviewee #5).

Stated by Swens & Diestelmeier (2022); interviewees (#1, #6, #9 & #10): In the context of the exemption, both project grids and large experiments would be automatically granted a license to supply energy to small customers, a privilege typically reserved for energy market parties, e.g., larger energy companies. Furthermore, both types of projects could set their own network tariffs without needing prior approval from the Dutch National Regulatory Authority, which would only need to approve the method of calculation rather than the tariffs themselves. The Decree was established as a 'regulatory sandbox', meaning that the number and duration of projects were restricted to 10 'project grids' and 10 'large experiments' annually, with a maximum duration of 10 years (van der Waal, Das & van der Schoor, 2020).

Interviewee (#1); Interviewee (#10); Swens & Diestelmeier (2022): The Experimentation Decree was initially intended to be available for four years (2015-2018), with the possibility of an additional four-year extension. However, due to a negative recommendation from the Council of State, the Decree was not extended (source:...kamerstuk....). The Council of State's main criticism was that the Decree may be incompatible with EU energy law, particularly the 2019 Electricity Directive, which had not yet been incorporated into Dutch law. It was argued by the Council of State that transposing EU law would render another regulatory sandbox for this purpose unnecessary.

4.5 INTRODUCTION EU LEGISTLATION

The EU CEP, REDII, and IEMD are three important legislative initiatives in the European Union (EU) related to energy and the environment. Here's an overview of each:

1. EU CEP (Clean Energy Package): The Clean Energy Package is a comprehensive set of legislative measures introduced by the European Commission to accelerate the clean energy transition in the EU. It consists of eight legislative acts and was adopted in 2018. The key objectives of the EU

CEP include promoting renewable energy, improving energy efficiency, empowering consumers, and enhancing the functioning of the energy market (European Commission Directorate-General for Energy, 2019a).

The EU CEP introduces new targets for renewable energy, with a binding target of at least 32% renewable energy by 2030 across the EU (European Commission Directorate-General for Energy, 2019a). It also sets energy efficiency targets and requires member states to establish long-term strategies to support the transition to a low-carbon energy system. The package also includes provisions to strengthen consumer rights, facilitate energy storage, and improve the functioning of electricity markets. According to Reijnders et al. (2020, p. 140): "citizen energy communities, as further described in the recently adopted Clean Energy Package of the European Union (EU). This new energy rulebook gives an obligation to the EU countries to adapt their legislation to allow for citizen energy communities. Because of this, these communities turn into official legal entities having corresponding rights. With the Clean Energy Package, citizen energy communities obtain rights to

- generate, consume, and sell their own renewable energy;
- share energy within the community; and
- engage in individual and "jointly acting" self-consumption."

2. REDII (Renewable Energy Directive): The Renewable Energy Directive, also known as REDII, is a specific directive within the EU CEP that sets out the legal framework for promoting renewable energy in the EU. It replaces the original Renewable Energy Directive (RED) adopted in 2009. REDII establishes binding national targets for renewable energy and introduces measures to promote the use of renewable energy in heating and cooling, transport, and electricity generation (European Commission Directorate-General for Energy, 2018).

Under REDII, EU member states are required to establish national renewable energy action plans and develop support schemes to incentivize the deployment of renewable energy technologies (European Commission Directorate-General for Energy, 2018). The directive also enhances cooperation mechanisms between member states.

3. IEMD (Internal Electricity Market Directive): The Internal Electricity Market Directive is another component of the EU CEP. It aims to create a more integrated and competitive internal electricity market within the EU (European Commission Directorate-General for Energy, 2019b). The directive builds on the previous legislation, the Third Energy Package, and introduces measures to further liberalize and harmonize the electricity market across member states.

The IEMD includes provisions to enhance market functioning, increase cross-border electricity trade, improve grid access and infrastructure development, and strengthen the role of consumers. It promotes the integration of renewable energy sources, demand response, and energy storage in the electricity market (European Commission Directorate-General for Energy, 2019b). The directive also establishes regulatory frameworks for network codes, market coupling, and regional cooperation among transmission system operators.

These legislative initiatives, the EU CEP, REDII, and IEMD, represent the EU's commitment to advancing the transition to clean and sustainable energy systems, promoting renewable energy, enhancing market competition, and empowering consumers. The implementation of these directives in member states helps drive the EU's energy and climate goals.

4.6 INTRODUCTION THE NEW DUTCH (DRAFT) ENERGY LAW

Interviewee #8: The Ministry of Economic Affairs & Climate Policy commissioned to increase the developments within the energy transition, current context new Energy Law which puts the Electricity and Gas Acts together, which contents will be updated. This is a rigorous modification.

Currently, the Netherlands is undertaking a comprehensive reform of its energy sector legislation, which involves revising existing laws and merging the Gas Act and the Electricity Act to establish a unified Energy Act (interviewee #10). However, the transposition of the Renewable Energy Directive and the Electricity Directive into national legislation is still pending. “The deadline for the transposition of the Renewable Energy Directive was 31 December 2020 and for the Electricity Directive 30 June 2021.” (Swens & Diestelmeier, 2022, p. 68).

The Dutch energy law refers to the legal framework governing the energy sector in the Netherlands. It encompasses various laws, regulations, and policies that aim to ensure a secure, sustainable, and efficient energy system. The Ministry of Economic Affairs and Climate Policy aimed to develop this new legislation based on old gas and electricity laws from 1998. However, after two years of research, these foundations were found to be outdated (interviewee #10). The Dutch energy law focuses on several key aspects, including (Minister of Economic Affairs & Climate Policy, 2021):

1. Energy Market Regulation: The law establishes rules and regulations for the liberalized energy market in the Netherlands. It governs the production, distribution, and supply of electricity and gas, and promotes competition and fair market practices.
2. Renewable Energy Promotion: The Dutch energy law includes provisions to promote the development and integration of renewable energy sources. This may involve support mechanisms, such as feed-in tariffs, renewable energy certificates, or auctions, to incentivize the deployment of renewable technologies.
3. Grid Management: The law addresses the operation, maintenance, and expansion of the energy grid infrastructure. It outlines the responsibilities of grid operators in ensuring reliable and efficient energy transmission and distribution, as well as facilitating grid access for market participants.
4. Consumer Protection: The law includes provisions to protect energy consumers' rights and ensure transparency in energy pricing, billing, and contractual agreements. It may establish mechanisms for dispute resolution, switching suppliers, and providing consumers with access to reliable and accurate energy information.

5. Environmental Considerations: The energy law addresses environmental considerations, such as reducing greenhouse gas emissions, promoting sustainable practices, and supporting the integration of environmental goals into the energy sector.

A revised version of the Energy Law was introduced in November 2021 (Minister of Economic Affairs & Climate Policy, 2021). Rather than distinguishing between the EU legal terms REC and CEC, the Dutch lawmaker opted to solely define the term Energy Community (referred to as 'energiegemeenschap' in Dutch) (interviewee #10). The definition states that an Energy Community is a legal entity that engages in energy market activities with the aim of benefiting its members or shareholders, as well as the local areas in which it operates, in terms of environmental, economic, or social advantages, rather than pursuing profit (Swens & Diestelmeier, 2022). The lagging Dutch development highlights the slow pace and lack of knowledge in legislation, which could lead the Netherlands to face difficulties. In comparison, the EU, specifically Brussels, moves at a faster pace. The Clean Energy Package, finalized in Brussels in 2019, required member states to implement it within 18 months (by December 2020). Due to mistakes made, the Netherlands is estimated to implement it only by January 2025, indicating a lag in adapting to Brussels' standards, such as in the case of energy sharing and supply.

4.7 CONCLUDING REMARKS

The study by Tarpani et al. (2022) identifies five key pillars for the development and increase in the number of energy communities, which are linked to regulations, economic advantages, technical constraints, sustainability, and social consciousness. These results emphasize the significance of policy management and highlight the challenges faced by government in assisting policymakers and specialists in facilitating the transition towards sustainable energy (Tarpani et al., 2022). In the Netherlands, "energy communities" are not explicitly defined by existing laws, but in EU legislation, e.g., CEP, REDII and IEMD, recognized citizen associations such as cooperatives are permitted to establish and possess local power networks, as well as engage in the electricity market with limited rights (Tarpani et al., 2022). The regulatory framework of the Netherlands and its relative success depend on two regulations: the Electricity Act (1998) and the Experimentation Decree (Exemption Policy) (2015-2018), to which SSA, GFH and GMDH are subjected to as legal experiments. Attempts to implement a second (follow-up) Experiment Decree have failed so far, but to some extent this will be covered by the new comprehensive 'Energy Law', that comprises the old Electricity & Gas Act (1998) (interviewee #10).

The conclusion of the study by Tarpani et al. (2022) is: Implementing a successful energy community implementation requires the presence of a supportive policy framework, having clear legal and regulatory rules, financial incentives, and strong local engagement and participation.

Interviewee #9: As a society we have a well-established technical perspective and sufficient knowledge of how local matching of electric supply and demand works, but the futuristic efforts should go to the question of how to organize this.

Concluding, the implementation of a smart grid in the Netherlands offers transformative potential, enhancing energy efficiency and carbon emissions reduction. However, its success hinges on understanding institutional dynamics. The country's liberalized electricity system, established in the late 1990s, fostered competition, innovation, and renewable energy growth, yet challenges like market concentration arose. Smart grids are pivotal for integrating renewables and optimizing energy use, demanding advanced technology and stakeholder collaboration. Energy communities, recognized by EU legislation, can play a pivotal role, necessitating legal clarity. The Experiments Electricity Act (2015-2018) promoted innovation, but its extension was rejected due to potential conflict with EU law, which not seemed to have happened so far. The Dutch government is working on a new comprehensive Energy Law to align with EU directives, emphasizing policy support and local engagement for successful energy community implementation.

5. SCHOONSCHIP AMSTERDAM (SSA)

In this section of this thesis, the Schoonschip case will be analyzed, first as a within-case analysis through the IAD-framework, and afterwards, in chapter 8, it will be compared in a cross-case analysis and concluded using the ASI diagram. The most important information about each case will be in its case description and IAD framework, some additional (theoretical) background information will be in the appendix.

5.1. GENERAL CASE DESCRIPTION

Schoonship is a unique sustainable initiative in Buiksloterham where a community of self-builders had decided to come together and create a neighborhood of houses on the Johan van Hasseltkanaal, a side channel of the IJ-river. The project consists of 46 floating homes, on 30 'arks', which are all designed to be self-sufficient in terms of energy and water usage at the household level, accommodating approximately 144 residents (Schoonschip Amsterdam, 2023).

A key characteristic of Schoonschip Amsterdam is its commitment to sustainability. Homes are designed to be as energy-efficient as possible, using features like triple-glazed windows, solar panels, and heat recovery systems to minimize energy consumption. The community also owns and operates a smart grid that allows residents to share excess energy with each other and feed it back to the grid. In addition, the homes use a decentralized wastewater treatment system, which uses natural processes to treat and reuse wastewater.

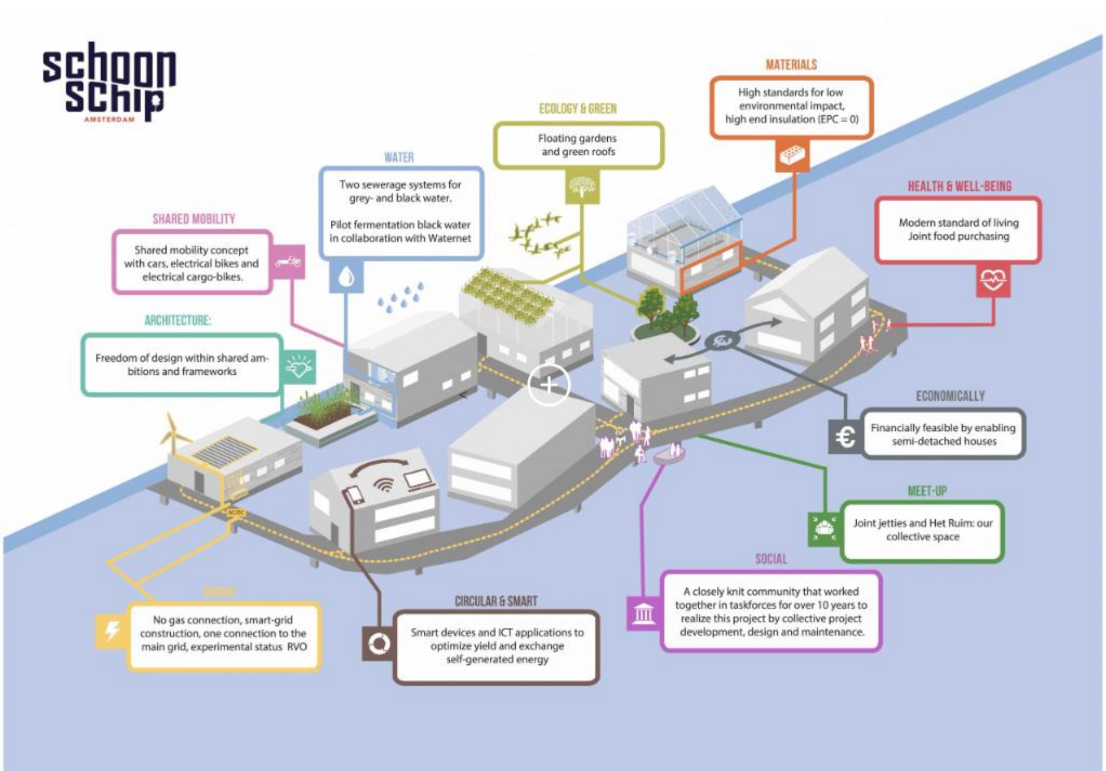

Figure 6 Schoonschip Amsterdam socio-technical system (source: Metabolic & https://schoonschipamsterdam.org/)

Key takeaways from Figure 6:

- Energy: No gas connection, smart-grid construction, one connection to the main grid, and experimental status RVO (i.e., Experimentation Decree)
- Circular & Smart: Smart devices and ICT applications (such as algorithms for electricity exchange etc.) to optimize yield and exchange self-generated energy.

5.2. OVERVIEW SCHOONSCHIP SMART GRID EXPERIMENT

According to Van der Waal et al. (2020): In 2016, a project of project scale was undertaken by a Homeowners' Association. The project aimed to implement various components, including an Energy Management System (EMS), renewable energy generation, battery systems, heat pumps, heat storage in buffers, and smart appliances. These elements have been successfully implemented in Schoonschip Amsterdam. The project involved the construction of 46 water houses. A more elaborate case overview can be found in

Table **2**.

Table 2 General Schoonschip case overview (adapted from Van der Waal et al., 2020)

Category	Description
Project Type	Project grid
Delineation	In the Amsterdam neighborhood of Buiksloterham, which is a city district that produces many sustainable building projects, Schoonschip is a homeowners' association (HOA; Dutch: Vereniging van Eigenaren) of the owners of 46 houseboats and one common boat.
Organization & Governance	The project commenced with a founding group of friends, which subsequently expanded to include additional friends and acquaintances. Beyond the pursuit of renewable energy, the project encompasses supplementary objectives, e.g., wastewater treatment and the utilization of recycled materials in construction. Daily decision-making responsibilities lie with the HOA's board. Working groups have been established to oversee specific aspects, such as the construction process. These working groups engage members by delivering presentations to ensure broad involvement. Certain decisions require the presence of all HOA members. *As stated in the interview (#1) most of the decisions/advises by these working groups are directly copied and adapted by the HOA. Therefore, it could be stated that the energy working group (in)directly takes the decisions with regards to the smart grid and all the energy related stuff.*
Energy System	The houseboats in this project are fully electric and connected to the national grid through a single connection. They are integrated into a project grid framework. The HOA generates electricity using individually owned solar panels. Each ark is equipped with batteries, which are collectively owned. Future plans involve the implementation of shared electric vehicle fleets. As a collective, the administration and portion of the maintenance are carried out in SSA. Every household is equipped with an energy management system (EMS), and a smart grid is established. The smart grid is part of a consortium initiative supported by external expertise that aims to optimize smart grid technologies and algorithms. Demand management strategies do not incorporate dynamic tariffs. Instead, efficiency is achieved through the utilization and storage of electricity during periods of high production facilitated by the smart grid *(this is different than GFH & GMDH where dynamic tariffs are the core business)*. The result of the energy management is to supply electricity to the main grid at the highest possible price.
Use of exemption under experimentation decree	The HOA functions as a producer, distributor, and supplier of electricity. The administration of electricity demand and supply is outsourced to a commercial electricity provider, Greenchoice. As a balance responsible party, Greenchoice is responsible for managing electricity demand and supply, ensuring an adequate supply during shortages and purchasing surplus electricity.

A more elaborate (scientific) information of Schoonschip can be found in Appendix C.

5.2.1 CHRONOLOGIC PROJECT OVERVIEW OF KEY (DECISION-MAKING) EVENTS

- 2008: First inspiration for a floating sustainable 'houseboat' and to establish a collective citizen initiative.

- 2009: The Schoonschip Association receives subsidy from the 'Stuurgroep Experimenten Volkshuisvesting' and hires consultancy 'De Regie' in order to get the first version of the project plan.
- 2010: A location is selected after a search of two years: the Johan van Hasseltkanaal in the area Buiksloterham in the North of Amsterdam.
- 2010: The Schoonschip foundation is established.
- 2011: Start of a feasibility study about the location by Space&Matter and Waterloft. Separately a feasibility study into the sustainability aspirations.
- October 2013: Schoonschip wins a tender of the Municipality of Amsterdam for allocating the location where it is built now in Amsterdam-North.
- May 2016: GridFriends collects a subsidy funded by the EU for a research project in order to set a new standard in the smart grid technology. Schoonschip is one of their 'test facilities' to realize a CO2-'neutral' living area (GridFriends EU subsidy 1 mln euro). Their goal with this is to enable local (energy) cooperatives to maximize their self-sufficiency.
    - What is GridFriends: "Grid-Friends is led by Centrum Wiskunde & Informatica (CWI) and includes the Fraunhofer Institute for Industrial Mathematics (ITWM) from Kaiserslautern, the companies Spectral Utilities and Evohaus, and the Schoonschip Foundation. The project is funded through the joint programming initiative ERA-Net Smart Grids Plus, with support from the European Union's Horizon 2020 research and innovation programme." (Amsterdam Smart City, 2016).
- July 2016: Request for the environmental permits to start building the floating homes etc. are sent to the municipality to get approval.
- October 2016: Schoonschip, under the name of Cooperative Management and Operating Association Schoonschip U.A. (in Dutch: Coöperatieve Beheer- en Exploitatie Vereniging Schoonschip U.A.) see Figure 9, is awarded the Experimentation/Exemption Policy status so they can 'independently' experiment with their smart electricity/energy system concept (RvO, 2016).
- March 2018: The Schoonschip homeowners' association (HOA) is established.
- December 2018: The first arks are brought in.
- March 2019: The first residents start living in the Schoonschip area (i.e., in the floating homes).
- 2020: The last arks are brought in in January 2020, so the project delivery is finalized.

5.3. INSTITUTIONS: IAD-FRAMEWORK AND RULES-IN-USE RESULTS

In this section the IAD-framework will be applied to the Schoonschip case. The exogenous variables consist of biophysical/material conditions, attributes of community and the rules-in-use which will be elaborated first.

Action situation

The action situation of Schoonschip consists of the environment and stakeholders engaged in decision-making about design, implementation, development and operation of Schoonschip's local smart electricity grid system.

Biophysical conditions

All the 'floating' homes are as energy neutral and sustainable as possible, i.e., in terms of materials used, highly insulated and with a unique homeowner-based design (Schoonschip, 2023). In terms of existing infrastructure Schoonschip has an internal electricity grid with one main connection to the low/medium voltage grid of DSO Alliander. Schoonschip has batteries, heat pumps and solar PV panels which enable the use of smart grid technologies such as their EMS. By means of this smart grid Schoonschip plans (is doing) to use it as a VPP for additional flexibility services for the energy market.

Attributes of the Community

All the residents have a high drive to act as sustainable as possible and an urge to live in a community; that is the reason for the interviewee (#1) to say: "The community is initiated as a real community and grew into an energy community on itself." Hence, Schoonschip is a community-based initiative and an energy community. The socio-economic characteristics of the community are well developed, as they wanted to incorporate social rent as well (Leclercq & Smit, 2021). This was not feasible after Schoonschip was constructed. So, the houses on the Schoonschip site are for economically well-developed people (interviewee #6 & #9). With regards to the home-ownership, all the home boats are self-developed, constructed (interviewee #1) and therefore privately owned, but together the area looks as a coherent whole. Therefore, despite the fact that every home is unique, they all belong together; this could be reflected in the people living in the Schoonschip project.

Rules-in-use

In Table 3 below the seven rules-in-use categories made by Ostrom (2010; 2011) are elaborated for the most important rules of Schoonschip Amsterdam and its smart grid project. A more elaborate table can be found in Appendix C.

Table 3 Schoonschip's rules-in-use categories

Rules-in-use	Outcome/interpretation
Boundary rules	Key stakeholders in the smart grid implementation at Schoonschip: • Homeowners' Association (HOA) and its energy working group: Acts as the executive operator of the smart grid. • Metabolic: Sustainability consultant involved in establishing the smart grid and facilitating the Experimentation Decree request. • Spectral Energy: System integrator for the Energy Management System (EMS), batteries, and other components. • Fraunhover: Involved in operating and developing the Virtual Power Plant (VPP) flexibility services. • Greenchoice: Energy company serving as the balance responsible party and consortium member of the VPP. • Netherlands Enterprise Agency (in Dutch: Rijksdienst voor Ondernemend Nederland (RvO)): Granted the Experimentation Decree. • Consumer and Market Authority (ACM): Approved tariffs as part of the decree. • DSO Alliander: Local grid operator with limited power due to Schoonschip developing its own grid under the Experimentation Decree. Residents have the freedom to choose their energy supplier, but currently, all homes are connected to Greenchoice. Decision-making is complex due to the diverse ownership of community-owned batteries, privately-owned heat pumps, and privately-owned solar PV panels. Compliance with smart grid requirements for privately-owned assets is crucial, even if a household withdraws from the smart grid and switches energy companies. The existing infrastructure for the project's electricity grid is community owned.

Position rules	• The project includes stakeholders such as Schoonschip's HOA, Energy working group, DSO Alliander, RvO, Greenchoice, the Municipality of Amsterdam, ACM, Metabolic, and Spectral Energy. • Schoonschip's HAO and energy working group serve as the (legal) project initiator and leader, managing the smart grid and local network. • The Experimentation Decree grants Schoonschip temporary responsibility for the local grid, but it will eventually be sold back to DSO Alliander. • Schoonschip is also an energy supplier under the Program Responsibility of Greenchoice, approved by the ACM. • Spectral Energy handles the digital Energy Management System (EMS) and battery development. • Fraunhover's involvement is for societal experimentation purposes, owning the Virtual Power Plant (VPP). • Metabolic, a sustainability consulting organization, contributed to the project's comprehensive strategy, focusing on energy and other sustainability aspects. • The initial project focus was on implementing a smart grid, taking advantage of the available exemption under the Experimentation Decree.
Choice rules	• Schoonschip established a Stichting or homeowners' association to realize their sustainable floating housing project. • Metabolic, a sustainability consulting firm, conducted a crucial sustainability and feasibility study for Schoonschip. • Metabolic was selected for the application of the Exemption under the Experimentation Decree, which played a key role in their collaboration with Schoonschip. • Metabolic set up a startup within their organization, supported by a fixed financial grant, and contributed significantly to the Schoonschip pilot project. • The timing of the Experimentation Decree between 2015-2018 was advantageous for Schoonschip's initiatives. • Schoonschip chose to participate in the Dutch electricity flexibility markets by offering their flexible capacity, requiring the establishment of a Virtual Power Plant (VPP). • Fraunhover and Spectral Energy are responsible for executing the VPP. • The availability of the Experimentation Decree prompted Schoonschip to consider implementing a smart electricity grid for their project.
Information rules	• The residents of Schoonschip experienced a two-year delay in receiving their 2020 energy bills, indicating a lack of information availability. • Good 'faith' in the energy working group of Schoonschip is crucial for residents to participate in the project. • The delay in the energy bill was attributed to technical and organizational reasons, including uncertainty about Value Added Tax (VAT) payment by the homeowners' association (HOA). • Fraunhover and Spectral Energy collaborated with the energy working group to develop, implement, and operate the smart grid and associated assets, while complying with GDPR and privacy laws. • The consequences of a household retracting from the common smart grid with privately owned heat pumps and solar panels are unknown, as no such cases have occurred before. • Similarly, the impact of households choosing a different energy company than Greenchoice under consumer law remains unexplored. • The energy working group possesses the most information, knowledge, and expertise regarding the smart grid and its assets, advising the HOA Schoonschip in their legal decision-making processes through a horizontal decision-making approach.
Aggregation rules	• Official decisions related to the Schoonschip project are made by the board of the homeowners' association, but they heavily rely on advice and suggestions from the energy working group and other working groups. • The open Virtual Power Plant (VPP) experiment for flexibility options research involves a consortium consisting of Spectral Energy, Fraunhover, Greenchoice, Greener, Prosoldiga, and HOA Schoonschip. • Decisions within this consortium are made collectively, considering the input from all involved parties. • Apart from the consortium, Schoonschip maintains a significant level of independence in decision-making processes concerning other stakeholders.
Payoff rules	• Significant financial investments were made in sustainability and legal research for the Experimentation Decree and Schoonschip's project grid/smart grid. • Metabolic, a consultancy, conducted the sustainability research with the support of subsidies. • Schoonschip is part of GridFriends, a consortium funded by the EU to set a new standard in smart grid technology and achieve a CO2-neutral living area. • Spectral Energy and Fraunhover are also involved in the GridFriends project. • The project incurred relatively high costs, with citizens investing their own money. • Schoonschip received the Energy and Climate Innovation Demonstration (DEI+) subsidy for their open Virtual Power Plant (VPP) due to their collaboration with commercial market parties, which is uncommon for private citizen projects (see Groene Mient).

	• Schoonschip is subject to an energy tax on the electricity produced and consumed within the community, which was initially expected to be tax-free, increasing project costs. • The charging and discharging of batteries also incurs a double energy tax, impacting project costs and the business model. However, this double energy tax for battery storage was eliminated for wholesale consumers in January 2022.
Scope rules	• The floating nature of Schoonschip enabled the establishment of their own grid, which benefits from more possibilities under the Experimentation Decree compared to a conventional grid. • This contributed to a more feasible business case for the Schoonschip project. • The energy working group, responsible for the annual energy bills of each home in Schoonschip, caused a delay in the energy bills, affecting the distribution of costs and benefits among households. • Freedom of choice for residents to select an energy company under consumer law introduces uncertainty and potential negative impacts on the community smart grid if a home switches energy companies. • The actual effects of such changes are unknown to Schoonschip and the energy working group, as they have not experienced this scenario before. • Once the exemption period expires, the project grid will transition into a conventional grid, likely to be sold to DSO Alliander, as they have an obligation to purchase the grid from Schoonschip as the grid operator in the area.

Participants

An elaborated description of the participants within Schoonschip's action situation can be found in Table 4.

Table 4 Participants Schoonschip

Most important stakeholders	- HOA (VvE) Schoonschip - Energy working group within Schoonschip - Stichting Pioneer Vessel (limited involvement) - DSO (Al)Liander - Greenchoice - RvO Netherlands - Consultant Metabolic - Spectral Energy - Fraunhover - Municipality of Amsterdam - Province of North-Holland - Government of the Netherlands/Ministry of Economic Affairs and Climate Policy - Transmission System Operator TenneT - ACM (approval of tariffs as part of Experimentation Decree)

Interactions

The most common types of interactions in an energy community with a smart grid system involve:

- Energy Trading: interactions may involve energy producers and consumers engaging in peer-to-peer energy trading, which in Schoonschip happens internally as peer-to energy community to-peer. Through smart contracts and blockchain technology, community members can interact directly to buy and sell energy, negotiate prices, and make transactions without relying solely on centralized energy providers. Within Schoonschip the energy working group is mainly responsible for this and the EMS, VPP etc. provided by Fraunhover and Spectral Energy. These interactions can occur in real-time and facilitate a more decentralized and efficient energy exchange.
- Demand Response Programs: Interactions would occur between energy consumers and the smart grid system to enable demand response programs, which happens between Schoonschip and the consortium partners mainly Greenchoice as the energy company in the VPP. Through smart devices and real-time data, consumers can interact with the grid system to adjust their energy

consumption patterns in response to price signals or grid constraints. These interactions help balance supply and demand, optimize energy usage, and improve grid stability.

- Data Sharing and Information Exchange: Interactions would involve the sharing of energy consumption data, grid performance data, and other relevant information among community members, energy providers, and grid operators. This type of interaction happens mainly internally within Schoonschip but also with Spectral/Fraunhover. This exchange of information enables better decision-making, load forecasting, and optimization of grid operations. It may also involve interactions with technology providers and data analytics firms to process and analyze the collected data.

Within the context of Schoonschip, additional forms of interactions manifest that hold significance, involving stakeholders, institutions, and technology. Particularly noteworthy among these informal interactions is the dynamic between the energy working group and the homeowners' association (HOA). In an informal capacity, the energy working group assumes decision-making authority concerning matters related to energy and the smart grid domain, despite the legal mandate resting with the HOA. Evidently, the HOA routinely embraces the determinations made by the energy working group. It is notable that this arrangement has not led to any substantive issues, as the effective functioning of the smart grid remains undisturbed.

Outcomes

The most important outcomes are stated by Milchram et al. (2019) in Chapter 3 (Appendix B), the ones chosen in this research are, e.g., implementation of smart grid ready assets (flexibility possibilities), sustainability, energy and economic efficiency.

Schoonschip tries to be as energy neutral as possible through own sustainable electricity generation, and many more other sustainable features of its community and living area (see Figure 6). Next to this, Schoonschip uses as little of the connected 'grid power' as possible through internal balancing, which is not happening to the full extent at the moment because of low electricity production in winter with the solar panels (interviewee #1). The homes are all electric and make use of smart matching of supply and demand via the internal EMS.

Results as stated by Swens in the EnergieSamen (Energie Samen & Swens, 2022):

- Internal balancing of supply and demand;
- Contracted connection capacity is 1/5th of standard connection capacity;
- Costs are 1/8th of 'normal costs',
- Ability to provide flexibility services. When there is a chance of overload, the batteries and heat pumps are deployed.

Therefore, Schoonschip needs 1/5th of the capacity DSO Alliander normally would offer/contract, which makes it possible to reduce the costs to 1/8th of what it would be for operating the grid and connecting something to the grid (*from literature findings' part in Appendix D)*. By installing 500+ solar panels on the rooftops of the Schoonschip homes, they are able to generate 92% of the total energy used by the neighborhood (Swens & Diestelmeier, 2022), only not in winter etc. (interviewee #1). To address any temporary shortages or excess electricity production, 30 batteries with a combined capacity of around 300 kWh/125 kW were installed, with each battery assigned to a specific ark (interviewee #1). Schoonschip employs an energy management system (EMS) that optimizes production, storage, and demand every 5 seconds, allowing it to shave consumption and production peaks to well below 100 kW (Swens & Diestelmeier, 2022). This peak shaving strategy enabled Schoonschip to connect to the common grid using a low-power connection with a capacity of only 100 kW, which is approximately one-sixth the capacity of a typical DSO connection for 46 households (interviewee #1).

Evaluative criteria

Next to the evaluative criteria as stated by Milchram et al. (2019) the goal attainment is an important evaluative criterion in this case. Goal attainment the definition used in this research is in Chapter 3. The goal attainment in the case of Schoonschip could be labelled as (very) sufficient, because of the fact that the values of Schoonschip are relatively very successful. Values such as sustainability in all its aspects is highly implemented in the norms, values and daily life of the community, e.g., a smart grid with smart grid ready assets, internal balancing, grid reduction, economic efficiency and many more sustainable ways of living beyond electricity use (like wastewater treatment). Next to this the smart meters are in place, flexibility services provided by smart assets, e.g., batteries and heat pumps and by their consumer behavior.

Economic efficiency/Affordability (Cherp & Jewell, 2014) for the residents of the community of Schoonschip and of its smart grid is relatively okay. This is because the residents are well paid people, as of the initiated social renting purposes of the project and its houses were not met due to too high costs (Leclercq & Smit, 2021). Next to this, for the people living there the electricity consumption is affordable and economic efficient, due to internal balancing, own electricity production, batteries and heat pumps etc. As said before these services and appliances are very expensive and the residents are well paid people with a high urge of sustainability, otherwise a system like Schoonschip would work less. Therefore, the internal acceptability (Cherp & Jewell, 2014) is fully integrated. The community feeling is very high which has to be if you want an energy community to be successful.

5.4. OVERALL CONCLUSION SCHOONSCHIP AMSTERDAM

Status Quo

The smart grid system is made up of several components, including solar panels, batteries, and a digital monitoring system. Each home in Schoonschip is equipped with its own solar panels, which generate electricity that can be used to power the home's appliances and devices. Excess energy generated by the solar panels is stored in batteries, which can be used to provide power during periods of low sunlight or high demand. The digital monitoring system allows residents to track their energy usage and production in real-time. They can see how much energy they are generating, how much they are using, and how much excess energy they have available to sell/feed back to the grid. This information is displayed on a dashboard that can be accessed from a computer or mobile device. One of the key features of Schoonschip's smart grid system is the ability to share energy with other residents. The system is designed to allow residents to trade energy with each other, depending on their individual energy needs. For example, if one household is generating more energy than it needs, it can share/sell the excess to another household who needs more energy. This helps to ensure that energy is used efficiently and minimizes waste. The smart grid system also allows residents to sell excess energy back to the grid.

Swens & Diestelmeier argue that (2022) Schoonschip has been recognized as an exemplary energy community that demonstrates the potential for local energy management to significantly increase the consumption of locally produced renewable energy and address issues of distribution and transmission capacity shortages and local congestion. Using local storage, peak shaving, and congestion mitigation, Schoonschip has contributed to an increase in the consumption of renewable energy while reducing pressure on distribution and transmission systems.

As stated by Swens & Diestelmeier (2022) and interviewee (#1) Schoonschip reveals a challenge associated with the liberalization of energy markets, specifically the impact of consumer choice on community energy projects. The community faced difficulties since individual members retained the right to switch to an energy supplier other than the community's, which could have a significant impact on the construction, ownership, and operation of their project grid. This situation creates uncertainty and complications for the calculation of grid operation costs and network tariffs. In essence, the principle of free choice of supplier in liberalized markets poses a significant challenge for the development of energy communities.

Why Schoonschip especially works:

- Community: readiness levels (6 categories) of residents.
- Institutional: the Exemption under the Experimentation Decree they got.
- Technology: is pretty well advanced with regards to smart grid readiness.
- Their (trade) markets wholesale contract VPP with flexible markets.
- Organization energy community: legal entities must be well established with governance forms.

ASI-diagram conclusion

The ASI-diagram, as based on Koppenjan & Groenewegen (2005) serves as a valuable visual tool for analysis. Its general depiction is found in Figure 4, and it has been adapted for application to the realm of smart grids in Figure 5. In the context of technological systems, the establishment of regulatory frameworks, often referred to as the 'rules of the game,' plays a pivotal role in governing the behavior of various stakeholders. These regulations can manifest in the form of formal legal statutes or more informally as industry-specific norms and practices. Institutions or institutional arrangements embody a set of guidelines that govern the interactions and conduct of actors within a given technological framework. This framework is equally applicable to the context of Schoonschip, leading to key insights.

Essentially, the ASI-diagram delineates an action arena for actors within the boundaries set by prevailing institutions. As detailed in section 5.3, this is particularly pertinent to the process of designing, implementing, evolving, and maintaining Schoonschip's local smart electricity grid system. The distinct nature of Schoonschip, with its unique attributes and legal status, results in an embedded action arena. Therefore, the degrees of freedom the actors have in this project is fairly comprehensive. The reasons behind this are twofold: Schoonschip operates as an autonomous project grid, effectively functioning as its own power supplier, network operator, and consumer. Furthermore, the comprehensive sustainability study conducted by Metabolic on behalf of Schoonschip contributes significantly to this autonomy. Operating within the broader institutional context defined by national legislation, ACM, RvO, the principal actors, including Metabolic, HOA, and the energy working group of Schoonschip, have effectively navigated this landscape to ensure the viability and effectiveness of the smart grid. The standout achievement in this regard is Schoonschip's exemption under the Experimentation Decree, which can be seen as an instance of interaction between actors and institutions.

The complex interplay between the technical system and the actors is equally crucial. Technology not only influences the actions of actors but is also influenced by their activities, particularly in terms of development. In the case of Schoonschip, a key observation is the successful acquisition of smart grid-ready assets such as heat pumps and batteries by the HOA and energy working group. This accomplishment can be attributed to collaborations with Metabolic, Spectral Energy, and Fraunhofer, exemplifying the bidirectional relationship between technology and actors. Vice versa, the actors involved with Schoonschip attained a VPP flexibility experiment in a consortium where Schoonschip is used as a flexible (electricity) buffer under the PV of Greenchoice.

Lastly, the ASI-diagram underscores the dynamic interplay between the technical system and institutions, highlighting the potential friction between technological innovation and the pace of institutional evolution and vice versa. A notable instance within Schoonschip pertains to the complex pricing and taxation structure, particularly concerning double taxation of specific electricity-related activities within the project. The complexity reached a point where the Tax Authority struggled to navigate it, illustrating the need for institutional adaptation to accommodate technological advancements.

Link with theory

When establishing a linkage between the aforementioned concepts explained within the Schoonschip domain, the integration of the IAD-framework and apply this framework to the seven categories of rules-in-use that exert impact on the action arena, the institutional determinants (rules-in-use) that bear the most profound implications, whether facilitating or constraining, are notably concentrated within the realms of boundary, position, choice, and payoff rules. Within these boundary and position rules are in the case of Schoonschip the most relevant, since its success is due to the ownership and operation of their own electricity grid. Changing legislation, termination of their Exemption under the Experimentation Decree and with that (possible) legal changing of ownership of the local (smart) electricity grid the boundary and position of the stakeholders within Schoonschip will change. Therefore, it is crucial to focus on the right (legal) actions for the HOA and energy working group for continuation. Hence, choice rules might have a significant impact in the future existence of the local smart grid of Schoonschip. Adopting a broader perspective within the IAD-framework, the biophysical conditions and attributes of the community emerge as salient exogenous variables. In summary, Schoonschip's journey from a community to an Energy Community involves the operation of a smart grid, engagement in flexibility markets, adherence to consumer law, and leveraging exemptions from electricity regulations. Their pioneering efforts, combined with the supportive regulatory framework and their own determination, contribute to their success as a sustainable floating neighborhood.

6. GRIFFLEX HEETEN (GFH)

In this section the GridFlex case will be analyzed, first in itself as a within case analysis by means of the IAD-framework and afterwards it will be compared in a cross-case analysis and concluded on by means of the ASI-diagram. The most important information of each case will be in its case description and IAD-framework, some additional (theoretical) background information will be in the appendix. For the Gridflex case this appendix is Appendix D.

6.1. GENERAL CASE DESCRIPTION

GridFlex Heeten was a three-year pilot program which started in 2017 where residents from the village of Heeten, together with companies and knowledge institutes, experimented whether and how 'zero on the neighborhood transformer' could be realized. The goal was to achieve a positive business case, scalable and applicable for the future. An ideological and important initiative (GridFlex, n.d.a).

The GridFlex project is in the Veldegge district in the village of Heeten, municipality of Raalte in Overijssel. An overview can be seen in Figure 7. In order to deal with renewable energy more effectively, sustainably and to create a local energy market, GridFlex Heeten project was founded as a citizens energy community (Reijnders et al., 2020) *(even though it could be categorized as a renewable energy community as well)*. This involved Escozon (entrepreneurial) cooperative U.A. and energy cooperative Endona U.A. The cooperatives together requested the Exemption under the Experimentation Decree (in Dutch: 'Regeling Experimenten Energiewet') in 2014 (interviewee #2) in order to learn more, and the Dutch Enterprise Agency (in Dutch: Rijksdienst voor Ondernemend Nederland) (RvO) approved it in 2015 (RvO, 2015). This is the 1st project in the Netherlands which earned an exemption to the Electricity Act under the Experimentation Decree (in Dutch: 'Experimenteerregeling Elektriciteitswet'). Therefore, the aim of GridFlex Heeten was to examine how supply and demand for self-generated energy could be better balanced. One way of testing this was to make better use of energy. The other way is storing energy at energy production peaks.

The collaboration of the project consortium was very important between all stakeholders, which resulted in a 100% participation rate of the households in the project, which is unique and has never been done before in pilot projects (interviewee #3).

Figure 7 GridFlex Heeten picture source: Enexis Nethebeer B.V. & Reijnders et al. (2020)

6.2. OVERVIEW GRIDFLEX SMART GRID EXPERIMENT

According to Van der Waal et al. (2020) in 2015, a large-scale project was initiated by an (Energy) Cooperative with the goal of generating renewable energy and collaborating with a biodigester (which was not implemented). The project aimed to supply energy to its members, increase direct energy usage, implement an Energy Management System (EMS), and incorporate energy storage. It involved 47 houses equipped with EMS and had a long-term target of reaching 5,000 members within 10 years. A more detailed case overview can be found in Table 5.

Table 5 General GridFlex case overview (adapted from Van der Waal et al., 2020)

Category	Description
Project type	Large experiment
Delineation	Endona envisions a future scenario where real-time electricity consumption in the region is increased, concurrently with the provision of locally generated renewable energy to the medium voltage grid part of Raalte. The initial trial of this endeavor was taking place in the village of Heeten.
Organization & Governance	The board members of Endona are registered as members of the energy cooperative, establishing a legal-organizational framework that ensures the continuity of daily management decision-making. Endona has a significant project portfolio and actively engages in multiple partnerships with grid operators, technology developers, and academic organizations.
Energy System	Endona, in collaboration with select partners, deployed sea salt-based batteries in the Veldegge district of Heeten. Additionally, in the community comprising 47 households, Endona implemented individual home-level energy management systems (EMS) and an overarching EMS that integrates the inputs from these individual systems to optimize energy usage at the neighborhood level. Furthermore, on a 3.5ha plot of former agricultural land, Endona successfully established a solar park featuring 7,200 solar (PV) panels.
Use of exemption under experimentation decree	The derogation is currently in effect (*but not used anymore*), allowing the cooperative Endona to exclusively engage in authorized production functions and balance experimentation as defined by the existing Electricity Act. Energy van Ons (in English: Energy of Us), a cooperative energy company, is currently responsible for power sales. Endona is actively addressing financial considerations due to the absence of a well-established business plan for electricity supply. Its long-term objective is to assume this role, enabling localized cost and benefit management of the energy system, potentially resulting in lower charges for customers through integrated management.

For the grid part of Raalte it is interesting → Endona only has an exemption for zipcode 8111 (Heeten), so curious here how Endona is going to manage this for Raalte, as according to the exemption it is not allowed (RvO, 2015).

A more elaborate (scientific) description of GridFlex can be found in appendix D.

6.2.1 CHRONOLOGIC PROJECT OVERVIEW OF KEY (DECISION-MAKING) EVENTS

- 2014: The founders of the energy cooperative Endona began with the exemption request (one of the first that got it) (interviewee #2).
- April 7th, 2015: Energy Cooperative Endona was founded (Energie Coöperatie Endona U.A., 2021).
- 2015: The Exemption under the Experimentation Decree was granted and the operational start date was at its latest on 4th of November 2016.
- 2017: Official start of the project.
- 2nd quarter 2018: nearby the GridFlex location a solar PV park is opened, which could be used by the project, since it's from the same energy cooperative, i.e., Endona.
- 2nd part of 2018: Dr Ten could not deliver the see salt battery development in time. Instead, lithium-ion batteries were installed, which are less sustainable and have less capacity (interviewee #5).

- March 2020: Start of the Covid-19 pandemic and restrictive measures, which had a great impact on the last year of GridFlex project, because, e.g., everybody had to work from so electricity consumption in the area went up and the results were not significant related to the other two years of the project.
- 2020: The project ended in this year and the 'significant' result is a community saving of €2500 and they bought an AED for the neighborhood with this money.

6.3. INSTITUTIONS: IAD-FRAMEWORK AND RULES-IN-USE RESULTS

In this section the IAD-framework for the GridFlex case will be elaborated. The exogenous variables consist of biophysical/material conditions, attributes of community and the rules-in-use which will be explained after this.

Action situation

The action situation of GFH consists of the environment and stakeholders engaged in decision-making about design, implementation, development and operation of GridFlex' local smart electricity grid system.

Biophysical/Material Conditions

- Type of buildings: newly built houses, so well insulated, a good energy label → energy efficient.
- Existing infrastructure: the used the conventional medium- and low voltage electricity grid owned and operated by DSO Enexis. The special thing about the GFH project area is that all the homes were behind one transformer, i.e., they could be considered as one large 'consumer' all together.
- (Renewable energy) Technologies used: photovoltaic solar panels in neighborhood, a nearby solar PV park owned by Endona, (sea salt/lithium-ion) batteries, EMS…

Attributes of Community

- Relatively younger people.
- As seemed after the project according to interviewee (#3), the neighborhood was 'new' at the start of the project, the social cohesion increased a lot because of the project and all the efforts by Endona, Buurtkracht, the five representatives from the neighborhood residents.
- The homes were privately bought and owned by the residents.

Rules-in-use

In Table 6 below the seven rules-in-use categories made by Ostrom (2010; 2011) are elaborated for the most important rules of GridFlex Heeten and its smart grid project. A more elaborate table can be found in Appendix D.

Table 6 GridFlex' rules-in-use categories

Rules-in-use	Interpretation
Boundary rules	Most important consortium partners/stakeholders in the project: • Endona (energy cooperative) • Escozon • Enexis (DSO) • University of Twente

	• Dr Ten • ICT Group • Buurtkracht foundation • Residents • RvO (Netherlands Enterprise Agency) • ACM (Authority for Consumers & Markets) The project was initiated by the energy cooperative Endona, who collaborated with Escozon to engage DSO Enexis in the project. Initially, Enexis showed reluctance but eventually joined after fruitful knowledge and interest exchanges. The neighborhood team from Veldegge in Heeten, consisting of five ambassadors from the area and Endona, achieved a 100% participation rate among residents, including a non-Dutch-speaking Polish household. Five neighborhood representatives facilitated project inclusion and decision-making. GridFlex residents maintained their 'small consumer connection,' forming a grand experiment within the exemption. They utilized the conventional grid owned and operated by the DSO.
Position rules	• Energy cooperative Endona was established as the legal entity owning the project's Exemption under the Experimentation Decree. • Escozon served as Endona's technical and legal advisor, jointly managing the project's content. • Enexis acted as the project 'secretary' (Dutch: penvoerder), holding significant legal importance. • University of Twente conducted research, managed data, and was subjected to the GDPR and privacy law compliance. • ICT Group owned and operated the EMS and collaborated on data management and privacy protection. • Dr. Ten provided technology solutions, including sea salt batteries. • Buurtkracht foundation acted as a societal consultant for community connections and sustainability improvement. • RvO and ACM served as external licensing authorities and potential funders.
Choice rules	• Each household in the GridFlex project maintained its own energy contract and supplier, limiting pricing flexibility within the exemption policy resulted in only price variation at network tariff levels. To compensate for the lack of flexibility opportunities, the decision was made to simulate the smart grid environment online. • Delays in the development and delivery of sea salt batteries by Dr Ten caused significant setbacks in certain aspects of the smart grid implementation. As a result, the choice was made to purchase lithium-ion batteries from the market to complete the pilot project. • The associated choice rule states that if an energy asset is not delivered on time, an alternative can be considered and implemented.
Information rules	• Initially, consortium partners were unaware of the limited flexibility in electricity prices under the exemption, including discussions with the Dutch tax authority to explore possibilities for manipulating energy tax. • The available technical information focused on batteries as a key component. • It is unclear what information was provided to the residents regarding the virtual smart grid environment and the continuation of their normal energy supply contracts. • A traffic light model was implemented for electricity prices, with red indicating high prices/limited sustainable supply, orange for medium, and green for low prices/high sustainable supply, allowing residents to adjust consumption behavior. • University of Twente and ICT Group complied with GDPR and other privacy legislation requirements.
Aggregation rules	• Project consortium made collective decisions through regular sessions involving representatives from all consortium partners. • Five representatives were appointed to advocate for residents' interests. • Monthly project meetings were held with all stakeholders, including at least one resident representative. • Due to delays in the development of sea salt batteries, the consortium decided to purchase lithium-ion batteries to ensure the feasibility of the pilot project. • The decision to switch to lithium-ion batteries was likely based on the rule that alternative options could be considered and implemented if the original energy asset was not delivered on time.
Payoff rules	• The project implemented a traffic light model with three different prices (red, orange, and green) to influence consumer behavior and increase flexibility and peak shaving. • The model successfully reduced neighborhood peaks by up to 36% without batteries, leading to a decrease in kW usage. • By implementing a new payment scheme, residents collectively saved €1,500 per year, equivalent to 14% of total connection and transport costs. • However, individual consumer behavior change resulted in no significant savings, highlighting the importance of automating smart grid asset processes. • The project did not yield a feasible business case due to fixed taxes and energy prices, even with the exemption. • The simulated smart energy system environment generated revenue of €2,500 in three years, lower than previous calculations.

	• The low price saving per kWh is attributed to the composition of energy prices in the Netherlands (Figure 10 in appendix D), which leaves little room for price variation and incentives for changing energy consumption patterns.
Scope rules	• The Covid-19 pandemic affected the costs, benefits, and business case of the Gridflex project, as many people had to work from home and electricity consumption increased. • The limited development of sea salt batteries, lack of smart assets, and restricted degrees of freedom in the exemption policy limited the number of technical alternatives/solutions. • Incentives for optimizing direct self-consumption were undermined by the tax refund scheme (Dutch: salderingsregeling), hurting the viability of home batteries as a business.

Participants

"To reach their goals the community has initiated the GridFlex Heeten project, where a consortium of Enexis B.V. *(project manager/secretary),* Endona U.A., Escozon U.A., Enpuls B.V., Dr Ten B.V., ICT Group N.V., and the University of Twente are working together." (Reijnders et al., 2020, p. 144; Interviewees #2, #3, #4 & #5). An elaborated description of the participants within Gridflex' action situation can be found in Table 7.

Table 7 Participants GridFlex Source: (GridFlex, n.d.b).

Most important stakeholders	- Energy cooperative Endona (EnergieDoorNatuurkracht): local energy cooperative and internal project manager. - Escozon: entrepreneurial cooperative who provided the development and implementation of sustainable energy concepts, also internal project manager. - Enexis Netbeheer: DSO of the region where Heeten is located and 'project leader' (Dutch: penvoerder) of the Gridflex pilot project. Research from the 'energy group': working group mathematics and embedded systems department (interviewee #5). - University of Twente: research and education in the field of energy management systems and pricing mechanisms in local distribution networks. - Buurtkracht foundation: social initiative (from DSO) that aims to connect and support people in neighborhoods in making their neighborhoods more sustainable. - Dr Ten: battery producer, developer and supplier for the project. - ICT Group: systems engineer within the field of smart energy. - Enplus: part of Enexis, focuses, among other things, on measuring and analyzing energy consumption and advising on energy infrastructure and savings. - The residents of Veldegge and of the reference group area. - RvO is also an important stakeholder as they grant subsidy and the exemption to experiment with electricity, they are part of the Ministry of Economic Affairs and Climate Policy. The ACM is also an important (regulating/)controlling stakeholder for the Electricity Law etc.

Interactions

The most common types of interactions in an energy community with a smart grid system involve:

- Energy Trading - In an energy community with a smart grid system, participants engage in energy trading activities. This involves the exchange of electricity between community members, which in the case of GridFlex is mainly between the community members and energy cooperative Endona with their solar PV park. This combined with the traffic light model for electricity consumption used in GridFlex allowed for a decentralized approach to energy supply and consumption.

- Demand Response Programs - The deployment of demand response programs is another significant interaction in an energy community with a smart grid system. In order to encourage consumers to modify their patterns of energy usage, the GridFlex Heeten initiative deploys demand response programs by focusing on consumer behavior. By providing incentives and clear information about grid conditions and energy prices, participants can make informed decisions on when and how to use electricity.
- Data Sharing and Information Exchange - A crucial aspect of smart grid systems is the sharing of data and information among community members and grid operators. By providing access to real-time energy data and consumption information, participants can make informed choices about their energy usage. Data storage and handling was done by ICT-group (for the EMS) and the University of Twente as research facility. Clear guidelines and protocols for data privacy, security, and consent are essential to foster a collaborative environment, e.g., the GDPR.

Additional forms of interactions manifest that hold significance within the context of GridFlex, involving stakeholders, institutions, and technology. Particularly noteworthy among these informal interactions is the dynamic between the consortium partners, the residents and the five neighborhood representatives. Prior to the start of the project back in 2017 Endona plus Buurtkracht Association needed to persuade the residents to participate in this smart grid energy project. The unintended social 'pressure' to participate plus local efforts led to 100% participation and increased social cohesion of this young neighborhood. During the experimental phase of the project monthly meetings were held with consortium partners to discuss matters of interest. The most important partners for this project were Escozon, Endona, Enexis and University of Twente. In the local neighborhood flyers and poster informed the residents from time to time combined with the five representatives. The users of the 'smart grid' had a dashboard in an application on their phones to see the electricity and price data. One of the findings from the experimental smart grid phase was the interaction between the users and the dashboard was lacking in the end, residents only looked at the application from time to time, while this was the mechanism to creat energy flexibility by steering consumer behavior.

Outcomes

The GridFlex Heeten pilot project aimed to reduce transport losses, decrease grid congestion, and minimize investments in the grid. The ultimate goal was to achieve zero transport of electricity over the transformer, effectively creating an islanded microgrid. The community in Heeten represented a collective generation and battery flexibility model (Reijnders, Gerards, Hurink & Smit, 2018).

The most important outcomes are stated by Milchram et al. (2019) in Chapter 3 (Appendix B), the ones chosen in this research are, e.g., implementation of smart grid ready assets (flexibility possibilities), sustainability, energy and economic efficiency. One important lesson learned from the case study is the significant impact that batteries can have. Reijnders et al. (2020) illustrate the reduction in neighborhood peaks with and without batteries, showing a decrease of up to 36% (from 39 to 25 kW). By implementing the new payment scheme described in Reijnders et al. (2020), the residents collectively could save €1,500 per year, equivalent to about 14% of the total connection and transport costs. It's important to note that this savings benefit applies to the entire neighborhood, therefore it is only €31.91 per household as 47 households were included in this project, concluding currently not considerably worth it as it also requires a lot of consumer flexibility as resulted from the GFH project. In addition, the residents were provided with information to help them decrease their energy consumption and shift it away from peak periods (interviewee #4 & #5). The situation also improved for the network operator, as the neighborhood exceeded the 15kW threshold only 18% of the time, compared to 34% without using batteries (Reijnders et al., 2020). "The first results show that batteries have a high added value when it comes to relieving stress from the grid, given some smart steering can be used. However, the influence of the flexibility of the inhabitants on the energy profile of the community remains still is unclear." (Reijnders et al., 2020, p. 153).

Evaluative Criteria

Next to the evaluative criteria as stated by Milchram et al. (2019) the goal attainment is an important evaluative criterion in this case. Goal attainment the definition used in this research is in Chapter 3. The goal attainment in the case of GridFlex could be labelled as sufficient considering the goal of being a pilot projects for batteries, change of consumer behavior. However, with regards to smart grid purposes with price variations, smart grid assets etc. the goal attainment could be stated as insufficient.

The question remains how successful the project was really (interviewee #2): no feasible business case has emerged (while SSA is 'profitable'). However, probably a lot was learned from this project for the future for, e.g., governments and the grid operators etc. Overall, the goal attainment as described above was not the best in the GridFlex project.

Economic efficiency/Affordability (Cherp & Jewell, 2014): The main economic outcome of the project is no feasible business case. €2500 revenue in three years. A virtual smart gird simulation environment instead of a real smart grid environment with smart assets etc., which resulted in 1500 €/year savings → ~€31.91 per household per year because of a small change in consumer behavior.

Lastly the acceptability (Cherp & Jewell, 2014): the neighborhood was new and still a 100% participation rate, local approach of Endona and Buurtkracht was the key to this success.

6.4. OVERALL CONCLUSION GRIDFLEX HEETEN

Status quo

The area of GridFlex in the Veldegge neighborhood in Heeten is again a 'normal' conventional residential area, but they still have the legal Exemption under the Experimentation Decree, which was only used for the three experimentational years of the project. Currently it is not used at all, but which Endona and Escozon want to use for the whole municipality of Raalte where the village of Heeten is part of. The Exemption only applies to zipcode 8111 area which covers the whole village of Heeten, but not Raalte and other parts of the municipality. It is interesting to see what how this zipcode restriction will affect Endona and Escozon's aspirations.

The GFH project examines the potential reduction in grid stress achievable by harnessing the flexibility of community members and their battery systems. The application of an innovative pricing method demonstrated a possible reduction in peak loads by up to 36%, resulting in cost savings for the community

(Reijnders et al., 2020). However, there are several barriers that need to be addressed for energy communities to realize these benefits. These include the need for well-structured organization and sufficient scale to compete with larger players. Additionally, current legislation poses a major obstacle, limiting the options for energy communities to achieve savings (interviewees #2; #3; #4 & #5). The new EU Electricity Directive offers some hope as it establishes citizen energy communities as official legal entities, though the specific rights and responsibilities are yet to be determined (Reijnders et al., 2020). But this comes with a high degree of uncertainty as it leads to risk aversion and wait-and-see behavior among stakeholders. So, in the scope of this thesis it possibly has a negative impact for experimental projects like analyzed in this (thesis) research.

Based on the research of GridFlex (n.d.b) it is evident that a local energy community holds potential for success. However, further efforts are required to establish a viable and compelling economic framework. In simple terms, the expenses and income associated with the community are currently not balanced.

Moving forward, there are several key priorities that need to be addressed. Firstly, the development of plug-and-play equipment is crucial to effectively manage installation costs. Secondly, it is essential to address the issue of conversion losses associated with the utilization of used battery technologies (lead acid, lithium-ion, and sea salt) (GridFlex, n.d.b). These particular technologies currently experience an excessive level of inefficiency in the conversion process.

According to the current regulatory framework, energy tariffs are restricted from fluctuating in a manner that effectively incentivizes end users to make substantial changes in their energy consumption patterns. Although transportation expenses constitute a minor portion of the overall energy cost in GridFlex Heeten, there is only limited flexibility to make adjustments in this aspect, which was only possible because of the Exemption under the Experimentation Deree GFH had (GridFlex, n.d.b). Consequently, the incentive that could be provided falls short of generating a significant impact.

Lastly, in order to propel and ultimately achieve success in a project like GridFlex Heeten, active engagement and participation from every stakeholder in the interconnected system is imperative.

ASI-diagram conclusion

The ASI-diagram based on Koppenjan & Groenewegen (2005), which is generally visualized in Figure 4 and applied to smart grids in Figure 5. 'Rules of the game' that direct and coordinate the behavior of actors are needed in technological systems. These agreements may be outlined in formal laws, or they may take the form of informal norms and attitudes in a particular industry. Institutions or institutional arrangements are thus a collection of guidelines that control how parties involved in a (technological) system interact. This can be applied to GridFlex as well to draw the main conclusions. First the action arena of actors is shaped by the relevant institutions, which is stated in section 6.3, generally stated around the design, implementation, development and operation of GridFlex' local smart electricity grid system. This action arena of GridFlex is relatively embedded, since the experimental pilot project is already over, and lessons are drawn. The degrees of freedom the actors had in this project were less than initially expected, due to the fact that the Exemption for grand experiments was more limited than realized. This had a huge impact on the outcomes and feasibility of the project, which resulted in no considerably profitable business case. One of the main aspects that caused these problems was the distribution of the energy prices in the Netherlands which can be seen in Figure 10 in Appendix D.

The technical system and the actors contain important interactions as well, since technology shapes the action of actors and actors influence the smart grid technology (development). In the case of GridFlex the main finding in this perspective is the fact that certain technological developments were lacking and thus impacted the outcomes and feasibility of the project. The main thing here was the sea salt battery development, although GridFlex revealed the potential of electricity storage in batteries.

The last important interaction deriving from the ASI-diagram is between the technical system and institutions. Here the main notion is the innovation of technology versus (lack of) institutional development and vice versa. Since the Exemption was more limited than expected, the project consortium had to virtual simulate the smart grid environment, which on itself also had to do with actors. As a cause of this were no smart grid ready assets only smart meters in place.

Link with theory

When making the connection between the concepts described above in the GridFlex section, the theory of the IAD-framework and apply it to the seven rules-in-use categories affecting the action situation, most significant institutional factors (rules-in-use) with regards to GridFlex, whether enabling or disabling, apply to the position, choice, information and scope rules. Looking at the IAD-framework on a wider scope, important factors are the evaluative criteria/outcomes as the goal attainment (see codebook Appendix B) is (totally) different then when the project started. Scope rules were the most relevant barriers for the outcomes and goal attainment as those limited the degrees of freedom of the GridFlex smart grid project. However, in conclusion, the GridFlex Heeten project provides valuable insights and promising results for energy communities. Based on these experiences, significant advancements can be expected in the field of energy communities in the coming years.

7. GROENE MIENT DEN HAAG (GMDH)

In this section of this thesis the Groene Mient case will be analyzed, first in itself as a within case analysis by means of the IAD-framework and afterwards it will be compared in a cross-case analysis and concluded on by means of the ASI-diagram. The most important information of each case will be in its case description and IAD-framework, some additional (theoretical) background information will be in the appendix.

7.1. GENERAL CASE DESCRIPTION

In the city of Den Hague, the Vruchtenbuurt is a mixed neighborhood of old and recently built homes. This neighborhood has the ambition to be as close to climate-neutral as possible by 2030. Inside of this ambitious neighborhood is the Groene Mient, a community of 33 buildings that serve as a pilot for building knowledge and the identification of challenges in the transition to energy-neutral smart buildings.

The Living Lab Groene Mient is an innovative and sustainable housing project, located in the Vruchtenbuurt, The Hague, that aims to create an environmental friendly and socially vibrant neighborhood. It is an example of a community-driven initiative focused on promoting sustainable living practices, fostering community engagement, and integrating ecological principles.

In 2017, during the official opening of Groene Mient, a declaration of intent (source: declaration of intent) was signed by key stakeholders, including Eneco, The Hague Municipality, DSO Stedin, and Joulz Services (a utility company in the Dutch energy sector and former part of a system operator), marking the start of the 'smart grid experiment Groene Mient'. In December 2019, the energy cooperation called Sterk op Stroom (SoS) was established to oversee the financial, legal and organizational aspects (of the smart grid) of the Groene Mient working group Watt. The project received a subsidy of €75.000 from the Province of South Holland to implement the project plan for the 'Living Lab Groene Mient: a proposal for a smart grid.' From 2019 to 2022, the 'Watt' working group and SoS collaborated with partner organizations and knowledge institutions to develop and test an experimental smart grid within the Living Lab Groene Mient residential area. The primary objective was to gain knowledge and experience alongside essential partners that could be utilized to create a smart grid for the Groene Mient's surrounding Vruchtenbuurt area. So, the overall purpose was to scale up the smart grid from the Groene Mient as living community to the bigger area of the Vruchtenbuurt.

7.2. OVERVIEW GROENE MIENT SMART GRID EXPERIMENT

According to Van der Waal et al. (2020, p. 18) In 2018, a large-scale project was initiated by Homeowners Associations. The project aimed to achieve goals related to energy generation, heat pumps, eliminating the use of gas, and implementing a neighborhood battery and electric vehicles (EVs). The project consisted of 33 energy-efficient newly built houses constructed in 2017, along with a communal garden. It should be noted that the information provided in the article by Van der Waal et al. (2020) is outdated and contains some misinformation, specifically regarding the neighborhood battery and EVs.

7.2.1 CHRONOLOGIC PROJECT OVERVIEW OF KEY (DECISION-MAKING) EVENTS

- 2014: The Groene Mient initiators gather in a Collective Private Client (Dutch: 'Collectief Particulier Opdrachtgever' (CPO)) to buy the needed space for the 'social ecological housing' project (Groene Mient, n.d.a).
- 2015: The tender for construction of the homes is completed.
- 2016: The area with all buildings is constructed.
- 2017: Development of the idea grew to not only make the Groene Mient's own homes and neighborhood sustainable, but also to explore for opportunities to have smarter and more affordable sustainable locally produced energy for the wider 'Vruchtenbuurt' neighborhood.
- September 2017: The ambition set to provide the Groene Mient residents with locally produced green power, but there should be a cooperation for this and an Exemption of the Electricity Act under the Experimentation Decree is required. In September 2017 a decleration of intent (Groene Mient, 2017) was signed with DSO Stedin, Joulz Services, Eneco Smart Energy and the Municipality of The Hague. This letter of intent was to draw up a project plan for an experimental energy grid (i.e., a virtual decentralized electricity grid) and to explore possibilities to whether and how energy can be generated, stored and consumed within Groene Mient.
- November 2018: The Exemption of the Electricity Act under the Experimentation Decree was granted to the Groene Mient project by RVO (RvO, 2018).
- 2019: SoS and the Groene Mient project receive a subsidy from the Province of South-Holland of €75,000 (Sterk op Stroom, n.d.).
- End of 2019: Foundation of the SoS energy cooperative.
- January 2020: Groene Mient residents could register for the energy cooperative SoS (Groene Mient, n.d.b).
- 2020 – 2023: Plan launched by the Groene Mient stating: "Over the next three years (2020-2023), Sterk op Stroom (SoS) will conduct research in an experimental setting (i.e., the Living Lab Groene Mient) and test the Smart Grid, i.e., the smart use of sustainably generated local electricity, in practice. This will include the use of smart ICT and hardware such as a neighborhood battery in which we can store energy or bi-directional charging stations." (Groene Mient, n.d.b).
- October/End of 2022: Due to the negative circumstances SoS energy cooperative decided to leave the smart grid (development) plan as it is for now (Working group Watt & Sterk op Stroom, 2022).
- November 2022: The document 'Report and conclusions from the Smart Grid experiment in the Living Lab Groene Mient' concluding that no feasible circumstances for a local smart grid yet identified (Working group Watt & Sterk op Stroom, 2022).

7.3. INSTITUTIONS: IAD-FRAMEWORK AND RULES-IN-USE RESULTS

In this section the IAD-framework for the Groene Mient case will be elaborated. The exogenous variables consist of biophysical/material conditions, attributes of community and the rules-in-use which will be elaborated after this.

Action Situation

The action situation of GMDH consists of the environment and stakeholders engaged in decision-making about design, implementation, development and operation of Groene Mient's local smart electricity grid system.

Biophysical conditions

Energy efficient housing, smart meters in place, but no smart assets. Initially the smart assets are things the project and its initiators wanted, but for example their heat pumps don't have an Internet of Things connection, so those cannot be used as smart assets to provide the intended electric flexibility.

They have a communal garden which increases the community feeling (interviewee #7). The Groene Mient houses are equipped with solar PV panels, solar boilers and solar (thermal) collectors, therefore all the homes are fully electric and don't have a gas (grid) connection. Next to this, they also have some heat pumps.

Attributes of the Community

The socio-economic characteristics of the Groene Mient's residents are characterized by the great risks the (potential) residents as they needed to invest a decent amount of money even before the construction face which was pretty uncertain at that time. All the homes are privately owned, same as the type of sustainable technology (solar PV, solar boiler or solar collectors) the households have.

It could be said that especially with the communal garden the Groene Mient is especially an energy neutral/efficient community rather than a hardcore smart grid community, but they are moving towards the smart grid due to the Exemption and its preferred implementation this fall.

Rules-in-use

In Table 8 below the seven rules-in-use categories made by Ostrom (2010; 2011) are elaborated for the most important rules of Groene Mient Den Haag and its 'smart grid project.' . A more elaborate table can be found in Appendix E.

Table 8 Groene Mient's rules-in-use categories

Rules-in-use	Outcome/interpretation
Boundary rules	The initial 'smart grid' experiment involved a project consortium with various stakeholders, including the Municipality of The Hague, DSO Stedin, Eneco Energy, working group Watt, energy cooperation SoS, and knowledge institutions. The consortium partners/stakeholders included: • Energy cooperative Sterk op Stroom: A legal entity required to form an energy community and execute energy actions related to the smart grid. • Houseowners association (VvE) Groene Mient: Received the Exemption of the Electricity Act under the Experimentation Decree. • GMDH residents: Made sociocratic decisions within Groene Mient. • Municipality of The Hague: Inclusion in the project consortium and decision-making process due to the project's location. • DSO Stedin: Legally bound to GMDH due to the geographic location of the project. • Province of South-Holland: Important stakeholder providing subsidy to GMDH. • Spectral Energy: Built the Smart Community Platform (SCP) and smart grid for GMDH. • Delft University of Technology & The Hague University of Applied Sciences: Knowledge institutions involved in data science aspects. • RvO: Granted the Exemption on behalf of the Minister of Economic Affairs & Climate Policy.

	• ACM: The Consumer & Market Authority responsible for approving electricity price tariffs within the Exemption. • Energy Supplier Eneco: Initial energy supplier and stakeholder in the project. • AquaBattery: Partner for sustainable and environmentally friendly battery arrangements. • All-in-power: Platform provider for future energy sharing with dynamic prices. • Energie Samen: National federation of energy cooperatives in the Netherlands. A boundary rule affecting degrees of freedom is that GMDH residents maintained their small consumer connection within the exemption, forming a 'grand experiment' that utilized the conventional grid operated and owned by the DSO.
Position rules	• Groene Mient and energy Cooperation SoS are project leaders and initiators of the smart grid project. • The Municipality of The Hague and DSO Stedin are important project partners, but cooperation needs improvement due to financial and regulatory issues. • The Province of South-Holland provides financial support. • Delft University of Technology and The Hague University of Applied Science serve as external data advisors. • RvO and ACM act as external licensing authorities and potential funders. • Spectral Energy provides the Smart Community Platform (SCP) and data protection for the smart grid.
Choice rules	• The municipality sells land to Groene Mient for the development of a green community residential area. • A declaration of intent is signed by Groene Mient association, the municipality, DSO Stedin, Eneco, and an energy company to learn from the project. • Energy cooperative Sterk op Stroom is established to manage the sustainable/smart grid aspect. • DSO Stedin cannot afford to actively invest in the smart grid due to financial constraints. • SoS decides to abandon the smart grid experiment due to feasibility issues. • The Exemption under the Experimentation Decree is not implemented. • The smart grid ambitions of energy cooperation SoS are put on hold for now.
Information rules	• Initial project plan/goals were based on insufficient information to implement a smart grid. • Technology and assets were not smart grid ready, such as older generation heat pumps without Internet of Things (IoT) connection. • Data collection and handling responsibilities raised concerns due to GDPR regulations and consumer privacy rights. • Knowledge institutions failed to fulfill promises regarding data handling, despite some scientific research conducted. • Spectral Energy and All-in-power are primarily involved in consumer electricity data and smart grid data handling and protection. • Universities have not fully utilized the data provided by smart meters in the Groene Mient houses.
Aggregation rules	• Decision-making process involved all stakeholders initially, with consent. • Lack of involvement from the Municipality of The Hague led to decreased motivation and success in implementing the smart grid. • Internal decisions within Groene Mient are made collectively by all 33 households.
Payoff rules	• The net costs and benefits of the project are not well established. • The project received a subsidy of €75,000 from the province, but more funding is needed to achieve the initial goals. • The data collection obtained in the project is estimated to be worth four times its initial subsidy value (€350,000). • Knowledge institutions, such as universities, could provide additional subsidies if they have access to the data for scientific analysis in collaboration with Groene Mient, energy cooperative SoS, Spectral Energy, and All-in-power. • The accessibility of the data for knowledge institutions is currently unknown.
Scope rules	• The smart grid and the Exemption under the Experimentation Decree are not currently operational in Groene Mient. • The project scope was expanded to include sustainable batteries and electric vehicles, but these elements are not yet in place. • The Exemption only applies to specific households within Groene Mient and limits the scope of outcomes. • Technical solutions are limited due to the development of smart grid assets within Groene Mient. • Experiments related to grid management and tariffs are being conducted with DSO Stedin before further actions can be taken under the Exemption. • The subsidy from the province has been fully utilized and the data collected has become highly valuable.

	• The lack of collaboration between Groene Mient/SoS and knowledge institutions has hindered the proper utilization of the valuable data.

Participants

An elaborated description of the participants within Groene Mient's action situation can be found in Table 9.

Table 9 Participants Groene Mient

Most important stakeholders	- SoS: legal entity needed for Exemption request and actions related to energy. - Municipality: is involved because the GMDH is in the Municipality of The Hague. - RvO: this was the stakeholder that needed to grant the Exemption, also on behalf of the Minister of Economic Affairs & Climate Policy. - ACM: The Consumer & Market Authority (Dutch: Autoriteit Consument & Markt) is a Dutch independent public regulator that needs to approve price tariffs for electricity within the Exemption, it makes sure the electricity market is regulated and stays 'fair'. - DSO Stedin: is legally binded to the GMDH, because of the geographic location of the project in The Hague, which is within the operational field of this grid operator. - TU Delft/Haagse Hogeschool: These are knowledge institutions that GMDH reached out to in order to contribute to the (scientific) field of smart grid development with all the obtained data from the smart meters and other (smart) devices. The other purpose is also to unlock/disclose and analyze GMDH data that can be used to determine whether the measures taken by GMDH/SoS are effective (e.g., in peak shaving, achieving energy savings, and others). - Spectral Energy: this stakeholder built the Smart Community Platform of the GMDH project and was responsible for proper data storage according the GDPR and other regulations. - Energy Supplier Eneco: Part of the declaration of intent so first energy supplier related to this project. - AquaBattery: was a partner to arrange a sustainable and environmental friendly battery. - All-in-power: platform provider (future) energy sharing with dynamic energy prices, mainly for the future development of the smart grid.

Interactions

A project like Groene Mient and its smart grid needs to fit in the policy framework of the municipality. Accordingly, the relation between the Groene Mient/SoS and the municipality is not the best anymore. According to the interviewee (#6) governmental challenges are exponentially bigger than technical challenges: with a number of partners including Municipality of The Hague, Delft University of Technology and The Hague University of Applied Sciences (as knowledge institutions) thought to agree on a project direction/strategy so that the other partners, e.g., DSO Stedin and Enenco in combination with the knowledge institutions would start to learn from this project. Initially it worked out in the course of the project most successful by means of the province's subsidy with the help of DSO Stedin, they didn't go very deep into the experiment and supply tariffs etc., while in GFH the DSO went pretty far with dynamic grid tariffs (why the difference?). In Groene Mient (with DSO Stedin) together with GFH they are currently doing experiment(s) regarding management of such a grid experiment: grid management and grid management tariffs or something like that. The one condition GMDH has to continue their smart grid experiment and their Exemption is if that research with GFH is showing positive results (interviewee #6). With the Municipality after many contacts basically back to square one, they are now working on something regarding a smart charging station, the relationship with the Municipality has to be rebuilt over and over again. GMDH has lost the municipality and the other way around, therefore the relationship is very thin. The municipality is mainly concerned with itself and its own challenges, and the projects have to fit in exactly with that (interviewee #6).

Interactions as energy trading, demand response and data sharing & information exchange are of high importance in an energy community. For Groene Mient, the energy cooperative SoS and the (renewable/citizens) energy community these only happen to a small extent, due to the fact that the Exemption under the Experimentation Decree is not operational yet, there are no smart grid ready assets in the project and all the data gathered is currently not used by any organization.

Outcomes

The most important outcomes are stated by Milchram et al. (2019) in Chapter 3 (Appendix B), the ones chosen in this research are, e.g., implementation of smart grid ready assets (flexibility possibilities), sustainability, energy and economic efficiency. Outcomes could also be made more quantitative with the Key Performance Indicators of a project, e.g., lower prices for consumers, less grid congestion etc. but in this analysis those are not known for the Groene Mient project for this research. The one thing that can be said about it is that the GMDH houses are relatively very sustainable with the technology and energy sources they have (all electric), so their energy bill is almost zero.

Together with the company All-in-power, (platform) dynamic grid tariffs, the Groene Mient project and its residents are flexible in the sense of consumer behavior. They can see in their application/dashboard when the energy prices are low or high supply form their own sources in order to put on the electric devices to increase 'human' flexibility to relieve the grid and to shave the (green power) peaks on it.

Stakeholder interaction outcomes (Working group Watt & Sterk op Stroom, 2022; interviewee #6): The municipal government of The Hague and grid operator Stedin express empathy towards the experiment but assert that they are currently unable to pursue financial innovation and investment in a smart grid for the Vruchtenbuurt neighborhood. The accessibility of RvO Innovation grants for volunteer-based organizations engaging in civic projects seems to be inadequate or absent. These grants lack a cost structure (including labor costs and own capital) that could serve as the basis for essential co-financing. The RvO (Netherlands Enterprise Agency, Dutch: 'Rijksdienst voor Ondernemend Nederland') provides insufficient support for ongoing experiments, specifically for local energy communities part of the Exemption policy under the Experimentation Decree of the Electricity Act of 1998. While there is room for experimentation, there is a lack of funding available, e.g., the Energy and Climate Innovation Demonstration subsidy (Dutch: 'Demonstratie Energie- en Klimaatinnovatie (DEI+)') (RvO, n.d.), which seemed to be due to its emphasis on significant innovations made by (commercial) market actors.

A neighborhood-level project is ineligible for any European funds, as the application process requires the involvement and support of the province or municipality. However, it is important to note that these governmental entities have distinct priorities, which may impact the availability and allocation of funds.

Spectral Energy, the system provider, is presently responsible for overseeing the SCP of the GMDH. However, they currently do not perceive any market potential for a local smart grid for residential users. Instead, their focus lies on the commercial market, where power corporations and other significant consumers can derive benefits from smart energy systems.

The knowledge institutions encountered difficulties in designing and getting research projects funded that effectively utilize the data collected from the smart grid experiment. Nevertheless, it is important to acknowledge that SoS's mindset and strategic actions, including the mid-project abandonment of a consortium during a project application, contribute to increased challenges in this regard. This mindset has led to a loss of confidence among the involved stakeholders.

Evaluative criteria

Next to the evaluative criteria as stated by Milchram et al. (2019) the goal attainment is an important evaluative criterion in this case. Goal attainment the definition used in this research is in Chapter 3. The biggest challenges that decreased the goal attainment are project-based, legal framework of the grid operator and making agreements with regards to grid tariffs (not successful yet but are starting with it), cooperation with local government and lack thereof, technological (control vs. monitoring), lacking financial opportunities/resources. Therefore, smart grid 'readiness' of their system and assets contains only smart meters in place and flexibility services provided by consumer behavior.

Economic efficiency (affordability) & acceptability (Cherp & Jewell, 2014): The community is very sustainable in the way of living in their norms, values, way of living, technology and communal garden. These characteristics and community feeling make the acceptance very high. Economic efficiency is high because the energy bill is almost zero, also due to the 'modern' houses (well insulated), technology, renewable resources, all electric etc

7.4. OVERALL CONCLUSION GROENE MIENT DEN HAAG

Status quo

The final outcomes so far reached by SoS/Working Group Watt is that it is currently not feasible to develop a local smart grid due to insufficient financial and organizational commitment. Despite some individual contributors from the Municipality of The Hague and Stedin, there has been a lack of support and flexibility from their organizations. As a result, energy cooperative SoS has decided to temporarily pause the plan to develop a local smart grid (Working group Watt & Sterk op Stroom, 2022). So, the status quo of the smart gird and the exemption they have under the experimentation decree is still not in place, due to several reasons, e.g., no smart grid ready assets like (first generation) heat pumps without internet of things connection, lacking partner commitment, financial and organizational aspects. The plan is to operationalize and implement the Exemption this fall (interviewee #6).

Overall conclusion from Working group Watt & Sterk op Stroom (2022) & Interview #6 & #7:
"Significant knowledge gained, yet further actions required." Through a three-year endeavor, a local experimental smart grid was constructed, involving various subjects, institutes, and potential funders. The project encountered challenges related to organization and legal aspects concerning the technology, necessary control devices, and control strategy within the GMDH homes/households. The municipality exhibited weak integration of policy and relationship management. Despite being a natural ally, Stedin,

while supportive, stated its inability to invest in the smart grid. State funding for citizen initiatives proved inadequate or unfeasible, e.g., Energy and Climate Innovation Demonstration subsidy (Dutch: DEI+), as a prerequisite for receiving support involved providing 50% of the co-financing in hard currency.

The public knowledge institutions participating in the 'living lab Groene Mient' do not adhere to research activities when it comes to data collection analysis, as per their policy intentions. The development of a local experimental smart grid necessitates a substantial amount of funding, as we have clearly observed (interviewee #6). It requires investments in the following areas (Working group Watt & Sterk op Stroom, 2022):

- Establishing information and communication technology (ICT) applications focused on the neighborhood, particularly a smart community platform (SCP).
- Implementing control technology capable of managing heat pumps, boilers, electric vehicles, and other energy-intensive devices.
- Developing a robust business case with the assistance of state innovation funding.
- Promoting social innovation and local energy systems through creating social support and engagement.

Future plans

Piloting a community of 33 energy-neutral buildings in The Hague, and making it scalable and reproductible for the rest of the neighborhood.

Challenge as described by Spectral Energy (Spectral Energy, 2023): "The creation of a local energy community that is scalable to the complete neighborhood of Vruchtenbuurt, which utilizes the full potential of this local energy community. Building a smart grid to create demand-side flexibility and contribute to the energy infrastructure by using 'surpluses.' Development of a sustainable, social, autonomous organizational structure of a local energy community. Lastly, broadening understanding and enriching knowledge on local energy communities by the creation of scalable and reproducible case studies."

ASI-diagram conclusion

The ASI-diagram based on Koppenjan & Groenewegen (2005), which is generally visualized in Figure 4 and applied to smart grids in Figure 5. 'Rules of the game' that direct and coordinate the behavior of actors are needed in technological systems. These agreements may be outlined in formal laws, or they may take the form of informal norms and attitudes in a particular industry. Institutions or institutional arrangements are thus a collection of guidelines that control how parties involved in a (technological) system interact. This can be applied to Groene Mient as well to draw the main conclusions. First the action arena of actors is shaped by the relevant institutions, which is stated in section 6.3, generally stated around the design, implementation, development and operation of Groene Mient's local smart electricity grid system. This action arena of Groene Mient is not embedded at all due to several disconnections between institutions, actors and technology. The degrees of freedom the actors have in this project is way less than initially expected, due to the fact that the Exemption for grand experiments was more limited than realized. Therefore, the Exemption is not operational yet. This has a huge impact on the outcomes and feasibility of the project so far, which results in no real smart grid in place.

The technical system and the actors contain important interactions as well, since technology shapes the action of actors and actors influence the smart grid technology (development). In the case of Groene Mient the main finding in this perspective is the fact that certain technologies are less developed than expected, e.g., heat pumps without an IoT connection and therefore not smart grid ready. This has a huge impact on the outcomes and feasibility of the project so far, which results in no real smart grid yet in place.

The last important interaction deriving from the ASI-diagram is between the technical system and institutions. Here the main notion is the innovation of technology versus (lack of) institutional development and vice versa. Since the Exemption was more limited than expected it is not in place yet. However, Groene Mient and energy cooperative Sterk op Stroom are planning to extend their idea of the smart grid to the neighborhood of the Vruchtenbuurt, but in the Exemption it's stated that it only applies to the Groene Mient homes. This is an example of innovative technology perspectives and lagging institutions.

Link with theory

When making the connection between the concepts described above in the Groene Mient section, the theory of the IAD-framework and apply it to the seven rules-in-use categories affecting the action situation, most significant institutional factors with regards to Groene Mient, whether enabling or disabling, apply to the boundary, position, choice, payoff and scope rules. The choice rules are a significant aspect in this, as certain choices made by the Groene Mient project partners and energy cooperative SoS have led to the current situation in which no smart grid exist, and the exemption is not operational. Scope rules are another relevant barrier for the outcomes and goal attainment as those limit the degrees of freedom of the Groene Mient smart grid project. Considering the IAD-framework on a wider scope, important factors are the biophysical conditions and rules-in-use as exogenous variables. Next to this, the evaluative criteria/outcomes as the goal attainment (see codebook Appendix B) is (totally) different then when the project obtained the exemption.

8. COMPARATIVE CASE ANALYSIS

The three cases analyzed in the former chapter will be cross-case analyzed in this chapter and it will be elaborated as a case comparison. Therefore, firstly the insights from the most important analysis, IAD-framework and its respective rules-in-use, will be delineated. Hereafter, the interactions between the most important parts of a smart grid system derived from the cases will be explored. Lastly, a conclusion to the case comparison is provided with the most influential institutional rules and factors.

8.1. FINDINGS FROM IAD-FRAMEWORK AND ITS RULES-IS-USE

In this section, the main findings from Chapter 5, 6 and 7 are compared for each component of the IAD-framework, with the most important focus for this thesis: the Rules-in-Use.

8.1.1 ACTION SITUATION

The action situation for each of the three analyzed cases in this research is generally formulated as: *"The action situation of case X consists of the environment and stakeholders engaged in decision-making about design, implementation, development and operation of case X' local smart electricity grid system."* The action situation is core in an IAD-framework analysis. Hence, this was the starting point for all three case analyses.

8.1.2 BIOPHYSICAL CONDITIONS

In the aforementioned (general) action situation the biophysical conditions are part of the exogenous variables that set the context of the action arena. For the three cases, these are examples of physical and material conditions, e.g., building types, infrastructure and renewable energy sources/technologies used, which can be seen in Table 10.

Table 10 Biophysical conditions of all cases

Case	Biophysical/Material Conditions
Schoonschip Amsterdam	Project grid, fully electric energy efficient (46) houseboats, all connected to the internal project grid and a single connection to the national (low and medium voltage) grid, 30 batteries, heat pumps, 500+ solar PV panels and an EMS including 6 or 7 smart meters at each home.
GridFlex Heeten	Large experiment, fully electric energy efficient houses (47), using conventional grid behind one transformer owned and operated by the DSO, so all the households have a normal individual grid connection, sea salt batteries, (later) lithium-ion batteries, home-level EMS including smart meters (but no smart assets), overarching EMS, local solar park 7200 PV panels.
Groene Mient The Hague	Large experiment, fully electric energy efficient houses (33), using conventional grid owned and operated by the DSO, so all the households have a normal individual grid connection, smart meters but no smart assets, heat pumps, solar PV panels, solar boilers, communal garden.

The analyzed cases of Schoonschip Amsterdam, GridFlex Heeten, and Groene Mient The Hague exemplify a range of strategies to address biophysical and material conditions in the pursuit of energy-efficient housing solutions. Applying the IAD-framework to the three cases reveals both commonalities and nuances in their biophysical conditions. While the fundamental biophysical factors share similarities across all three cases, there are also distinct variations that warrant attention.

Schoonschip Amsterdam (SSA) stands out as a unique case within the framework due to its possession of smart grid-ready assets and a more extensive infrastructure. The presence of numerous smart meters and its comprehensive energy-efficient features differentiates SSA from the other cases. This uniqueness stems from its intricate interplay of elements such as project grid, batteries, heat pumps, and solar PV panels, contributing to a distinct biophysical setup.

On the other hand, GridFlex Heeten (GFH) and Groene Mient The Hague (GMDH) exhibit more comparability in terms of their biophysical conditions. Both cases share the underlying principles of fully electric energy-efficient houses and utilization of the conventional grid operated by the Distribution System Operator (DSO). However, there are notable distinctions: GMDH has yet to fully operationalize its exemption, while GFH has completed its experimental phase. These temporal differences highlight the evolving nature of their biophysical conditions under the IAD framework.

In essence, while the biophysical conditions are rooted in common principles across all three cases, the IAD-framework allows to discern the unique attributes of each case. The distinctive characteristics of SSA, coupled with the shared features and temporal variations of GFH and GMDH, emphasize the significance of context-specific considerations in shaping biophysical conditions within the broader framework of institutional analysis and development.

Collectively, these cases underscore the diverse paths communities can take to address biophysical and material conditions in the realm of energy-efficient housing. From collaborative project grids to innovative battery technologies, advanced energy management systems, and localized solar parks, these approaches reflect a shared commitment to sustainability and energy efficiency. As urban environments evolve and energy demands increase, these cases provide valuable insights into how innovative strategies can be tailored to specific contexts, fostering a more sustainable future.

8.1.3 ATTRIBUTES OF COMMUNITY

In the context of the aforementioned action situation, the attributes of the community function as exogenous variables that establish the contextual framework of the action arena. The three cases under consideration all fall within the spectrum of Renewable and/or Citizen Energy Communities (REC/CEC), as explained in Chapter 4. This classification is partly driven by a strong commitment to sustainability, particularly evident in the cases of Schoonschip and Groene Mient, which transcend mere energy communities. GridFlex is designated as a REC/CEC primarily due to its internal electrical connection and its association with the former smart grid. Beyond their shared pursuit of energy efficiency, these cases exhibit broader objectives. Schoonschip, for instance, extends its scope to encompass goals such as wastewater treatment and the utilization of recycled materials in construction. Similarly, Groene Mient integrates a communal garden that serves multiple sustainability purposes.

Analyzing the socio-economic characteristics of these cases, Schoonschip's unique housing arrangements and distinctive lifestyle contribute to its well-developed status. In contrast, GridFlex' attributes can be considered average, characterized by contemporary homes in a conventional neighborhood setting. Groene Mient's socio-economic profile surpasses the norm, as its residents undertook substantial financial risks during the investment phase prior to construction.

It's noteworthy that in terms of homeownership, each project adheres to private ownership models. Notably, Schoonschip and Groene Mient evolved from emerging communities into energy communities, whereas GridFlex was deliberately established as an (energy) community by its initiators, resulting in universal participation.

In summary, all three cases can be classified as REC and/or CEC. The sustainability drive is more deeply ingrained and pronounced in Schoonschip and Groene Mient, while GridFlex' REC/CEC designation hinges on its integration with the smart electricity grid and the exemption. Furthermore, the socio-economic characteristics differ, with the financial investment risks undertaken by Schoonschip and Groene Mient residents setting them apart from GridFlex, which had already completed its construction phase.

8.1.4 RULES-IN-USE

In the aforementioned (general) action situation the rules-in-use are part of the exogenous variables that set the context of the action arena. The most important and main rule-in-use in this thesis research is the Exemption of (parts of) the Electricity Act under Experimentation Decree, which all three projects have.

Boundary Rules

In examining the cases of Schoonschip, GridFlex, and Groene Mient within a smart electricity grid project, a key boundary rule emerges, primarily determined by the role of the local Distribution System Operator (DSO). The cases reveal distinct DSO involvements:

- Schoonschip, with Alliander as the DSO, operates a private project grid, resulting in limited DSO engagement due to its private ownership.
- GridFlex, managed by DSO Enexis, showcases substantial DSO involvement as the grid's legal overseer, profoundly impacting project outcomes.
- Groene Mient, with DSO Stedin as the local operator, sees less DSO participation than GridFlex, owing to various factors including financial considerations.

In these contexts, this important boundary rule dictates grid management authority. Schoonschip uniquely shifts authority to its Homeowners' Association (HOA), aligning with experimental dynamics. This altered rule highlights positional interplay in grid management. Schoonschip's transformation into an energy supplier underscores its rule's significance. However, this adjustment is temporary, restoring DSO control in a few years. This study underscores that actor participation in local smart grid projects stems from intricate regional, social, contextual, and legal influences.

Position Rules

The most important positions in the three cases within the scope of this research are the legal entity for the Exemption under the Experimentation Decree and the smart grid operator. For each case those are:

- Schoonschip, the Homeowners' Association (HOA) serves as the legal entity, with the energy working group acting as the operator of the smart grid.

- GridFlex, the energy cooperative Endona holds the legal entity position, while entrepreneurial cooperative Escozon serves as an internal project consultant. The smart grid operation involves other consortium partners like ICT Group and University of Twente.
- Groene Mient, the HOA is the legal entity, with the energy cooperative SoS responsible for smart grid operation. Additionally, All-in-power manages dynamic tariffs and the platform.

The positions in these local energy projects reveal intricate interrelations. Schoonschip's HOA and Energy working group collaborate with DSO Alliander, showcasing community-regulatory engagement. Gridflex' cooperation between Endona, Escozon, and Enexis emphasizes multi-dimensional partnership. Groene Mient's leadership by Groene Mient HOA and energy Cooperation SoS, with involvement from DSO Stedin, demonstrates a complex interplay between community-driven leadership, compliance, and external expertise. These positions underscore the interwoven dynamics of community, technical knowledge, regulatory compliance, and external support, shaping local energy planning outcomes. After all, most positions are set by law.

Choice Rules

In the context of innovative sustainability projects, the concept of choice rules revolves around actions that could have been taken based on specific circumstances, often influenced by policy, agreements, or regulations. In the analyzed cases:

- Schoonschip, Successful implementation hinged on key actions like forming a homeowners' association (HOA) and collaborating with Metabolic for sustainability expertise. Applying for the Exemption under the Experimentation Decree was crucial. The connection between Schoonschip and Metabolic facilitated the establishment of a smart grid.
- GridFlex, Within the constraints of the Experimentation Decree, the lack of pricing flexibility led to a decision to simulate the smart grid online. Delays in battery delivery prompted a change to lithium-ion batteries. The associated choice rule allowed alternatives when energy assets were delayed.
- Groene Mient, Forming an HOA and signing a declaration of intent were vital for the Exemption. Groene Mient's partnership agreement led to the establishment of energy cooperative Sterk op Stroom. However, financial and feasibility challenges led to the abandonment of smart grid ambitions.

In conclusion, the analyzed cases underscore that pivotal actions, driven by legal and informal considerations, significantly determine the success of sustainability projects. The decision to apply for Exemption under the Experimentation Decree and the establishment of legal entities play central roles. The interplay between policy, legal entities, partnerships, and adaptability defines the trajectory and outcomes of these projects. Next to that, the choice for smart grid technology had a significant impact on the successful outcomes of the different cases.

Information Rules

The diversity of participants, such as residents and consortium partners, in different projects dictates the nature and quantity of information accessible. This is contingent on the project's legal framework.

- In the Schoonschip case, a delay in receiving the 2020 energy bill highlighted information shortcomings. However, residents' active engagement relies on a high level of trust in the Schoonschip energy working group.
- GridFlex initially had adequate information for project initiators and partners, unaware of the Exemption's limitations on price variations, hampering the business case. Biophysical misconceptions and unforeseen issues like sea salt batteries further complicated matters.
- Groene Mient's insufficient information during project inception hindered smart grid implementation. Outdated technology like non-IoT-connected heat pumps reflected this gap.

The European Data Protection Regulation (GDPR) necessitates cautious handling of Energy Management System (EMS) and household data, upheld by both external and internal parties across the three cases.

In conclusion, information availability varies per case based on stakeholders involved. For smart grid pilot projects, EMS data management has to align with GDPR. Information specifics and handling methods are context dependent.

Aggregation Rules

Across distinct smart electricity grid (pilot) projects, decision-making processes diverge, involving a range of stakeholders, both internal and external. Examining each case in this research:

- In the Schoonschip case, official decisions are exclusively vested in the homeowners' association board. Recommendations from the energy working group and other units are typically mirrored by the appropriate legal entity. Essentially, Schoonschip's decisions, including those about their smart grid, occur internally.
- GridFlex's project consortium operated collaboratively, convening sessions with representatives from all partners. Local decisions in Heeten involved the entire consortium. Residents were represented by five advocates and engaged in monthly stakeholder meetings.
- In Groene Mient, initial decisions had consensus among stakeholders. However, diminished involvement from entities like the Municipality of The Hague impacted project motivation. Internal decisions in Groene Mient adhere to full consensus of all 33 households, adhering to a sociocratic model.

Concluding, Schoonschip's decision-making characterizes internal co-creation, GridFlex's process aligns with a consortium coalition, and Groene Mient's decisions align with a project consortium approach, contingent upon its continuity.

Payoff Rules

In the context of the payoff rules, which dictate the allocation of costs and benefits from specific actions and outcomes, these cases provide insights into the normative aspects that govern smart electricity grid projects.

- Schoonschip's adherence to energy tax regulations for its community-generated electricity, initially tax-free, increases project costs. However, the project remains viable and successful.
- GridFlex's attempt to influence consumer behavior through pricing models yielded modest individual savings (~€30/year), highlighting the need for automated smart grid asset processes to drive substantial change.
- Groene Mient's net costs and benefits remain ambiguous, with a modest subsidy of €75,000 from the province and potential for substantial value in collected data, opening doors for collaboration with knowledge institutions. This project did not get more subsidy while there is room for experimentation, there is a lack of funding available, e.g., the Energy and Climate Innovation Demonstration subsidy (Dutch: 'Demonstratie Energie- en Klimaatinnovatie (DEI+)') (RvO, n.d.), which seemed to be due to its emphasis on significant innovations made by (commercial) market actors. However, Schoonschip got this subsidy due to their consortium flexibility VPP project with Greenchoice and more.

These cases underscore that payoff rules impact project feasibility and success. Dynamic tariffs for demand management were employed in GridFlex and Groene Mient, aiming to reshape consumer behavior. The conclusion drawn is that payoff rules significantly influence project outcomes, varying across smart electricity grid projects.

Scope Rules

The institutional mechanisms governing the adoption of scope rules are a crucial part of the potential outcomes, as well as jurisdiction and status of the outcome.

- In the Schoonschip case, its status as a floating neighborhood facilitated the establishment of a unique project grid under the Experimentation Decree, affording more possibilities than a conventional grid. This distinct circumstance contributed to a more viable business case for Schoonschip. However, the freedom of energy company choice within consumer law posed challenges.
- For GridFlex, limited technical alternatives were available due to constraints like the absence of developed sea salt batteries, absence of smart assets, and a simplified customer behavior model. The Exemption's narrower scope and the impact of tax refund schemes further complicated matters.
- In the case of Groene Mient, the intended smart grid was not realized, and the Exemption under the Experimentation Decree remains non-operational, in contrast to the other projects that swiftly executed the Exemption. The scope rule limiting the Exemption to Groene Mient households posed challenges for extending it to the entire Vruchtenbuurt neighborhood.

In conclusion, the analysis reveals varied outcomes concerning scope rules across cases. While some legislative aspects influence all three pilot projects, the temporary status in Groene Mient and Schoonschip, and the eventual status in GridFlex, differ due to multiple factors, including the influence of scope rules.

8.1.5 PARTICIPANTS

A smart grid electricity system with an Exemption to the Electricity Act in the Netherlands has different types of stakeholders involved, e.g., from smart grid operator to the local government. This does also apply to the three cases considered in this (thesis) research. Overall, the same nature of actors is involved to start with local scale, e.g., one legal entity for the (request) Exemption under the Experimentation Decree, a local smart grid operator either an energy cooperative or working group in this case and local people (residents). Next to this, the (regional) distribution system operator is (should be) highly involved. To operate the smart grid with an EMS there has to be a company or whatsoever that maintains and develops the digital system. The Municipality could be an important (legal) stakeholder if for instance the neighborhood still has to build or is being constructed at that time like the Groene Mient. Another important stakeholder for the successful deployment of the smart grid are consulting and smart asset (e.g., heat pump, battery) companies to enable the system with the right knowledge and assets. In the Dutch electricity system (large) energy companies that supply energy to (individual) customers currently still play a huge role, so these are also important in the smart electricity grid systems considered here. Greenchoice is the single big energy company that provides Schoonschip, with their single connection, energy in times of low solar PV production and provides flexibility in the VPP experiment. The situation at GridFlex was like any other neighborhood with all individual connections and energy companies, but since the homes were behind one transformer the area could be simulated as if it was one large consumer with one energy supplier. Groene Mient has in theory all individual connections with the grid, so all the households could have a different energy supplier, but since they are a strong community most of them have All-in-power and the energy cooperative Sterk op Stroom as energy company. The next important stakeholder(s) is the Netherlands Enterprise Agency (RvO) as the grantor of the Exemption under the Experimentation Decree. Besides this the Consumer and Market Authority (in Dutch: Autoriteit Consument en Markt (ACM)) for approval of tariffs as part of Experimentation Decree. The national government especially the Dutch Ministry of Economic Affairs and Climate Policy is also a significant one, as the RvO is part of it.

To conclude, participants are part of the action arena in the IAD-framework accompanied by the action situation are crucial with regards to the implementation of smart grids. Although the participants in various cases might have some fundamental similarities, their individual characteristics and situations can differ, leading to unique outcomes and considerations. It is crucial to recognize and account for these differences when designing and implementing policies or interventions. By acknowledging the unique context of each case, strategies can be tailored better, same for rules, and approaches to effectively address the specific needs and challenges of the participants involved.

8.1.6 INTERACTIONS

Interactions that are core for this (thesis) research happen between technology and institutions within the action situation at hand. The most common type of interactions in an energy community with a smart grid system involve energy trading, demand response and data sharing & information exchange.

- Energy Trading: The (final) goal is to enable peer-to-peer energy trading that involves energy producers and consumers. However, in the current Dutch regulatory framework this is simply not possible. That is why the most successful case Schoonschip acts as their own producer, distributor and supplier (own tariffs), but they do peer-to energy community to-peer supply. The other two cases were not smart grid ready due to institutional barriers under the Experimentation Decree and technological difficulties and setbacks in development.
- Demand Response: Interactions could occur between energy consumers and the smart electricity grid system to enable demand response programs. This is currently only possible and in place at the Schoonschip project where smart assets provide this and the experiment of the VPP. At GridFlex and Groene Mient they focus on increasing flexibility through a shift in consumer behavior with energy efficient technologies instead of smart grid ready assets.
- Data sharing & Information exchange: Data on energy use, grid performance, and other relevant information would be shared during interactions between community members, energy providers, and grid operators. These types of interactions are or will be strictly regulated by the GDPR and other privacy laws. It is unclear who and what each role would entail in the data and information area of smart electricity grids.

In the context of Schoonschip, significant informal interactions emerge involving stakeholders, institutions, and technology. Notably, the energy working group holds decision-making authority over energy and smart grid matters, though legally belonging to the homeowners' association (HOA), without substantial issues. Similarly, within GridFlex, informal dynamics between consortium partners, residents, and representatives contributed to a successful smart grid project, driven by persuasion and local efforts. Challenges arose in aligning Groene Mient's smart grid with municipal policy, straining the Groene Mient/SoS-municipality relationship. Governmental challenges outweigh technical ones, emphasizing the need for unified project strategies. GMDH's smart grid experiment's continuation hinges on successful research collaboration with GFH. According to Groene Mient the municipality's self-focused challenges strain its relationship with GMDH.

Conclusion, overall interactions play a crucial role in influencing the behavior, decision-making, and collective outcomes of participants in collective action situations shaped by technology and institutions.

8.1.7 OUTCOMES & EVALUATIVE CRITERIA

The main outcomes focused on in this (thesis) research are the implementation of smart grid ready assets (flexibility possibilities), sustainability, energy and economic efficiency. To evaluate these outcomes there are evaluative criteria to assess the 'success' of these outcomes. The chosen ones to focus on are goal attainment, economic efficiency/affordability and acceptability. The most important aspect is the goal attainment that is comprehensive towards all outcomes and in a sense evaluates them:

- Case Schoonschip: The achievement of goals in the case of Schoonschip can be considered highly successful due to the strong integration of sustainability values in the community's norms, values, and daily practices. The community has implemented a range of sustainable initiatives, including the establishment of a smart grid with smart grid-compatible assets, internal balancing, grid reduction, and various other sustainable practices that go beyond electricity consumption, such as wastewater treatment. Additionally, the implementation of smart meters and the utilization of flexible services provided by smart assets like batteries and heat pumps, along with conscious consumer behavior, further contribute to the overall sustainability of the community. Overall, Schoonschip has demonstrated a commendable level of achievement in terms of sustainable living practices.
- Case GridFlex: The goal attainment of GFH falls below expectations, given the current situation involving the Exemption. The composition of energy prices in the Netherlands poses challenges. Moreover, the lack of smart grid ready assets and limited flexibility options restrict the potential for significant improvements. GFH primarily relies on consumer behavior for flexibility, and their traffic light method has not resulted in substantial changes in behavior or savings per household.
- Case Groene Mient: The biggest challenges that decreased the goal attainment are project-based, legal framework of the grid operator and making agreements with regards to grid tariffs (not successful yet but are starting with it), cooperation with local government and lack thereof, technological (control vs. monitoring), lacking financial opportunities/resources. Therefore, smart grid 'readiness' of their system and assets contains only smart meters in place and flexibility services provided by consumer behavior. Therefore, the most noteworthy finding is that the exemption has not yet been effectuated with no max. date of implementing, while SSA and GFH needed to implement it within one year after granting the exemption.

In conclusion, Schoonschip demonstrates highly successful goal attainment through strong sustainability integration, smart grid implementation, and diverse sustainable practices. In contrast, GridFlex faced some challenges with the Exemption, energy price composition, and lack of smart grid-ready assets, while Groene Mient's goal attainment is hindered by project-based, legal, and financial constraints.

8.2 CONTEXT FACTORS AFFECTING PROJECT'S SMART GRIDNESS

In Table 11 below this research lists the most relevant context factors found in the analyses of the cases that affect the outcomes and 'smart gridness' of the analyzed cases. In the institutions category each of the seven institutional rules-in-use is considered in the categorization of barriers (-) or opportunities (+). The enabling (+) and hindering (-) effects of each (institutional) circumstance is thoroughly discussed in the former sections.

Table 11 Barriers and Opportunities to each project

	Schoonschip Amsterdam	GridFlex Heeten	Groene Mient The Hague
Technology	**+**	**+/-**	**-**
Actors	**+**	**+**	**+/-**
Institutions (including all seven rules-in-use)	**+**	**+/-**	**+/-**
Goal attainment	**Yes**	**Yes/No**	**No**

The most important context factors found in the cases are technology aspects, stakeholders/actors, institutions and the goal attainment of each project. Technology this factor assesses the influence of technology on each project. Schoonschip Amsterdam has a positive impact, indicating that technology is aiding the project's success. GridFlex Heeten's impact is mixed, suggesting both positive and negative effects. In contrast, Groene Mient The Hague is negatively impacted by technology.

Actors this category evaluates the role of various actors in the projects. In both Schoonschip Amsterdam and GridFlex Heeten, actors have a positive impact, implying that their involvement contributes to the projects. Groene Mient The Hague experiences a mixed impact, indicating that the role of actors have been positive and negative.

Institutions, including the application of established rules, play a role in shaping the projects. Schoonschip Amsterdam has a positive impact by the analyzed institutions. GridFlex Heeten and Groene Mient The Hague experience mixed impacts, suggesting that institutions have both positive and negative effects.

Lastly, goal attainment which assesses whether the projects have achieved their goals. Schoonschip Amsterdam and GridFlex Heeten have achieved their goals, indicated by "Yes" and "Yes/No" respectively, suggesting some level of goal accomplishment. However, Groene Mient The Hague has not achieved its goals, indicated by "No."

In summary, the table presents a comparative overview of the barriers and opportunities faced by each project across different dimensions, including technology, actors, institutions, and goal attainment. It highlights the varying impacts these factors have on the success of the projects.

8.3 CONCLUDING REMARKS

In this chapter, the findings from Chapter 5, 6 and 7 are summarized for each component of the IAD-framework, with a particular focus on the rules-in-use.

The action situation of each analyzed case is described as the environment and stakeholders involved in decision-making regarding the design, implementation, development, and operation of the local smart electricity grid system. The biophysical conditions, such as building types, infrastructure, and renewable energy sources/technologies used, vary between the three cases. All three cases can be categorized as Renewable and/or Citizen Energy Communities (REC/CEC) and have additional sustainability objectives beyond energy efficiency. Socio-economic characteristics differ, with Schoonschip and Groene Mient being more developed and unique compared to GridFlex. All homes in each project are privately owned. The main rule-in-use in all three cases is the Exemption of (parts of) the Electricity Act under the Experimentation Decree. The involvement of the local distribution system operator (DSO) varies between the cases, with different levels of engagement from Alliander, Enexis, and Stedin. The important positions in each case include the legal entity for the Exemption and the smart grid operator. The decisions regarding the Exemption and the establishment of legal entities vary between the cases.

The interaction between technology and institutions is very important as (technical) innovation is faster than the laws and regulations development. Interaction between actors and institutions also very important because this comprises the people that make the rules and have to obey the rules in a complex socio-technical system as a smart grid project system. Of course, the interaction between the technology and the actors cannot be neglected as technology shapes the possible actions could be taken by actors and actors facilitate smart grid technology development.

Overall, the findings demonstrate that the Rules-in-Use in the analyzed cases significantly impact the outcomes of the smart electricity grid projects, and these outcomes vary depending on the specific context and circumstances of each case.

8.3.1 EXTENDING THE CASE CONCEPTS

It could be concluded from Schoonschip, GridFlex and Groene Mient and the analysis of the seven energy and flexibility services (the seven value propositions defined by USEF (2019) as can be seen in Figure 8) provided in the current legislation reveals that energy communities face difficulties in participating in some of these services. Certain services may not be allowed or adequately valued under the Dutch law, while others may be unprofitable or challenging to establish. The analysis of each service is as follows (Reijnders et al., 2020):

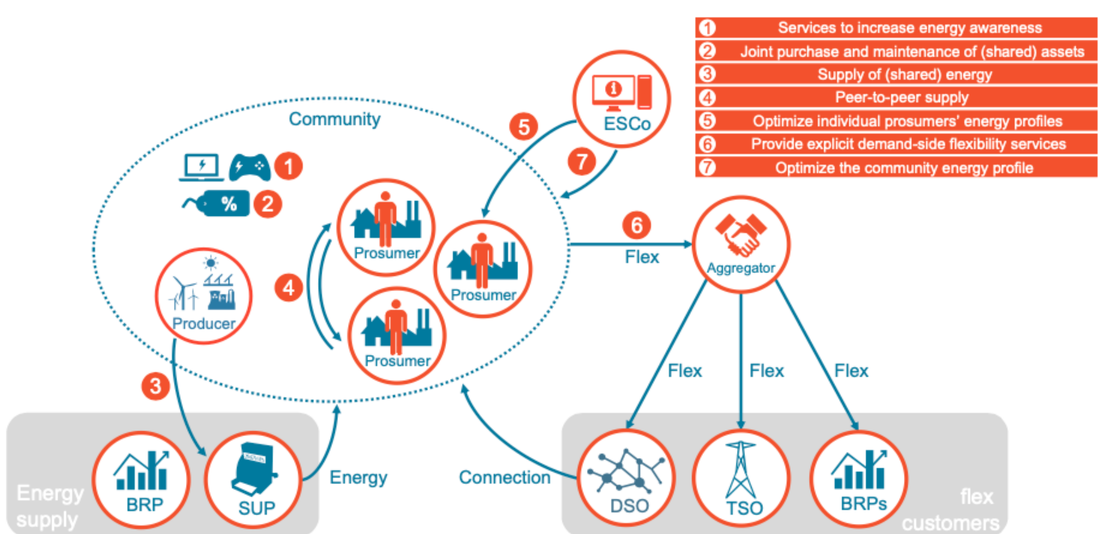

Figure 8 Seven energy and flexibility services (value propositions). Source: USEF/Reijnders et al. (2020)

1. **Services to increase energy awareness:** Pilot projects show that using smart meter data to extract consumption patterns and provide information to residents can enhance energy awareness, increase self-consumption rates, and promote efficient energy usage.
2. **Joint purchase and maintenance of (shared) assets:** Energy communities can collectively buy solar or wind installations, enjoying tax exemptions on the annual consumption from these sources (Dutch: postcoderoosregeling and its successor the (SCE) Subsidy Cooperative Energy production). However, there is limited encouragement for regular (and not annual) physical joint self-consumption.
3. **Supply of (shared) energy:** Energy community has the potential to act as an electricity supplier, but this entails significant responsibilities and may not offer substantial benefits compared to traditional suppliers.
4. **Peer-to-peer supply**: Current legislation prohibits peer-to-peer supply, requiring selling permits and balancing responsibilities (Dutch: 'Programmaverantwoordelijkheid') for participants. Implementing this within a community would necessitate all members switching to the specific supplier offering peer-to-peer propositions.
5. **Optimize individual prosumers' energy profiles** *(implicit demand response)***:** Fixed grid costs and limited energy price variation discourage reducing grid usage during peak times. The tax refund scheme (Dutch: salderingsregeling) for annual self-consumption undermines incentives for direct self-consumption optimization and hampers the business case for home batteries. The phase-out of the tax refund scheme (between 2023-2031) may support growth in the battery market.
6. **Provide explicit demand-side flexibility services:** Smaller energy communities struggle to participate in explicit demand response due to high minimum product sizes and the need for supplier consent. Engaging in explicit demand response is nearly impossible unless they join a larger body.
7. **Optimize the community energy profile:** Current legislation lacks provisions for negotiating specific energy tariffs or allowing communities to disconnect from the main grid, resulting in no benefits for optimizing community energy profiles.

9. SMART GRID EXPERT FINDINGS

This chapter explores the interviews that with its main content explain the (external) context in which the smart electricity grid (pilot) projects analyzed in this thesis research developed and still develop over the years. In this section the main interview findings will be via the ASI-diagram as described in chapter 2.

9.1. TECHNOLOGICAL SYSTEM

Smart grids are technology-based systems that integrate various technologies to balance electricity supply and demand. They also involve organizational and cooperative aspects with stakeholders. Smart grids have flexible definitions and can operate at various scales, but neighborhood-level implementation is particularly advantageous. Currently, the implementation of a fully functional smart grid requires obtaining an exemption. Without this exemption, the essential aspects of a smart grid cannot be realized, limiting the ability to address existing problems effectively (interviewee #11).

According to the interviewee (#12), a smart grid should be equipped with smart devices at the distribution, transmission, and end-user levels. Key characteristics include bidirectional power flow from end users to energy providers, enabled by smart devices and flexible end-user capabilities such as storage devices and demand side management. To accommodate this bidirectional flow, equipment and infrastructure need to be upgraded to support the functionality of a smart grid.

A smart grid is an energy system designed to improve energy efficiency and optimize the coordination of interconnected stakeholders (interviewee #13). It utilizes strategies and technologies to effectively balance energy supply and demand. The key objective is to enhance the overall efficiency of the system and seamlessly integrate all participants involved in grid operations.

A smart grid is characterized by its ability to facilitate prosumerism, promote interactions among multiple players, accommodate intermittent energy sources, enable microgrids, and integrate various functions that are typically separate in the marketplace (interviewee #14).

9.2. ACTORS

Key stakeholders

The key stakeholders in smart grids include the grid operator as the central problem owner, companies seeking solutions, aggregators with IT capabilities to match supply and demand, EU with legislative influence, residents, government, local municipalities, and site-specific local companies. Currently, PVs (energy suppliers) must be matched with grid operators, while aggregators are expected to play a role as per future EU legislation (interviewee #11).

The main stakeholders in the transition to smart grids are end users who need to adopt and adapt to new technologies, and distribution system operators (DSOs) who bear the primary responsibility for the distribution infrastructure (interviewee #12).

Key stakeholders in the bottom-up approach to addressing energy goals and grid challenges include citizens, support organizations, grid managers, regional operators, energy companies, government entities, and facilitators/aggregators, forming a multi-actor game (interviewee #14).

Energy Communities

An energy community is a distinct organizational structure that goes beyond financial interests and prioritizes communal benefits in addressing energy-related issues (interviewee #13). It seeks to promote community well-being, environmental sustainability, and local empowerment by actively tackling energy challenges and embracing opportunities. The Dutch Enterprise Agency (RvO) found that creating an Energy Community is a complex process, as revealed by the Experimentation Decree and its projects. Nonetheless, the Experimentation Decree provided valuable insights on establishing effective Energy Communities (interviewee # 8).

Energy communities have to be recognized as socio-legal institutions where multiple actors collaborate to integrate functions like production, consumption, and storage (interviewee #14). They emphasize local character, limit the influence of larger commercial entities, and can be perceived as market participants or entities with civil society elements.

Stakeholders vs. Formal rules (interviewee #9)

To encourage experimentation, there is a need for increased flexibility and reduced reluctance among DSOs. DSOs tend to interpret rules conservatively, limiting their willingness to engage in experiments. Lawmakers should create more room for interpretation, enabling grid operators to experiment without hesitation. Shifting towards a mindset of asking forgiveness rather than seeking permission is a positive development, and the Authority for Consumers & Markets (ACM) plays a role in determining the permissibility of actions. This shift is also occurring within the ACM itself.

Energy Cooperatives as a (new) market player (interviewee #10)

The market is moving much faster these days, so there has to be searched for solutions together with market parties, where energy cooperatives are a great example, e.g., Endona and Sterk op Stroom.
Energy cooperatives and grid operators (DSOs) share aligned interests, but energy supply companies lack alignment. EU legislation allows customers to participate in the energy market, which is facilitated through energy cooperatives becoming competitors to their former suppliers. This creates market disruptions due to clashes between the old energy system and the new one. The ongoing competition is expected to address these issues and bring about necessary changes in the energy market.

Changing market parties

In the rapidly evolving market, collaborative solutions with market parties, including energy cooperatives, are essential. Energy cooperatives align their interests with grid operators, unlike energy supply companies. The traditional energy system involved a simple connection between customers and suppliers, but EU legislation now enables customers to participate in the market through energy cooperatives. This creates competition with former suppliers and disrupts the market, highlighting the clash between the old and new energy systems. Ongoing competition is expected to address these issues and bring about necessary changes.

There are currently two dominant models being discussed. The first model is collective self-consumption, where consumers share the excess energy they generate among themselves, separate from their contracted energy supplier. The second model involves an energy supplier owned by cooperatives, which facilitates sharing and maintains a connection to the market. The interviewee (#10) anticipates that these two models will shape the future market.

Role of the government (interviewee #14)
Government policies at various levels are vital for the success of local smart grid projects. National regulations, particularly those outlined in the Electricity Act, enable and support these initiatives. At the local level, policies concerning licensing, destinations, subsidies, and financial support are significant. The government focuses on regulatory measures rather than direct public-private collaborations. Early-stage collaboration among stakeholders is facilitated to ensure effective coordination and engagement in smart grid projects.

9.3. INSTITUTIONS

Experimentation Decree and its future (interviewee #8)

- With the Exemptions operating there are lot of setbacks for initiators: managing one's own grid in practice is much more complex than expected, people were enthusiastic when applying for such an exemption, thinking that managing one's own grid is nice, but rules that apply to grid managers also apply if you manage your own grid, e.g., Groene Mient. Therefore, anno 2023 not all projects that got the exemption have started because of various reasons: financing problems, contractors, business case (Energy tax is a major obstacle, affects many business cases), one of the main reasons is managing and operating an own grid is way more difficult than initially expected (Interviewee #8).
- The outcome of the new Dutch Energy Law is that the Electricity Act, on which the Experimentation Decree is based, will be invalidated. This raises concerns about whether the new Dutch Energy Law will still include barriers for energy communities and smart grids, as the law is being rewritten and may undergo changes. Additionally, the new legislation aligns with European regulations such as the Clean Energy Package, Renewable Energy Directive II, and Internal Electricity Market Directive, which significantly impact the Experimental Decree.
- Under the new Dutch comprehensive Energy Law, the project's exemptions lasting 10 years will eventually expire. When this happens, the grid operator in the area will assume responsibility for the project grid. To address this transition, a temporary exemption position will be established, bridging the gap between the old Electricity Act and the new Energy Law.
- The Experimentation Decree is beneficial, but its evaluation has been lacking due to delays in project implementation. It takes time for projects to take off, hindering a comprehensive assessment. The scalability of the exemption policy to larger projects is a question, as its current content may not be suitable (interviewee #13).

New Dutch Energy Law and EU legislation (interviewee #10)
The Council of State of the Netherlands advised the government to reconsider the proposed comprehensive Energy Law due to several formulation issues. The law refers to everything as energy supply rather than energy sharing, which conflicts with EU definitions and regulations that distinguish

between the two. This discrepancy between Dutch and EU terminology may hinder the implementation of the law. In March 2023, the European Commission made adjustments to EU legislation, introducing separate rules for energy sharing. Consequently, the Dutch government is lagging behind and the new Energy Law, intended for presentation to the House of Representatives in June 2023, is already outdated. Energy sharing is fundamentally distinct from energy supply, emphasizing the need for accurate terminology and regulatory alignment.

At the European level, policies like RED 2 and IEMD influence the initiation of local smart grid projects, supporting Energy Communities and enabling experimentation and integration of functions. Financial support, especially grants, are essential for project implementation. Regulatory barriers to energy storage adoption, such as restrictions on DSOs engaging in storage activities, can lead to frustration, contrasting with the allowances for consumers and energy companies (interviewee #14).

Grid regulation & Information exchange

The current focus in grid management regulation revolves around optimizing grid utilization, addressing congestion, and improving overall efficiency. The definition of a 'smart grid' remains subjective, dependent on the extent to which it enables efficient grid utilization (interviewee #13). The management and retention of exchanged information in a smart grid introduce challenges, particularly in determining the responsible party. The Distribution System Operator (DSO) is a potential candidate for managing this information, but establishing authority and accountability necessitates careful consideration to ensure effective utilization and handling within smart grid systems (interviewee #13).

More (energy) suppliers on one connection (MLOEA) (in Dutch: meer (energie)leveranciers op een aansluiting) (interviewee #10): There is a need for institutions and legislation to support the concept of simultaneous multiple contracts on the same connection. This would enable local energy sharing between neighbors instead of feeding excess solar energy back into the grid. Although this ambition is included in the law, the Ministry lacked an understanding of how to regulate and implement such arrangements in practice.

Institutional challenges

Laws and regulations often pose challenges for local smart-grid projects, particularly in areas such as storage capacity and the constraints of existing market frameworks. Creating space for experimentation and establishing an institutional setting that supports smart grids is essential. Evaluating existing legal models and their compatibility with energy communities and smart grids is crucial for facilitating the establishment of different institutional forms, such as cooperatives or limited liability companies, within the regulatory framework (interviewee #14).

Future prospects (interviewee #10):

To optimize the future energy system, attention must be given to the rules and roles involved. Currently, the energy system comprises five roles: grid operators, suppliers, meter operators, and Program Responsible Parties (PVs). Energy cooperatives are entering the system, raising questions about their classification: are they customers, do they have program responsibility, can they supply energy, and do they operate their own grid? Some energy cooperatives have considered establishing their own physical grids, but this may lead to competition with major energy suppliers and grid operators. It is crucial to avoid conflicts with grid operators and instead collaborate to ensure that energy cooperatives are supported and facilitated by Distribution System Operators (DSOs). Program responsibility entails tasks like forecasting, portfolio management, and imbalance settlement, and the entry of cooperatives alongside energy suppliers with program responsibility requires coordination with grid operators to manage portfolio effects and prevent additional imbalance costs for suppliers.

9.4. BARRIERS AND SUCCESS FACTORS

The established regulatory frameworks of the European Union (EU) are aimed at promoting the development of numerous projects across various European countries, as stated in the interviews with interviewees (#9, #10 & #14). The Experimentation Decree allows prohibited activities, fostering learning and knowledge exchange for successful local sustainable projects. The European Clean Energy Package promotes integrating local initiatives into the future energy system. Concerns arise regarding the role of big utilities and coexistence with smaller projects. The governance triangle involves government, market, and societal control, with societal control promoting collaboration between government and citizens (interviewee #14). This cooperation empowers citizens, ensuring inclusive decision-making and a balanced energy sector governance structure.

Need for…

- According to the interviewee (#9) smart grid success factors: Sufficient organizational power, money and urgency are very important.
- We need knowledge management: regional umbrellas, e.g., Energie Samen, (perhaps local governments should fill this in). Local business and projects involving citizens should also be able to consult with (local) experts etc. (interviewee #9).
- The development of a smart grid project relies on timely collaboration and broad participation. Regional Energy Strategies (RES) from provinces and district-level plans are crucial. Similar coordination is needed at the municipal level for effective area-specific planning (interviewee #11).
- The initial phase of a smart grid project requires problem identification and assessment of its suitability as a solution. Clearly defining the rights and responsibilities of involved parties, including the grid operator and connected entities, is crucial for legal clarity (interviewee #13). Guidelines on cost allocation and benefit sharing should be established to avoid complications. Early discussions and agreements are necessary to create a well-defined framework for successful smart grid implementation.
- The successful implementation and development of a smart grid project require identifying key stakeholders, understanding the problem, and establishing ownership. Clear definitions of roles, responsibilities, and the organizing entity are crucial (interviewee #9). It is important to consider the resources and interests of all stakeholders to foster collaboration. Conducting a preliminary assessment aligns interests and sets the stage for effective collaborative action.

The main barriers to smart grid development are outdated laws and regulations that do not keep pace with technical advancements. Smart grids are crucial for the future energy system, but their development is hindered by slow regulatory progress. Policy makers should prioritize national-level development while encouraging local experimentation and knowledge sharing to learn from successful practices implemented elsewhere (interviewee #11).

The current disablers of smart grids can be categorized into three main areas (interviewee #12). Socially, there is a lack of awareness and understanding among end users and stakeholders about the severity of environmental problems and the potential benefits of smart grids. Technically, there are challenges related to control and inertia in smart grid systems. Institutionally, coordination among stakeholders, including DSOs, the electricity sector, and policy-makers, is difficult, and decision-making processes are complex. A dedicated platform for coordination and agreement among stakeholders is needed to overcome these barriers and facilitate the energy transition. From Ostrom's IAD-framework perspective the main rules that influence smart grids are information and position rules. With smart grid development it's all about policy making (interviewee #12).

Motivation, knowledge, and resources are critical for the success of a smart grid project. Overcoming challenges such as knowledge sharing, information sharing, funding, and aligning motivations is essential for progress and effectiveness (interviewee #14). Insufficient knowledge and resources can hinder smart grid development.

9.5. CONCLUDING REMARKS

Laws, regulations, and policy instruments play a crucial role in shaping the development of Smart Grid (SG) projects. They aim to prevent abuse of power, promote a free market, and define the roles and responsibilities of stakeholders. Clear regulations are necessary to provide guidance and avoid legal uncertainty. Grid operators can incentivize stakeholders through grid tariffs to address challenges like congestion and flexibility. Effective regulation of network tariffs can drive progress in resolving these issues (interviewee #13). Striking a balance between clear regulations and flexibility is key to fostering the development of SG projects and achieving desired outcomes.

The scalability of smart grids is primarily influenced by the dynamics between stakeholders and the existing legislation and regulations, rather than being solely a technological issue. Recent insights highlight that Brussels has shown greater proactiveness compared to The Hague, emphasizing the significance of energy cooperatives and the need for changes in the market structure. Through case analysis, it was initially anticipated that certain laws, such as X, Y, and Z, would pose challenges. However, the problems encountered were found to be more extensive, including issues within the legislative process itself. One major barrier is the methodology of ensuring that legislation remains relevant and enables a facilitating role in a rapidly evolving technical environment.

The main findings of the research by Van der Waal et al. (2020) include the potential and limitations of bottom-up, participatory innovation in a polycentric system. They come to the conclusion that taking a more comprehensive approach to experimenting, coordinating the objectives of many actors, offering more incentives, and providing knowledgeable and financial assistance will improve bottom-up participatory innovation in the energy sector.

10. CONCLUSION & DISCUSSION

To enhance the sustainability of the Dutch energy system, the implementation of local smart (electricity) grid systems offers viable solutions to evolving challenges. Such systems employ an ICT- layer to precisely regulate the production and consumption of local renewable energy. The creation of such systems is still in its early stages, as this master's thesis demonstrates. Several barriers and potential solutions have been identified from the perspective of complex socio-technical systems with an emphasis on institutions. Therefore, in this chapter first the sub research questions (SRQ) are answered, which all together form a general answer to the main research question in the next section of this chapter. Thereafter, the (scientific) discussion is outlined as contribution of the results of this research to relevant scientific debate with the limitations of this research. At last, the future scientific and policy recommendations are presented to solve limitations of current research and to provide advice for policy makers.

10.1 ANSWERING RESEARCH QUESTIONS

The purpose of this research is to explore and get insights in the institutional settings of the Dutch system design with regards to smart (electricity) grid development, implementation and usage. In the following answers are given to the three sub research questions to give a comprehensive answer to the main research question of this (thesis) research, starting with the first one.

10.1.1 SUB RESEARCH QUESTION 1

SRQ1: *What constitutes the institutional environment of smart grids?*
Chapter 4 of this study primarily focused on this sub-question. The required information for this section was predominantly gathered through a review of grey literature and supplemented by insights gained from conducted interviews. The employed ASI-diagram was customized and drew inspiration from the IAD-framework, serving as a tool for the initial investigation of smart grids in the Netherlands.

The liberalized Dutch electricity system transformed the market, creating a competitive environment that aimed to benefit consumers and promote sustainable energy practices. The Innovation Program for Smart Grids (IPIN) served as a pilot project and a predecessor to smart grids in the Netherlands. The study found that smart grids and energy systems would become increasingly important in the long run, necessitating immediate action. However, the urgency surrounding the need for flexibility in the electricity system, as emphasized by IPIN, gradually diminished back then in the early 2010s. The economic value of flexibility is crucial for the significance of smart grids. The transformation of the energy system from a conventional (liberalized), centralized, and top-down approach to a decentralized and bottom-up model is driven by concerns about climate change. Smart grids play a vital role in integrating renewable energy sources and optimizing energy usage by combining information and communication technology (ICT) with real-time monitoring. The ‘new’ energy system prioritizes decentralized energy production complemented with smart grids. Enabling these energy system changes requires not only technological advancements but also institutional developments, including legislation. Institutional changes should occur from the EU level to the Dutch national level and subsequently to regional and local levels. EU regulations, such as the European Clean Energy Package (CEP), Renewable Energy Directive II (REDII), and the Internal Electricity

Market Directive (IEMD), cover developments at the European level. Member states, including the Netherlands, need to incorporate these regulations into their national legislation, which is currently being developed as of the new comprehensive Energy Law combining the existing Electricity and Gas Acts. To overcome limitations imposed by the outdated Electricity Act, the Experimentation Decree was established in the Netherlands. This decree allows exemptions from specific articles of the Electricity Act to provide more flexibility for experimentation. This thesis research analyzed several cases that obtained exemptions under the Experimentation Decree. Furthermore, the emergence of energy communities, which could possibly be filled in as energy cooperatives or collectives, is significant in the development of smart grids. These communities focus on sustainable energy production and usage at the neighborhood level. The new European legislation distinguishes between Renewable Energy Communities (RECs) and Citizens Energy Communities (CECs) in line with the goals outlined in RED II and IEMD. The cases studied in this research could be considered both RECs and CECs with their smart grid implementations.

10.1.2 SUB RESEARCH QUESTION 2

SRQ2: *How is smart grid technology implemented in local experimental community energy projects?*
Chapters 5 to 9 of this study primarily focus on addressing this sub-question. The required information for this section was predominantly obtained through an extensive review of literature, including grey literature, supplemented by insights gleaned from the conducted semi-structured interviews. The framework utilized was tailored and integrated from the Institutional Analysis and Development framework, selected to facilitate the acquisition of pertinent information.

The implementation of smart grid technology at the local level is influenced by several factors. To implement a real smart electricity grid in the Dutch system, obtaining an Exemption, such as the one provided by the Experimentation Decree, is crucial as it allows more flexibility. Legal entities such as homeowners' associations (HOAs) or energy cooperatives were necessary to request and attain the Exemption, making the projects analyzed in this research considered as Energy Communities under the new EU regulations (CEP, REDII, and IEMD).

Before implementing a smart grid, a project plan and feasibility study are essential for successful implementation and development. The Schoonschip Amsterdam, GridFlex Heeten, and Groene Mient The Hague cases highlight the importance of conducting feasibility studies before seeking Exemptions under the Experimentation Decree. This is because the degrees of freedom can be more restricted than initially anticipated due to the status of being a grand experiment (GridFlex and Groene Mient). A project grid such as Schoonschip imposes relatively more success. Technological requirements pose challenges for achieving goals when aiming for a smart grid. Meeting the definition of a smart grid in this research involves considering various factors such as smart grid technology, including smart meters and smart grid-ready assets. An Energy Management System (EMS) and its associated stakeholder(s) play a significant role in smart grid technology implementation as the digital layer of the smart electricity grid where transactions occur. The involvement of the local Distribution System Operator (DSO) is crucial, particularly in the context of the changing electricity system. Their participation is necessary for the successful implementation of a smart electricity grid.

10.1.3 SUB RESEARCH QUESTION 3

SRQ3: *How does context (institutions, technology and stakeholders) influence the development of smart grids in the Netherlands?*

Chapters 5 to 8 of this study extensively delve into this sub-question, focusing on the comprehensive analysis of the Schoonschip Amsterdam, GridFlex Heeten, and Groene Mient The Hague projects. The information essential for these sections primarily derives from a meticulous review of literature, encompassing grey literature, coupled with the invaluable insights garnered from the conducted semi-structured interviews. The framework employed for this purpose was carefully tailored and integrated from the Institutional Analysis and Development framework, strategically adopted to ensure the acquisition of pertinent and accurate information.

As of the IAD-framework in the three analyzed cases the exogenous variables are most significant to influence, whether facilitating or constraining, smart (electricity) grid implementation in local projects. These exogenous variables consist of the biophysical conditions, attributes of community and rules-in-use. The main focus is on the rules-in-use and its seven categories influencing the internal action situation of the IAD-framework as described in chapter 2.

Technology, Actors and Institutions interactions conclusions

In Table 11 in chapter 8 this research lists the opportunities (+) and barriers (-), derived from the ASI-diagram, that affect the outcomes and 'smart gridness' of the analyzed cases. In the institutions category each of the seven institutional rules-in-use is considered in the categorization of barriers or opportunities. The enabling (+) and hindering (-) effects of each (institutional) circumstance is thoroughly discussed in the former sections of this research.

The three case studies, Schoonschip Amsterdam, GridFlex Heeten, and Groene Mient The Hague, were assessed based on several factors. Technology was found to be a positive influence in Schoonschip, a mixed success at GridFlex and a disabling effect for Groene Mient as they don't possess smart grid ready assets. Actors played a positive role in Schoonschip Amsterdam and GridFlex Heeten, but their impact was mixed in Groene Mient The Hague. Institutions, including the seven rules-in-use (categories), had a positive impact on Schoonschip Amsterdam, a mixed effect on GridFlex Heeten, and a negative effect on Groene Mient The Hague. Goal attainment was achieved in Schoonschip Amsterdam and to a certain extent in GridFlex Heeten, while it was not attained in Groene Mient The Hague. These findings highlight the varied dynamics and outcomes of sustainable projects based on the interplay of technology, actors, institutions, and goal attainment.

In conclusion, when examining the implementation and development of a smart electricity grid, it is crucial to consider the interactions between technology, institutions, and stakeholders. The relationships between these elements, as highlighted by the ASI-diagram, play a significant role in shaping the outcomes of such projects. Analyzing the interactions provide valuable insights into the dynamics and complexities involved in smart grid initiatives. By understanding and addressing these interactions, stakeholders can make informed decisions and take appropriate actions to ensure the successful implementation and development of smart electricity grids.

Overall, the main findings from the cases show that, from the used IAD-framework, the biophysical conditions, attributes of community, goal attainment (original project goal vs. outcome) as part of the evaluative criteria, and especially the rules-in-use have a severe influence on the outcomes of local smart electricity grid implementation and development in the Netherlands.

10.2 ANSWERING MAIN RESEARCH QUESTION

Main Research Question: *What are the impacts of institutional rules on the development and implementation of smart grids in the Netherlands at community level?*
The study consists of a comparative case study analysis with a total of three cases. For each case the IAD-framework is used to explore and map the institutional factors influencing the development and implementation of the local smart electricity grid. To obtain the needed information a (grey) literature study was done, fourteen semi-structured (expert) interviews were held, with people from the cases, field experts and scientific experts for additional information and qualitative data. These interviews were (deductively) coded with categorizations based on the theoretical framework(s) used. This all together tries to give a comprehensive answer to the main research question as stated above.

Main institutional conclusions
Schoonschip Amsterdam, GridFlex Heeten, and Groene Mient The Hague were analyzed in the context of the Institutional Analysis and Development (IAD) framework. The aim was to identify the most significant institutional rules and their impact on the action situation. In Schoonschip, the boundary, position, choice, and payoff rules were found to be most affecting. Additionally, the biophysical conditions and attributes of community were considered important exogenous variables. GridFlex revealed that position, choice, information and scope rules were significant, with the goal attainment as part of the evaluative criteria and outcomes differing from the project's inception. In Groene Mient, the boundary, position, choice, payoff, and scope rules were identified as influential. Biophysical conditions and rules-in-use were considered as influential exogenous factors. Furthermore, the goal attainment is notably different from the Groene Mient project's exemption stage. By applying the IAD framework and considering various institutional factors, these case studies provided insights into the dynamics and complexities of decision-making and governance in sustainable smart electricity grid projects.

Formal rules-in-use:

- Boundary rules: This type of rules provides details on how many and which stakeholders are involved in the local smart electricity grid project, as well as how they enter and exit the decision-making process.
    - Conclusion: The analysis of Schoonschip, GridFlex, and Groene Mient smart grid projects reveals a critical boundary rule shaped by the role of local Distribution System Operators (DSOs). Each case showcases varying DSO involvements: Schoonschip operates a private grid with limited DSO engagement; GridFlex, under DSO Enexis, sees significant influence;

Groene Mient, under DSO Stedin, experiences less involvement. This boundary rule dictates grid authority, evident as Schoonschip grants power to its Homeowners' Association. However, this shift is temporary, highlighting the interplay of grid management dynamics. The study underscores diverse actor roles influenced by regional, social, contextual, and legal factors.

- Position rules: This type of rules defines the positions stakeholders have in the local smart electricity grid project and its decision-making process.
    - Conclusion: Within the scope of this study, the pivotal roles in the examined cases are the legal entity obtaining Exemption under the Experimentation Decree and the smart grid operator. The roles for each case are as follows: Schoonschip: Homeowners' Association (HOA) as the legal entity and the energy working group as the smart grid operator. GridFlex: Energy cooperative Endona as the legal entity, with Escozon and other partners as the smart grid operators. Groene Mient: HOA and energy cooperative SoS, backed by DSO Stedin, as legal entity and smart grid operator respectively. These roles reflect intricate interactions, exemplifying community-regulatory engagement (Schoonschip), multi-dimensional partnerships (GridFlex), and the interplay of leadership, compliance, and expertise (Groene Mient). The positions underline the complex interplay of community, technical expertise, regulation, and external support, shaping local energy planning outcomes, often determined by legal frameworks.
- Choice rules: Next to that, the choice for smart grid technology had a significant impact on the successful outcomes of the different cases. This type of rules categorizes the actions taken, not taken or should have been taken at specific moments in time
    - As it is important to make the right choices at the right time, however sometimes it is also a bit of luck and the right timing as seemed from the cases analyzed in this (thesis) research. Conclusion: Schoonschip's success was tied to actions like forming a homeowners' association (HOA), collaborating with Metabolic, and obtaining Exemption under the Experimentation Decree, enabling the establishment of a smart grid. GridFlex navigated the Decree's constraints by simulating the smart grid online due to pricing limitations and adapting battery choices due to delivery delays. Groene Mient's Exemption depended on forming an HOA and partnership agreement, but financial and feasibility challenges hindered smart grid ambitions. These cases underscore the significance of pivotal actions driven by legal, informal, and contextual factors. Applying for Exemption and forming legal entities play crucial roles, alongside policy, partnerships, and adaptability, shaping project outcomes. Additionally, the choice of smart grid technology significantly influences project success.
- Information rules: This type of rules indicates what information is open to participants, how it is utilized, and with whom it is shared.
    - Conclusion: Information rules played a pivotal role in shaping the feasibility and results of the Schoonschip Amsterdam project. Conversely, GridFlex Heeten encountered operational limitations due to information rule constraints, resulting in altered outcomes. Meanwhile, Groene Mient The Hague possesses abundant accessible information, though

its underutilization stems from multifaceted reasons. As a consequence, this category of rules hasn't significantly impacted the smart grid's functionality, given its incomplete implementation.

- Aggregation rules: This type of rules categorizes the process through which decisions are made, such as whether they are made alone or in cooperation with others.
  - Conclusion: In diverse smart grid projects, decision-making diverges involving internal and external stakeholders. Schoonschip's decisions are internally driven, while GridFlex's consortium collaborates, and Groene Mient follows a sociocratic model. Each approach reflects project dynamics and continuity. At all of the three cases this category of rules did not make a severe disabling impact on the desired outcomes, rather an enabling one.
- Payoff rules: This type of rules specifies the costs and benefits linked to particular activities and outcomes.
  - Conclusion: Examining payoff rules in smart grid projects highlights normative aspects governing allocation of costs and benefits. Schoonschip complies with energy tax regulations, GridFlex's pricing models yield modest savings, and Groene Mient navigates ambiguous costs and benefits, emphasizing the impact of such rules on project outcomes and feasibility.
- Scope rules: These indicate the range of potential outcomes as well as the applicable law and the status of those outcomes, such as whether they are final or not.
  - Conclusion: In different smart grid cases, institutional mechanisms governing scope rules significantly shape potential outcomes and project status: Due to the legal status and degrees of freedom of Schoonschip Amsterdam the outcomes are not limited by the scope rules. Schoonschip's unique floating neighborhood status enabled a distinct project grid under the Experimentation Decree, enhancing viability. Challenges arose from energy company choice. On the other hand, GridFlex and Groene Mient are specified as a grand experiment under the Experimentation Decree which limits(ed) their range of outcomes significantly. Therefore, the desired and obtained outcomes are different than originally expected. GridFlex faced technical limitations like absent sea salt batteries and narrower Exemption scope, impacting outcomes. Groene Mient's smart grid and Exemption faced delays, driven by scope limitations for extension beyond the intended area. Variations in legislative influences and project status are evident.

Legal/Contextual/Technical Barriers:

- The energy market is too heavily reliant on the outdated linear, centralized energy system, and there is no active incentive for local power management (see the example of the tax refund scheme as addressed in chapter 6). Business model for some local electricity solutions is still missing.
- Inadequate legislation and regulatory frameworks pertaining to smart electricity grid systems.
  - The Exemptions under the Experimentation Decree (2015-2018) is not extended for possible future projects and a sequel to it is rejected by the Council of State.

  - Another example of this is that acquisition of permits for reciprocal energy exchange is challenging. This discourages beginning a project. The new Dutch Energy Law draft contains provisions for energy supply while it should implement the EU provisions for energy sharing, which should make things simpler in the future. It claims that if a (energy) community registers as a market party on the connection and employs MLOEA (multiple suppliers on a connection), energy sharing will be made possible.
- It is more environmental friendly to jointly purchase a large battery than to buy smaller batteries, but doing so is also more difficult because you also have to become each other's energy suppliers, obtain permissions, pay taxes, and operate your own grid.
  - As a result of this, Schoonschip had to pay double energy tax for the electricity charged and discharged from their batteries. Use the grid to draw energy (discharge it), store it in your battery, and then transfer it to your neighbor while still paying a double energy tax. For big consumers such as Schoonschip, that was altered in January 2022. Still applicable to small consumers, such as in the GridFlex and Groene Mient projects.
  - Commercial electricity storage is prohibited by law for public parties such as a DSO, but this is up to the liberalized 'market' according to the ACM.
- Unfair competition between regional leaders (big conventional energy corporations) and upstarts as the local initiatives (energy communities/cooperatives existing of (retired) volunteers).
  - These local projects with its composition are often still not taken serious enough in the energy system by the big entities, e.g., municipalities, grid operators and energy companies. To some extent this view is changing in the right direction.
- Between many municipal/local smart electricity projects, there is a lack of coordination and cohesion. This connection is mostly important because of:
  - The need for standardized exchange of data and procedures.
  - Need for a unified understanding of the function of regional power networks in the energy system, because various theories exist today on the function that smart local electrical systems will play in the future Dutch energy system. A clear vision of how smart local energy systems relate to all stakeholders is also not yet available. For instance, there are differing views on the availability of flexibility, who will provide it, how it will be organized (centralized or decentralized), and how much the government, grid operators, the market, or consumers will participate in the provision of, organization of, and maintenance of smart local energy systems.

Legal/Contextual/Technical Opportunities:

- Good stakeholder management which enhances local energy communities/cooperative and 100% neighborhood participation.
- A well-developed sustainability and feasibility study before beginning a smart electricity project, e.g., the case of Schoonschip, so that it is known what to expect.
- Exemption under Experimentation Decree (to some extent)
- EU: CEP, REDII & IEMD (especially with the renewable/citizens energy communities)
- New comprehensive Dutch Energy Law to some extent.

- Nationwide comprehensive energy cooperatives such as Energie Samen & OM nieuwe energie.

10.3 DISCUSSION

This (thesis) research focused on the institutional rules that impact the local smart electricity grid implementation and development in the Netherlands. In order to do this, three pilot projects at a local level were analyzed on their institutions, technology and involved actors. The results empirically acknowledge that the current rules-in-use, the regulative, and legislative frameworks in the Netherlands are not all suitable for the implementation and development of (local) smart grids, as acknowledged by Wolsink (2012) and Verbong, Beemsterboer & Sengers (2013). Through the examination of the seven institutional factors that influence the implementation and development of local smart grid projects, the study sought to ascertain the dynamic interactions between these factors, technology, other institutions, and actors. Furthermore, the study aimed to identify specific institutional factors that either facilitate or limit smart electricity grid development in the Netherlands.

Combining insights with IAD-framework literature and this thesis' contribution

The Institutional Analysis and Development (IAD) framework offers a valuable approach for examining the complexities of institutional contexts within intricate socio-technical systems like smart grids, as shown by scholars, e.g., Lammers, Hoppe, Milchram, Diestelmeier and more. This framework focuses on coordinating actions, aiding in designing effective institutional setups for energy transition efforts. Particularly relevant to energy transition research, the IAD framework bridges the gap between social interactions and the physical environment, facilitating a comprehensive understanding of smart grid adoption. Local decision-making in smart grid projects often grapples with complexity. The IAD framework's categories of rules-in-use simplify decision landscapes, helping local actors make informed choices aligned with transition goals. Furthermore, the introduction of the Actors, System & Institutions (ASI) diagram enhances analytical capabilities, as argued by Enserink et al. (2022) and Koppenjan & Groenewegen (2005). This diagram visually represents the complex relationships among actors, technology, and institutions, aiding in policy analysis and identifying potential challenges and opportunities within smart grid systems. In essence, the IAD framework, coupled with the ASI diagram, empowers stakeholders to navigate the multifaceted terrain of smart grid implementation. By addressing coordination challenges, integrating diverse dimensions, and simplifying decision-making complexities, this framework offers a comprehensive toolkit for advancing smart grid technologies within the context of energy transition.

Validity of results

The main findings of the case analyses showed that the institutional factors indeed influence, whether enabling or disabling, smart grid implementation and development at a local level. The validity of the findings remains questionable, since three cases are analyzed. The results could be misinterpreted by the researcher, which in other cases could lead to different outcomes and interpretation of the required institutional factors. Next to this, the cases are to a certain degree different in their essence. Schoonschip Amsterdam is an ongoing successful project with different technology, attributes of community (actors), and rules (institutions) applicable to it than the other two projects. This is due to its legal status as a project grid as part of the Exemption under the Experimentation Decree. GridFlex Heeten was an early pioneer in this regard. The project already finished its experimental phase and is again a normal conventional neighborhood currently, the exemption is still in place. GridFlex had less degrees of freedom than for example Schoonschip, due to its legal status as a grand experiment. The same goes for Groene Mient The Hague. Both GridFlex and Groene Mient do/did not have smart grid ready assets, therefore their main focus is/was to focus on the flexibility of consumers and their electricity usage behavior, while at Schoonschip this flexibility is provided by smart grid ready assets, e.g., heat pumps and batteries. Since the outcomes are significantly different, how comparable are the results in practice.

Validity of research

As part of the methodology in this research the Institutional Analysis and Development framework of Ostrom is used to obtain the right information for the case analyses. In order to use this IAD-framework to compare multiple cases most of the variables should be relatively the same to facilitate constant external factors for each case. It was expected, since all the projects have an Exemption under the Experimentation Decree, that in this (thesis) research all three the cases have relatively constant external variables that are comparable. It seemed that the external variables, in the IAD-framework called exogenous, such as biophysical conditions, attributes of community, and rules-in-use for the cases were more different than anticipated. This difference leads to one of the main findings/conclusions in this research, but therefore the question arises if and to what extent these findings are still scientifically valid considering the used framework.

10.3.1 LIMITATIONS

The limitations of a scientific (thesis) research are part of the discussion section, therefore the main limitations will be outlined.

- In this study three projects are selected among the 18 projects granted an exemption experimentation decree, there might have been an opportunity to select cases that were even more comparable, focusing exclusively on project grids or large experiment statuses.
- The choice for semi-structured interviews to obtain the most relevant (case) information. Is semi-structured the best way for this type of research. Should structured or unstructured interviews have been better.
- The type and number of interviewees differs per case study. Schoonschip's case study consists of a single interview with therefore only one perspective, which could lead to subjective answers. GridFlex' case study consists of four different interviewees from different organizations, different interests, and different involvement related to the project. This decreases the chance of too subjective perspectives on the project. Groene Mient's case study consists of two interviewees, which still has a significant chance of subjective answers and to a certain extent this seemed to be.
    - So, from the held interviews there were more perspectives shed on GridFlex than on Schoonschip and Groene Mient. This leads to more subjectivity at those two cases which does not take away the variability and uncertainty.

- Is the IAD-framework the right framework for institutional analysis and this type of research.
  - As said from this framework, the comparability of the analyzed cases remains unclear.
  - This framework requires a plain and narrowed down definition of its action situation(s). The ones for the cases were: The action situation of the project consists of the environment and stakeholders engaged in decision-making about design, implementation, development and operation of the project's local smart electricity grid system. Is this action situation formulated to broad, should it be narrowed down into multiple smaller action situations.
- Next to this, the amount of scientific research into the cases is significantly different. Schoonschip has a well-established scientific basis on different topics, such as energy communities and the Exemption under the Experimentation Decree. As GridFlex is already a finished project it also has a well-established scientific basis on its main findings. This project is also scientifically analyzed with regards to the Exemption under the Experimentation Decree, its energy community status, and in the technology field of mainly the batteries and EMS algorithms used. Groene Mient however, is not scientifically analyzed with regards to the Exemption under the Experimentation Decree, and its energy community status, only to a small extent on its smart meter data.
- The last main limitation that impacted the feasibility of this study lies in the theoretical framework(s) used in this research. The chosen theory is the IAD-framework which mainly analyzes the institutions. But what do these institutions mean? Should additional frameworks have been used to categorize the institutions found to be significant in this (thesis) research? Examples of frameworks that were considered to be used are the 4-layer model of Williamson, as well as the 3-layer categorization by Ostrom within the IAD-framework, and the alignment perspective. This led to difficulties and some delay in the analysis of the cases.

10.3.2 FUTURE RESEARCH: SCIENTIFIC RECOMMENDATIONS

In this section suggestions for future research are given to solve limitations of current research.
Recommendations:

- All the type of rules and their influence are changing as the energy and regulatory system are changing. Especially, positions (rules) are changing due to changing and unknown legislation. So, there should be more scientific research in the positions of actors involved in a smart electricity grid at local level.
- Therefore, more pilot projects should be analyzed, especially when the new Dutch Energy Law is in place, also with the continuation of the Exemption under the Experimentation Decree, and how this will evolve under regulatory changes.
- Scientific contributions in the field of smart grid research are changing from technology oriented to institutional and to some extent stakeholder related research. Therefore, future research could focus even more on this, but do not neglect technological innovations.
- As the European regulations (EU CEP, REDII and IEMD) has to be implemented in each member states' own national legislation, future research could consider comparing different smart electricity projects in other countries than the Netherland or even comparing cases from different European countries.

- Enhanced interdisciplinary research: Given the multifaceted nature of smart grid implementation and energy transition, interdisciplinary research should be encouraged. This can yield comprehensive insights into the complex interactions between institutions, actors, and technology within the smart grid system.
- Integrated frameworks: Develop integrated (decision-making) frameworks that incorporate the IAD framework and ASI diagram. These frameworks can help policymakers and stakeholders visualize and comprehend the intricate socio-technical dynamics of smart grid projects, facilitating better policy formulation and strategic planning.
- Empirical case studies: Conduct more empirical case studies applying the IAD framework and ASI diagram to real-world smart grid projects. These studies can uncover the practical challenges and opportunities in institutional design, decision-making processes, and stakeholder interactions. Comparative case studies across different contexts can provide valuable insights into the generalizability of findings.

By following these suggestions in this research, the academic world could gain a better grasp of how institutions play a role in adopting smart grids. This can help to create better policies, involve stakeholders more effectively, and achieve successful transitions to cleaner energy sources.

10.3.3 POLICY RECOMMENDATIONS

Different types of policy recommendations are given:

- Obtain financial support for innovative smart electricity grid initiatives.
    - Standardize
    - Examine the characteristics of a thriving market for smart electrical systems. For instance, are smart electricity systems capable of participating in congestion markets, will novel markets for flexibility emerge that allow their involvement, or will there be simplified mechanisms facilitating the energy trading of smart local energy systems?
    - Provide subsidies in the form of financial assistance for one-time purchase costs, project financing on a one-time basis, and fees based on locally consumed kilowatt-hours (kWh).
    - Allocate adjustments in monthly energy costs as follows: now 60% or half of the price goes to energy tax, approximately 1/3rd belongs to energy delivery encompassing electricity prices, and almost 1/3rd is for grid fees.
- Develop a well-defined vision that establishes clear roles in policy formulation, implementation, and evaluation.
    - The ambiguity surrounding stakeholder roles in smart local power systems poses a significant challenge in the energy landscape. This includes uncertainties about the responsibilities and benefits for various entities such as the government, market actors, grid operators, local energy collectives, and citizens. A clear and comprehensive vision is needed to establish a framework that promotes collaboration, co-creation, and commitment among stakeholders. Furthermore, legal frameworks should incorporate the division of responsibilities to provide clearer guidelines. However, achieving such a vision requires substantial time, coordination, and active collaboration.

- Incorporate provisions in policy to accommodate the advancement and development of local smart energy systems.
    - Facilitate experimentation within legislation, as exemplified by the ongoing progress observed in the implementation and development of the new comprehensive Dutch Energy Law.
    - Ease the permitting process for energy exchanges to enhance efficiency and facilitate smoother transactions.
    - Expand the MLOEA principle to make it more advantageous for multiple entities to purchase a battery together.
- Promote a positive framing of opportunities associated with smart local electricity projects. This aims to mitigate skepticism among grid management, energy suppliers, and municipalities regarding smart local electricity projects.
- Standardize data exchange: smart assests, smart meters, but also smart devices.
- Lastly, there is lack of cohesion between various local smart electricity projects → solution Energy Together (in Dutch: Energie Samen) and OM New Energy (in Dutch: OM Nieuwe Energie) as umbrella organizations representing multiple energy cooperatives.

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APPENDIX A INTERVIEWS

Due to confidentiality reasons, the reports of the interviews with the developers have been removed from this version of this thesis. If the full reports would like to be viewed, the researcher should be contacted.

Interviewees overview

#Interviewee	Position and expertise	Organization/Case
1	Resident of Schoonschip and chair of smart grid working group	Schoonschip Amsterdam
2	Project consultant and living close to project	GridFlex and Escozon U.A.
3	Board member of local energy cooperative	GridFlex and Endona U.A.
4	Representative of local DSO involved in project consortium	GridFlex and DSO Enexis
5	PhD'er/researcher involved and researching project and its data, mainly batteries	GridFlex and University of Twente
6	Resident of project and board member energy cooperative	Groene Mient and Sterk op Stroom
7	Resident of project	Groene Mient
8	Field expert: with regards to Exemption Experimentation Decree	RvO
9	Field expert: former manager in IPIN demonstration pilots, and expertise in energy transition	Energy consultancy
10	Field expert: former Chief Technology Officer of a DSO with expertise in energy transition on the local, national and international level	Energy consultancy and DSO
11	Academic expert: former researcher in research about smart grids introduction in the Netherlands	(former) University of Twente
12	Academic expert: research smart (micro) grids	Delft University of Technology
13	Academic expert: research into energy communities, smart grids vs. EU legislation	University of Groningen
14	Academic expert: research/expertise about the legal part of smart grids	University of Twente

Interview questions

Subjects:

- Understanding of Smart Grid (definition)
- Stakeholders
- Technology (cases)
- Institutions
- Bottlenecks
- Success factors
- Further contact info/articles….

Interview consent form

You are being invited to participate in a research study titled Institutional smart (electricity) grid analysis in the Netherlands: A comparative case study. This study is being done by Mees Dekkers and supervised by Thomas Hoppe from the TU Delft.

The purpose of this research study is to analyse the Dutch smart electricity grid development in an institutional manner in order to draw lessons from 'successful' case studies for policy recommendations. You are asked for an interview about the applicable case which will take you approximately 60 minutes to complete. This interview will focus on your knowledge about the local smart grid project you are/were involved in. The interview will have a format of a semi- structured interview, which will be guided by open questions drawn by the interviewer. The data will be used for my Master of Science thesis graduation only, which will be published in the TU Delft repository online at https://repository.tudelft.nl/ for research purposes only.

The interview may take place in person or online, depending on your preferences. It is likely to be recorded, if agreed, please indicate if you agree: YES / NO.
So, there will be a recording, but this will only be stored on the interviewer's telephone/laptop for the duration of the project. Next to this, an interview summary will be made and used for the research, this will be made anonymized. As with any (online) activity, the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by all personal data collected about you (name and contact information etc.) used to organize this meeting will be deleted.

The points from the interview will be used to amplify the arguments. Therefore, I would like to use quotes in my thesis with a reference to your name and/or function. If you give permission to use anonymized quotes form the interview, please indicate this: YES / NO.
If you don't agree: the only information that will be used in the main text of the thesis relation to the project, e.g., resident, researcher, otherwise things will be anonymized.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions.

In order to get in contact, you can reach out to m.t.dekkers@student.tudelft.nl or my supervisor t.hoppe@tudelft.nl.

If you agree with the information provided above, please sign here:

__________________________ _________________________ ________

Name of participant Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

________________________ __________________ ________

Researcher name Signature Date

APPENDIX B CODEBOOK

Table 12 Codebook used with Atlas.ti

Label	Definition
Biophysical/Material Conditions	Milchram et al. (2019, p. 6): "Physical environment influencing possible actions taken in action situations, e.g., existing infrastructure."
Attributes of Community	Milchram et al. (2019, p. 6): "Socio-economic characteristics of the participants' community."
Boundary Rules	(Affect actors): "Specify the number of actors that participate in the local energy planning project (e.g., municipal policy officer etc.), and how those actors join and leave the decision-making process." (Lammers & Hoppe, 2019, p. 245).
Position Rules	(Affect positions): "Specify the set op positions actors hold in the local energy planning process (e.g., project leader, network manager)." (Lammers & Hoppe, 2019, p. 245).
Choice Rules	(Affect actions): "Specify the set of actions that can (could have), may or must not (have) been taken place at specific points in time, e.g., deriving from informal agreements or from policy instruments, laws or regulations." (Lammers & Hoppe, 2019, p. 245).
Information Rules	(Affect information): "Specify the amount and type of information available to participants (e.g., about the technology, policies, meetings, or costs- and benefits) and how this information is used and shared (e.g., boundary spanning). (Lammers & Hoppe, 2019, p. 245).
Aggregation Rules	(Affect control): "Specify how decisions are made, e.g., by an individual actor, or in collaboration with others (e.g., coalitions, co-creation)." (Lammers & Hoppe, 2019, p. 245).
Payoff Rules	(Affect net costs and benefits): "Specify the costs and benefits that derive from particular actions and outcomes, e.g., costs of project, pack-back time, distribution of costs and benefits among actors." (Lammers & Hoppe, 2019, p. 245).
Scope Rules	(Affect potential outcomes) "Specify the set of possible outcomes, as well as jurisdiction and state of outcomes, e.g., geographic region and events affected, temporary or final status of the outcome." (Lammers & Hoppe, 2019, p. 245).
Goal Attainment	"Original project goal vs. achieved outcome during the period under analysis." (Lammers & Hoppe, 2019, p. 245).
Key moments	"An instance in the decision-making process that influenced the outcome of decision-making, i.e., the introduction of a smart energy system." (Lammers & Hoppe, 2019, p. 245).
Definition of smart grids	"Definition of the term 'smart energy system' or 'smart grid' used by the interview partners." (Lammers & Hoppe, 2019, p. 245).
Success factors/Learning Moments	Things that truly helped the smart grid's implementation, execution, or results were... And if things had gone better, there were also potential success factors—more precisely, learning elements.

Evaluative Criteria	"Criteria that are used to assess interactions and outcomes, e.g., sustainability, distributional equity and economic efficiency." (Milchram et al., 2019, p. 6).

Other IAD-framework definitions uses for case analyisis:

- **Rules-in-use** (formal: laws & regulations): "Institutions, e.g., formal laws and regulations that enable and constrain behavior of participants." (Milchram et al., 2019, p. 6).

- **Action situation:** "Social space of interaction, in which participants decide on their individual actions given the information they have about how those actions lead to outcomes and the costs and benefits associated with those actions and outcomes." (Milchram et al., 2019, p. 6)

- **Participants:** "Individual actors or actor groups, e.g., governmental and non-governmental bodies of firms." (Milchram et al., 2019, p. 6).

- **Interactions:** "Procedural aspects, i.e., interaction among participants in an action situation." (Milchram et al., 2019, p. 6).

- **Outcomes:** "Results of interactions, which may be institutions, knowledge, or operational outcomes such as the implementation of new technologies." (Milchram et al., 2019, p. 6).

APPENDIX C SCHOONSCHIP

In this appendix all the additional Schoonschip information is shown.

Rules-in-use results

Rules-in-use	Outcome/interpretation
Boundary rules	Most important stakeholders: - HOA Schoonschip: legal entity for the Exemption Electricity Act under the Experimentation Decree. o Schoonschip's energy working group: executive operator of the smart grid under supervision of the HOA, it makes all the decisions and knows all the characteristics of the local smart grid. - Metabolic: sustainability consultant who was paid to help Schoonschip establish the smart grid and the Experimentation Decree request and granting. - Spectral Energy: system integrator for the EMS, batteries etc. o Fraunhover: for the operation and development of the Virtual Power Plant (VPP) flexibility services. - Greenchoice: balance responsible party and also in the consortium of the VPP. - RvO: grantor of Experimentation Decree. - Consumer and Market Authority (in Dutch: Autoriteit Consument en Markt (ACM)): for approval of tariffs as part of Experimentation Decree. - DSO Alliander as the local grid operator until Schoonschip main connection to the national grid. A boundary rule that limits the power of DSO Alliander and of energy companies is that under the Experimentation Decree Schoonschip was able to develop its own grid, so it is its own grid operator, to some extent energy supplier, energy consumer etc. To some extent this rule eliminates a stakeholder like the DSO. Another boundary rule which affects the degrees of freedom is the fact that despite Schoonschip's own project grid residents keep their freedom to choose whatever energy company they want under the (protection) of the consumer law. But for now, all the homes are connected to one and the same energy company: Greenchoice. The fact that the batteries are community owned, heat pumps are under private ownership, solar PV panels are also private owned makes the decision making (with all homes) very challenging. Also, because the community requires a household that the privately owned assets are made and kept smart grid ready, otherwise this could affect the range of (technical) outcomes. What if a household wants to withdraw from the 'smart grid', chooses another energy company and takes the solar panels and heat pumps out of the community smart grid what happens then? While the statutes of Schoonschip say that (e.g.) a heat pump must be smart grid ready even though privately owned. The existing infrastructure for the project electricity grid is community owned.
Position rules	The actors involved are described: for example, Schoonschip and its Energy working group for the smart grid, the DSO Alliander, RvO for the Experimentation Decree, Greenchoice as the still needed energy company, the Municipality of Amsterdam, the ACM and so on. Some of these stakeholders are part of the consortium by law, e.g., DSO Alliander, RvO and the ACM. Other ones like sustainability consultant Metabolic and Spectral Energy are reached out to by Schoonschip and its developers. HOA Schoonschip is in this case the project initiator and to some extent project leader, its Energy working group is the operator of the smart grid, the local network is also managed by the Energy working group of Schoonschip. After the Experimentation Decree expires the local grid has to be sold back to DSO Alliander. So, for now Schoonschip is still the network manager but in future this could go to the DSO. This all depends on how the new Dutch Energy law and European legislation will develop. Schoonschip is due to this Experimentation Decree also energy supplier under the Program Responsibility (Dutch: Programmaverantwoordelijkheid) of their energy supplier Greenchoice, for which they had to approve their calculations by the ACM. Spectral Energy is the system integrator, builder and owner of Schoonschip's digital EMS and developer of the batteries. Fraunhover is included for societal experimenting purposes: developer and owner of the VPP. The energy community → sustainability consulting organization called Metabolic (a significant stakeholder), produced a comprehensive (holistic) strategy that included many various types of sustainability, with energy being one of them. Back then, Schoonschip and its community began with the smart grid, considering the potential of a smart grid since the chance for such an exemption under the Experimentation Decree was available at the moment.
Choice rules	Examples: Schoonschip had to take action to establish a Stichting or homeowners' association ('Vereniging van Eigenaren' in Dutch) for the sustainable floating housing project to be realized. Sustainability consulting firm Metabolic did an important sustainability and feasibility study for Schoonschip, in which the choice of Metabolic for application of the Exemption under the Experimentation Decree has been a key moment. They set up a startup from their consulting firm/organization with financial grant fixed and they helped a lot with Schoonschip pilot (€100,000 paid to Metabolic for it). Next to this, the timing of the Experimentation Decree between 2015-2018 was lucky. Another example about the action that Schoonschip chose to offer their flexible capacity to be a player in the Dutch electricity flexibility markets, for which they needed a Virtual Power Plant to exist in order to facilitate the options to join those markets. → Fraunhover and Spectral Energy are responsible for the execution of the VPP. Lastly, an example of a choice rule is that only after the possibility of the Experimentation Decree was in place Schoonschip thought about a smart electricity grid and not before.

Information rules	A good example here is that the residents of Schoonschip received their 2020 energy bill two years late. This shows that the information available to the residents is lacking, but they need to have good 'faith' in the energy working group of Schoonschip to be part of this project. This delay in energy bill had several reasons, e.g., technical and organizational reasons, the question if the HOA had to pay Value Added Tax (VAT) was that difficult the tax authority did not even know the answer. This example is supported by the fact that "Schoonschip's information sharing happens in 'good faith', control strategy is aligned, everything is measured per house by 6 to 7 smart meters, they settle everything at the end." (Interviewee #1). Fraunhover and Spectral Energy developed, implemented and operate the smart grid (+VPP) and all the assets in collaboration with the energy working group. This all has to be according the GDPR and other privacy laws. The effects if someone retracts from the common smart grid with their privately owned heat pump and solar panels are not (yet) known, because this never happened before, so this information is not available. The same goes for if a household under the consumer law chooses for a different energy company than Greenchoice, this effect is also not (yet) known. The energy working group has the most information, knowledge and expertise with regards to the smart grid, smart grid assets (e.g., heat pumps, batteries and solar panels) so they advise the HOA Schoonschip that has to take legal decisions. These opinions of this decisions etc. come directly fully from the Energy working group as horizontal decision-making process.
Aggregation rules	All the decisions made in and around the Schoonschip project have to be done officially by the board of the homeowners' association, but the advice and suggestions made by the energy working group and other working groups are (almost always) fully copied by the right legal body to make the decisions. The open VPP experiment for flexibility options research is in a consortium together with: Spectral Energy, Fraunhover, Greenchoice, Greener, Prosoldiga, and HOA Schoonschip. All the decisions are taken with the whole consortium. For the rest SSA is quite independent in its decisions with regards to other stakeholders.
Payoff rules	A lot of money was invested in research into sustainability and legal research for the Experimentation Decree and Schoonschip's project grid/smart grid. The sustainability research was done by consultancy Metabolic with the help of subsidies. Schoonschip is part of GridFriends: GridFriends collects a subsidy funded by the EU for a research project in order to set a new standard in the smart grid technology. Schoonschip is one of their 'test facilities' to realize a CO2-'neutral' living area. Spectral Energy and Fraunhover are also included in this. So, costs of the project are relatively high, citizens invested a lot of their own money. The Energy and Climate Innovation Demonstration (in Dutch: DEI+) subsidy Schoonschip got for their open VPP is because of the fact that they cooperate with 'commercial' market parties. This subsidy normally does not go to 'private' citizen projects (see Groene Mient case). Energy bill two years late, this could be considered as a particular action by the energy working group who is responsible for each home's annual energy bill and indirectly thus as delayed/uncertain distribution of costs and benefits among actors (each household in Schoonschip). There is an energy tax with regards to electricity produced and consumed within Schoonschip, while initially this would have been free of tax, which increases the costs of the project (Swens & Diestelmeier, 2022). The same goes for a double energy tax with charging and discharging of the batteries, for both actions the energy tax has to be paid, which affects the project costs and business model as well Schoonschip (Swens & Diestelmeier, 2022). As said by interviewee (#2) in January 2022 this double energy tax for battery storage is eliminated for wholesale consumers.
Scope rules	The fact that Schoonschip is a floating neighborhood made it possible to establish their own grid, which under the Experimentation Decree has more possibilities than the conventional grid. This is a causal reason that made it possible to have a more feasible business case for the Schoonschip project. The fact that all the homes/residents have freedom of choice with regards to an energy company under the consumer law. This can impact the outcomes if one home chooses to do change energy company, then the community smart grid is negatively affected. What the actual effect will be is also uncertain to Schoonschip and the energy working group itself (interviewee #1), because they do not have experienced this before while it actually can happen. The project grid (after exemption expires) becomes a conventional grid and is probably going to be sold to DSO Alliander, who has an obligation to buy the grid from Schoonschip as the grid operator in the area.

Additional Information

Background and history of origin

Schoonschip was founded in 2010 by a group of Amsterdam residents who shared a vision for developing a sustainable, socially conscious community. The project took several years to come into fruition, as the founders had to navigate complex zoning and regulatory requirements to bring their vision to life. They ultimately succeeded, however, and the first residents moved into their homes in 2018.

One of the key features of Schoonschip Amsterdam is its emphasis on the community. In 2018 the residents established a homeowners' association (HOA), or VvE (in Dutch: Vereniging van Eigenaren), which allows them to collectively manage the upkeep and maintenance of the homes and common areas. Residents also participate in working groups focused on topics like smart grid & energy, water quality and ecology, which provide opportunities for them to collaborate and share ideas. Additionally, there is a party committee that organizes events and social activities for the community.

Schoonschip aims to be a frontrunner and innovator by fostering the newest sustainable technologies and solutions. To achieve this goal, it partners with forward-thinking companies and governments and exchange our knowledge by engaging in pioneering projects at the local, national and European level.

Infrastructure, building & demographic characteristics

To meet their energy requirements, the neighborhood in which Schoonschip is located uses 516 photovoltaic solar panels with each of the 30 arks having a large battery of 10 kWh to store temporary energy surpluses. These homes are linked through their own home smart grid, allowing them to share electricity with each other in Schoonschip's smart grid system is. An innovative energy management system (EMS) is used that allows residents to share energy with each other and feed excess energy back to the grid. The system is an integral part of the community's commitment to sustainable living and helps to minimize energy consumption whilst reducing carbon emissions.

As an exemption to the law, the residents have one connection to the common electricity grid, i.e., medium and low voltage grid owned and operated by DSO Alliander, through an agreement they made in 2016 with the Rijksdienst voor Ondernemend Nederland (RVO) called ‘Exemption Policy’/ ’Experimentation Decree’ or in Dutch ‘Experimentenregeling Elektriciteitswet’.

There is only a single connection to the regional electricity grid. Everything after that part of their grid is privately owned, for now as long as the experimentation decree is still valid until 2026 (interviewee #1). The electrical assets connected to the community’s smart grid are each households solar PV panels, the multiple smart meters, the 30 heat pumps and the batteries each house has (interviewee #1; Schoonschip, 2023).

Implement construction characteristics: Homes are very well insulated, requiring less energy than conventional homes, and not connected to any gas grid. All homes/housing units in Schoonschip are connected to the local smart grid, which enables them to mutually exchange/trade electricity in a smart way (Schoonschip, 2023).

Demographic/social

Living together in Schoonschip involves residents collaborating and motivating each other adopting a more sustainable way of life. This is a significant principle for the community. To ensure affordable housing, half of the arks in Schoonschip have been designed as semi-detached homes, allowing two households to live on one ark, which entails a unique feature in the Netherlands. Homeowners’ association Schoonschip and its residents seek to collaborate with the surrounding neighborhood of Buiksloterham to create an attractive living environment, which involves exploring ways to contribute positively to this.

Stakeholder overview

Homeowners' Association (HAO) Schoonschip, the Energy working group within Schoonschip, Pioneer Vessel foundation (but with regards to the smart grid it doesn't do that much, source: interviewee #1), DSO Alliander, Greenchoice, RvO Netherlands, Consultant Metabolic, Spectral Energy, the Municipality of Amsterdam, Province of North-Holland, Government of the Netherlands/Ministry of Economic Affairs and Climate Policy, Transmission System Operator TenneT, ACM for approval of tariffs as part of the Exemption under the Experimentation Decree. Sort of an overview of the most important internal stakeholders can be seen in Figure 9.

(Internal) Stakeholder overview:

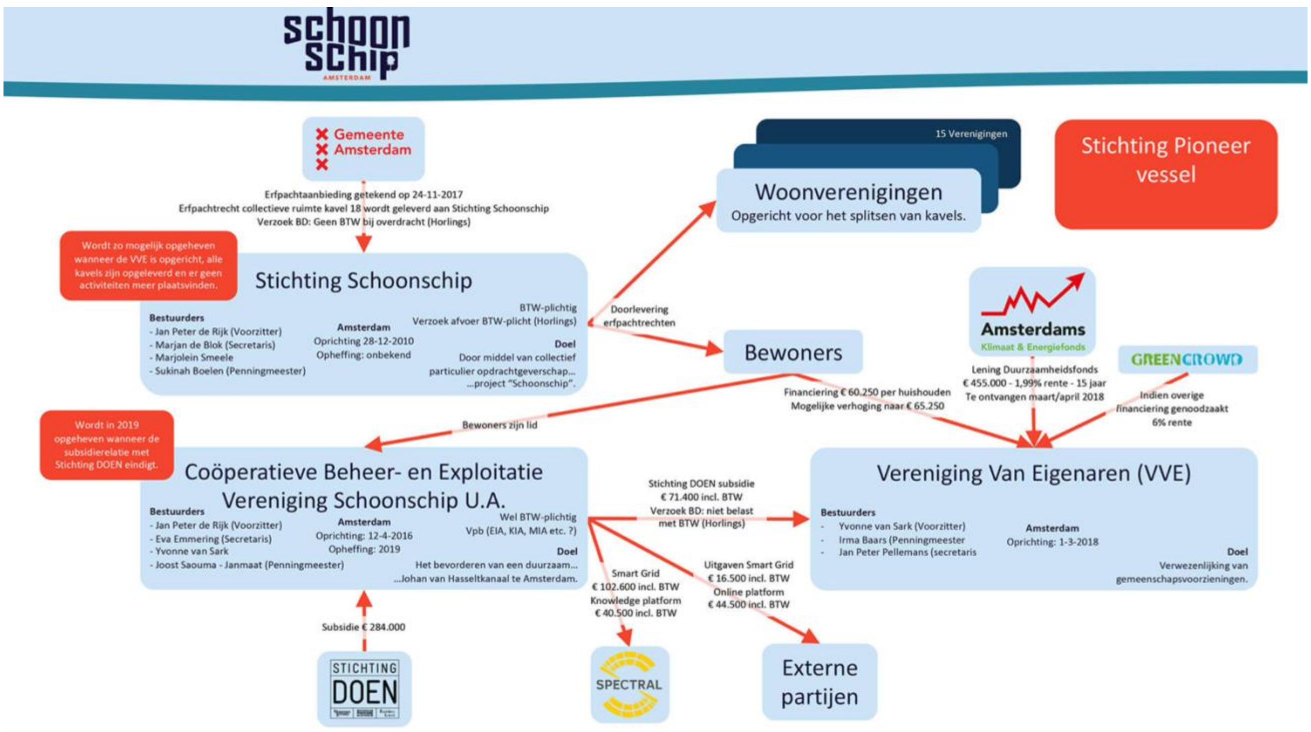

Figure 9 'Organogram' Schoonschip Amsterdam (source: greenprint schoonschip website)

Literature findings about Schoonschip

According to Van der Waal et al. (2020, p. 7) details about case description Schoonschip:

- "Project type: Project grid
- Delineation: Schoonschip is an homeowners' association (HOA, Dutch: Vereniging van Eigenaren) of the owners of 46 houseboats and one communal boat in the Amsterdam quarter Buiksloterham, which is a city quarter that develops all kinds of sustainable building projects.
- Organization & governance: The project was started by a group of friends, who were later joined by other friends and acquaintances. There are other goals than renewable energy, e.g., wastewater treatment, and the use of recycled building materials. The board of the HOA is responsible for daily decisions. Working groups have been established, e.g., in supervising the building process. These working groups may give presentations about their findings, to keep all members involved. For some decisions it is necessary for all members of the HOA to be present. *As stated in the interview (#1) most of the decisions/advises by these working groups are directly*

copied and adapted by the HOA. Therefore, it could be stated that the energy working group (in)directly takes the decisions with regards to the smart grid and all the energy related stuff.

- Energy system: The boats are all-electric, part of a project grid, and connected to the national grid via one connection. The HOA generates electricity through individually owned solar panels. Batteries are placed on each boat, but collectively owned. Shared electric vehicles are part of future plans. The administration and some of the maintenance are done collectively. A smart grid is in place, and every household has an energy management system (EMS). The smart grid is part of a project of consortium with external expertise, which researches the optimization of smart grid technologies and algorithms. Dynamic tariffs are not foreseen as part of demand management. Efficiency should occur through the smart grid: using and storing electricity when production is high *(this is different than gfh & gmdh where dynamic tariffs are the core business nowadays).* Eventually, the energy management should result in providing electricity to the main grid at the highest price.
- Use of EDSEP (exemption under experimentation decree): The HOA acts as a supplier, producer and distributor. The administration of electricity use and supply is outsourced to a commercial electricity company (Greenchoice), which acts as a balance responsible party (BRP) and provides electricity when a shortage occurs, and buys surplus electricity."

The homes in the community have an average annual energy consumption of approximately 2,500 kWh, which is significantly lower than the expected amount considering the additional electricity required for electric heating (Swens & Diestelmeier, 2022). By installing 500+ solar panels on the rooftops of these homes, they are able to generate 92% of the total energy used by the neighborhood (Swens & Diestelmeier, 2022), only not in for example winter time (interviewee #1). To address any temporary shortages or excess electricity production, 30 batteries with a combined capacity of around 300 kWh/125 kW were installed, with each battery assigned to a specific ark (interviewee #1). Schoonschip employs an energy management system (EMS) that optimizes production, storage, and demand every 5 seconds, allowing it to shave consumption and production peaks to well below 100 kW (Swens & Diestelmeier, 2022). This peak shaving strategy enabled Schoonschip to connect to the common grid using a low-power connection with a capacity of only 100 kW, which is approximately one-sixth the capacity of a typical DSO connection for 46 households (interviewee #1).

Energy tax allocation issues (Swens & Diestelmeier, 2022) & (interviewee #1): Two additional significant issues arose during the implementation of the project, specifically related to the allocation of energy taxes. As per the regulations outlined in the Environmental Tax Act, all forms of electricity generation, whether independent, communal, or obtained from commercial sources, are subject to energy taxation (Swens & Diestelmeier, 2022). This provision posed challenges for most early energy communities, including the project of Schoonchip. Originally, the plan was to exempt the electricity generated and immediately consumed within the project grid of Schoonschip from energy taxes. However, the tax authority concluded that any electricity transferred within the Schoonschip community should be subject to energy taxation, and the project grid defined under the Experimentation Decree should be recognized as a conventional taxable grid according to the Environmental Tax Act (Swens & Diestelmeier, 2022). This determination had a significant impact on the project's financial feasibility. Another issue faced by the project was the occurrence of double taxation on electricity storage. Energy tax was applied twice to the electricity stored in batteries installed at Schoonschip: once during the charging process and again when the electricity was supplied to one of the (home) boats. In response to discussions in the legislative body, the Secretary of State of the Ministry of Finance pledged to address this issue by January 1st, 2021, as part of the implementation of the EU Electricity Directive. However, the anticipated modification has not yet come into effect, resulting in Schoonschip being subjected to double taxation on previously stored electricity.

Main things from webinar Slim Energie Delen Job Swens part (Energie Samen & Swens, 2022):

- **General purpose:** Floating district as sustainable and autarkic as possible.
- **Energy purpose:** As energy neutral as possible through own sustainable electricity generation, as little use of 'grid power' as possible through internal balancing (which is not happening at the moment because of low electricity production in winter with the solar panels (interviewee #1), all electric and smart matching of supply and demand.
- **Setup:** Energy-neutral community existing of 46 households on 30 arks, 46 private solar PV systems with a total of 516 solar panels, community is the owner and operator of the local electricity grid, one common (local) grid connection, 30 private owned batteries, 30 heat pumps owned by the community (interviewee #1), local/internal balancing demand, supply and storage of electricity.
- **Results:** internal balancing of supply and demand, contracted connection capacity is 1/5th of standard connection capacity, costs are 1/8th of 'normal costs', ability to provide flexibility services. When there is a chance of overload, the batteries and heat pumps are deployed.
    - So, Schoonschip needs only 1/5th of the capacity (Al)Liander would offer/contract normally, which makes it possible to reduce the costs to 1/8th of what it normally would be for operating the grid and connecting something to the grid.

Community owns the local power grid, therefore they can do what is not yet possible under the current law, even with an exemption, regarding power exchange and everything that comes with it. So, DSO Alliander owns the grid up to Schoonschip's connection. Everything on the water belongs to the community.

Conclusion: what a project needs to be fully (energy/electric) independent: an exemption of the Electricity Law, as well as their community owned power grid, because if not then the DSO is the owner and operator of the grid. After the exemption expires in 2026 or ten years after their operating date (RvO, 2016) the grid is probably going to be sold to the DSO Alliander (interviewee #1). The operating date is not known to the energy working group, so assumed is that the regularly length of the exemption expires ten years after request in 2026 (interviewee #1). The new Dutch Energy Law is already moving towards some specificities of Schoonschip so that the Schoonschip's flexibility options are possible under this new law without the need for an exemption to that law (Energie Samen & Swens, 2022; interviewee #1).

Interview findings

Energy Community according to interviewee (#1): "Schoonschip is in its essence initiated as a community, but grew into an Energy Community, with the purpose of (becoming) being the most sustainable floating neighborhood in Europe."

(Interviewee #1) The smart grid is operated by the 'energy working group' of Schoonschip. In practice there are four goals: get basics in order, send energy bill, manage exemption, everything you have to do as Grid Operator/DSO and Energy Supplier from the exemption. Schoonschip has its own grid: a so called 'project grid'. They have one (consumer) connection to the low/medium voltage grid and they pay 'rent' on that, where they have partly freedom to do what they want with their energy, but within 'consumer law'. Their goal is to make smart grids useful for grid constraints, act on flexibility markets as virtual (small) power plant (VPP) in a consortium with Greenchoice and the Province of North Holland is among them combined with wind farms. Another goal is to experiment to draw lessons on a national level. Schoonschip can be unique as pioneer: role small-scale decentralized flexibility in energy transition. They want to explore what they can do anything significant with their batteries and heat pumps, also for affordability of the energy transition vs. having these devices controlled by the DSO.

(Interviewee #1) Exemption to the electricity law in practice: They can control (limited) electricity consumption. Schoonschip's people do go further in sacrificing comfort than others because of their sustainability motivation. They use the grid connection more than expected. They are not yet (far from in winter) self-sufficient, still need enough energy from the grid, but they do serve as a flexibility buffer (testing ground) with their hot water vessels/heat pumps and batteries. Although (at first) also maximizing self-consumption (using as much of their own generated power as possible) but they are going more towards smart trading on the (trading/)flexibility markets (primary and secondary market) to make their business case even more profitable, this in the consortium with Greenchoice and with their (intended) Virtual Power Plant (Topsector Energie, n.d.).

Interviewee (#1) said about consumer law: Within consumer law you are always allowed to opt out, if a household opts out then the community has a big problem (also a new and unknown situation), because they don't know the consequences. In the statutes they incorporated some duties, such as the battery and the heat pump must be smart grid ready, (Consumer law: freedom of choice for an energy supplier), very important even with disengagement you must comply with this energy supplier's choice. This is supported by Reijnders, van der Laan & Dijkstra (2020, p. 143): "The community, as a legal entity, must respect the freedom of individual consumers to choose their supplier without being expelled from the community."

Interviewee (#1): "The Exemption/Experimentation Decree is an important factor in Schoonschip's success, but huge willingness of the group and willingness to take risks is also necessary. As an example: their energy bill of 2020 is just sent to the residents, so they are forgiving. Technical equipment needed but also a bit of luck."

Schoonschip, initially established as a community, has evolved into an Energy Community with the ambition of becoming the most sustainable floating neighborhood in Europe (interviewee #1).

The community operates a smart grid through its 'energy working group'. Their goals include ensuring the basics are in order, managing the energy bill, and dealing with regulatory requirements as a Grid Operator/DSO and Energy Supplier under the exemption. Schoonschip has its own grid, referred to as a 'project grid', with one connection to the low/medium voltage grid for which they pay rent. While they have some freedom in energy usage within consumer law, they aim to make the smart grid useful for addressing grid constraints and participating in flexibility markets as a virtual power plant (VPP) alongside Greenchoice and the Province of North Holland. They also see themselves as pioneers in exploring the role of small-scale decentralized flexibility in the energy transition, using their batteries and heat pumps to contribute to the affordability of the transition (interviewee #1).

Regarding exemption from electricity law, Schoonschip has limited control over electricity consumption. The community members willingly sacrifice comfort to prioritize sustainability, utilizing the grid connection more than anticipated. Although they are not yet self-sufficient, especially in winter, they serve as a flexibility buffer through their hot water vessels, heat pumps, and batteries. While initially focused on maximizing self-consumption, they are shifting towards smart trading on flexibility markets to enhance their business case, collaborating with Greenchoice and their intended VPP.

Consumer law is an essential consideration for Schoonschip. Individuals always have the option to opt out, but this could pose significant challenges for the community. To address this, they have incorporated certain duties in their statutes, such as ensuring that batteries and heat pumps are smart grid ready, while respecting the freedom of individual consumers to choose their energy supplier without being expelled from the community (interviewee #1).

According to interviewee (#1), the Exemption/Experimentation Decree has played a crucial role in Schoonschip's success. However, the community's achievements also stem from their strong willingness to take risks and their collective commitment. As an example of this: the two years late delivery of their energy bill for 2020 was accepted because of the community’s forgiving capacity. Also, for success both the required technical equipment and a bit of luck is needed.

In summary, Schoonschip's journey from a community to an Energy Community involves the operation of a smart grid, engagement in flexibility markets, adherence to consumer law, and leveraging exemptions from electricity regulations. Their pioneering efforts, combined with the supportive regulatory framework and their own determination, contribute to their success as a sustainable floating neighborhood.

APPENDIX D GRIDFLEX

In this appendix all the additional GridFlex information is shown.

Rules-in-use results

Rules-in-use	Interpretation
Boundary rules	Most important consortium partners/stakeholders: - Endona - Escozon - Enexis - University of Twente - Dr Ten - ICT Group - Buurtkracht foundation - Residents - RvO - ACM -The initial project and consortium were initiated by the energy cooperative Endona.. Together with Escozon they reached out to DSO Enexis to become part of the project. First Enexis was not eager to step in the project, but after good knowledge and interests exchange Enexis joined the project... -The neighborhood team consisting of five ambassadors from the area Veldegge in Heeten together with Endona accomplished a 100% participation rate of residents, even a Polish household that did not speak any Dutch. Therefore, all of the households and residents were included in the project and decision-making via five neighborhood representatives. -Another boundary rule which affected the degrees of freedom is the fact that GridFlex residents kept their '**small consumer connection**', all together within the exemption they formed a '**grand experiment**', which uses the conventional grid operated and owned by the DSO at place.
Position rules	The exemption under the experimentation decree required some sort of legal entity, so energy cooperative Endona was founded as the 'owner' of the exemption/the project. Escozon was Endona's technical and legal advisor and together they were content-based project manager. Enexis became the so-called project 'secretary' (Dutch: penvoerder) and therefore, (legally) one of the most important stakeholders in the project… University of Twente (UT): researcher, data manager, protector under the GDPR and other privacy laws. ICT Group: EMS owner, operator and as the UT data manager, protector under the GDPR and other privacy legislation. Dr. Ten: technology provider, e.g., sea salt batteries… Buurtkracht foundation: role as a societal consultant about connecting people in a neighborhood and improving sustainability. RvO & ACM act as external licensing authorities and possible funders.
Choice rules	Every household kept its own energy contract and company and due to lack of degrees of freedom within the exemption policy the GridFlex project and Endona had little room for price variation only at the network tariff level, which leaves almost no improvement to flexibility opportunities. Therefore, the choice was made to simulate the smart grid environment online. The battery company (Dr Ten) was lacking in its development and delivery of sea salt batteries. This caused serious delays with certain parts of the smart grid, so the choice was made to buy lithium-ion batteries on the market for the last part of the pilot project. The choice rule associated with this can be formulated as: If an energy asset is not delivered in time than an alternative can be considered and implemented.
Information rules	Initially the most important consortium partners did not know that the exemption left so little room for playing with electricity prices to improve flexibility. They even spoke with the Dutch tax authority (Dutch: Belastingdienst) about possibilities to play with the energy tax part (~60%) of the electricity price. From interviewee (#4): "Consumer price: tariff elements, grid operator, supplier, energy tax (60%). Exemption only on grid operator part: Tax authorities did not want to cooperate and neither did energy suppliers, so only grid operator tariff remains and you cannot generate much flexibility with it." Technical information available to consortium partners: batteries… The question remains which information was available to the residents (interviewee #4)? Did they know there was a virtual non existing smart grid environment as if the exemption was 100% in place, while the residents kept their normal energy supply company and contract? From this a traffic light model was in place for the electricity prices, where a signaled red light contained high prices/low (sustainable generated) electricity supply, orange medium and green low prices/high (sustainable generated) electricity supply. With this information the residents could intervene in their normal consumption and adjust consumption behavior. University of Twente and ICT Group were of course subject to the GDPR and other privacy legislation…
Aggregation rules	The project consortium did everything as a collective, they had multiple sessions where representatives of all project consortium partners were present in and around the local area in Heeten where the decisions were made with all consortium stakeholders.

	The residents had five representatives for their interests. There were monthly project meetings with all stakeholders and with minimal one representative of the residents. The most important stakeholders of the consortium decided to agree with purchasing lithium-ion batteries when the development of the sea salt batteries was lacking behind; which was for the sake of the feasibility of the pilot project.
Payoff rules	A payoff rule is the price mechanism of the traffic light model with three different prices: red light signal to residents meant high electricity consumer prices and low (renewable) generation, orange medium and green low prices and high production. With this the project tried to influence consumer behavior to increase flexibility and peak shaving. After the project this model resulted in the reduction in neighborhood peaks with and without batteries, showing a decrease of up to 36% (from 39 to 25 kW). By implementing the new payment scheme described in Reijnders et al. (2020), the residents collectively could save €1,500 per year, equivalent to about 14% of the total connection and transport costs. Consumer behavior change per household resulted in no significant behavioral change (a price reduction of ~€30 per year, since the residents did not look at the application as much as expected (interviewee #5). So, automating most of the smart grid assets processes is better. No real feasible business case as a result of the GFH project: taxes and energy (company) prices were fixed even with the exemption…. → simulated smart energy system environment digitally with revenue of 2500 euros in 3 years? (Interviewee #3). But this is less than Reijnders et al. (2020) calculated… Low price saving per kWh is due to the composition of energy prices in the Netherlands, which includes grid tariffs, supply costs, taxes, and levies (interviewee #4) as shown in Figure 10 in Appendix D. The fixed grid costs and regulated prices leave very little room for variation in electricity prices, making it difficult to provide incentives for customers to change their energy consumption patterns.
Scope rules	The last year of the Girdflex project took hold when the Covid-19 pandemic emerged, which affected the costs, benefits and the business case as many people needed to work from home. The electricity consumption went up and that year was not representative as the other two years. So, the results and possibilities of outcomes decreased as measuring electricity consumption etc. was affected and the scope of outcomes changed. The number of technical alternatives/solutions was limited due to the lack of sea salt battery development, no smart assets, and a traffic light model for customers to adapt their behavior and less degrees of freedom in the exemption (policy). Incentives for direct self-consumption optimization are undermined by the tax refund scheme (Dutch: salderingsregeling) for annual self-consumption, which also hurts the viability of home batteries as a business.

Additional information

Infrastructure, building & demographic characteristics

<u>Infrastructure</u>

Solar-PV park in Heeten initiated by the local association (in Dutch: Stichting) of Endona (meaning 'Energie Door Natuurkracht'; Energy by natural power in English), with 8000 panels, which provides enough energy for roughly 600-700 households.

The EMS: Energy Management System → smart devices in the meter box/fuse box that are connected to an application where participants and the companies/research institutes could see/monitor and have an insight in the generated (energy) data. Interviewee (#4): Part of this EMS was a virtual (fake) environment created as a platform where they acted like the ideal scenario of a full smart grid with flexibility, storage of energy in batteries. At the same time the residents still had a contract with their traditional energy supplying company and they could not vary the energy price as much as they wanted → the exemption was more limited than expected.

ICT Group: Energy Management System developed. The smart meter can also control the battery(s). Transparency is of high importance, so the customers/users have an application where they can monitor their data which is anonymized due to GDPR privacy issues.

Standardization is an important issue for the future, also with regards to the costs.

Batteries 8 (/9): Salt batteries, which had a huge delay in development, and were therefore implemented to a lesser extent than initially expected → in compensation for the simulation conventional lithium-ion batteries were used.

University of Twente: they get the anonymized data in their algorithmic systems, so they can check what's happening in the neighborhood with all the electricity flows → to predict what is the best scenario in the near future for batteries, solar panels, usage etc.
Traffic light system: red, orange and green → the better the color the lower the price at that moment for electricity usage.

Building/construction
It was a relatively new neighborhood, with 'modern' housing, so the houses were already quite energy efficient. 49 households with only one 'trafo' (transformer) as they call it, so (extremely) useful for such an experiment. Next to this there was a reference group of 25 households throughout the village of Heeten, which also got an EMS (energy management system) to subtract data for the Gridflex project. The project measures not at household level but at the transformer level, which is a bandwidth model that Enexis (and ACM) are going to develop further in the future.

Demographic
The residents were fairly young people with younger children, so they were possibly more open minded and into an innovative project as Gridflex.
5 ambassadors from the neighborhood called 'Buurtteam' who convinced all the people to participate → initiated by Endona in cooperation with Association (in Dutch: Stichting) Buurtkracht.
Important aspect what they said is that the residents were not going to pay more for their electricity than they used to.
It was very important that it was a local project, initiated by local people that knew the people/the neighbors etc. for the 100% participation → (ENERGY) COMMUNITY ASPECT.
In the end from the data they could not see significant behavioral change in the electricity usage with regards to the traffic light model. → so, standardization and automatization is really important.

Stakeholder overview

"To reach their goals the community has initiated the GridFlex Heeten project, where a consortium of Enexis B.V. (project manager/secretary), Endona U.A., Escozon U.A., Enpuls B.V., Dr Ten B.V., ICT Group N.V., and the University of Twente are working together." (Reijnders et al., 2020, p. 144) (Interviewees #2, #3, #4 & #5).
Source: (GridFlex, n.d.b)

- **Energy cooperative Endona** (EnergieDoorNatuurkracht): local energy cooperative and internal project manager.
- **Escozon**: entrepreneurs cooperative who provided the development and implementation of sustainable energy concepts, also internal project manager.
- **Enexis Netbeheer**: DSO of the region where Heeten is located and 'project leader' (Dutch: penvoerder) of the Gridflex pilot project. Research from the 'energy group': working group mathematics and embedded systems department (interviewee #5).
- **University of Twente:** research and education in the field of energy management systems and pricing mechanisms in local distribution networks.
- **Buurtkracht foundation:** social initiative (from DSO) that aims to connect and support people in neighborhoods in making their neighborhoods more sustainable.
- **Dr Ten:** battery producer, developer and supplier for the project.
- **ICT Group:** systems engineer within the field of smart energy.
- **Enplus:** part of Enexis, focuses, among other things, on measuring and analyzing energy consumption and advising on energy infrastructure and savings.

- The **residents** of Veldegge and of the reference group area.
- **RvO** is also an important stakeholder as they grant subsidy and the exemption to experiment with electricity, they are part of the Ministry of Economic Affairs and Climate Policy. The **ACM** is also an important (regulating/)controlling stakeholder for the Electricity Law etc.

Literature/Current scientific knowledge & Interview findings

Literature source 1: According to Van der Waal et al. (2020, p. 6) (all quoted from a table)
GFH part: *(important to note is that the authors are not totally correct with their information, these points will be clarified in italic)*

- "Project type: large experiment
- Delineation: the first pilot is in the village of Heeten, but eventually Endona wants to supply the medium voltage grid (part Raalte) with locally produced renewable energy as well as increase the regions' real-time electricity use. → *Endona only has an exemption for zipcode 8111 (Heeten), so curious here how Endona is going to manage this for Raalte, as according to the exemption it is not allowed (RvO, 2015).*
- Organization and governance: Endona is an energy cooperative, with the board members registered as its members. This *(legal-organisational)* structure has been chosen to keep decision-making with its day-to-day management. Endona has a large portfolio of projects and is part of several collaborations with grid operators, technology developers and knowledge institutions.
- Energy system: With some of its partners, Endona installed sea salt batteries *(in the neighborhood of Veldegge in Heeten)*. It also implemented household level energy management systems (EMS) in a neighborhood with 47 households, and an overarching EMS that uses the inputs from these EMS for neighborhood level optimization. Furthermore, Endona developed a solar park with 7,200 photovoltaic (PV) panels on 3.5 ha of former agricultural land.
- Use of Exemption under Experimentation Decree: The derogation has not yet been effectuated *(this is not correctly written by the authors (Van der Waal et al., 2020) because the exemption needed to be operational before November 4th, 2016 (RvO, 2015) and the project of GFH started in 2017)*.The cooperative Endona only acts as producer and does balancing experiments that are allowed within the framework of the current Electricity Act. At present, the electricity sale is through a cooperative energy company *Energie van Ons (in English: Energy of Us)*. Endona has not found a suitable business model for being electricity suppliers and is investigating the financial risks. In the long run, it wants to take on this role so both the costs and benefits of the energy system are local, and they can possibly offer a lower price to their users because of the integrated management."

Literature source 2 + interviews:
Reijnders et al. (2020): *(Still needs to be adapted to a readable text)*
The primary focus of discussion revolves around the concept of (citizen/renewable) energy communities comprising citizens and the diverse range of energy-related services and flexibility they can offer. The global emergence of these communities has prompted an inquiry into their underlying motivations and challenges. Joining an energy community is primarily driven by an increased awareness of environmental concerns, while a lack of clear legislation poses a significant obstacle. One notable case study, GridFlex Heeten, conducted in the Netherlands, is currently under investigation in this research.

In the village of Heeten, the Netherlands, there is a citizen energy community consisting of 47(-50 interviewee #3) households. These households worked together to reduce stress on the local distribution network by focusing on reducing peaks at the transformer via flexibility of the batteries and the flexibility of the citizens. They have initiated the GridFlex Heeten project, collaborating with various organizations and utilizing battery flexibility and innovative pricing mechanisms. The project aimed to lower stress on the network, avoid or postpone grid reinforcement, reduce grid losses, and save costs for both the network operator and participants. They could do this especially, because: "Endona U.A. has obtained an exemption on the Dutch energy law for experimenting with different electricity tariffs so that these pricing mechanisms can be validated in this field test." (Reijnders et al., 2020, p. 144).

According to the new European Union definition of energy communities: the GridFlex Heeten project is considered a 'Citizen Energy Community' (CEC) (Reijnders et al., 2020). Next to this according to the definition of a 'Renewable Energy Community' (REC) and the sope of this (thesis) research GridFlex can also be considered a REC.

About origin of an energy community volunteers (like Endona) (Reijnders et al., 2020, p. 144): *"Most often, a community initiative starts with an enthusiastic group of people. However, it seems that it is challenging to ensure continuity. The reasons for this may be that the risks are hard to bear and difficult to share amongst the community members or that the community faces some competition of traditional suppliers who have certain competitive advantages due to their larger size."*

The community includes households with rooftop PV installations and 5 kWh batteries behind the meter. Smart meter data and PV production information from all households were shared, providing insights into local energy streams (interviewee #5). The inhabitants received information about their energy consumption through a mobile application, including current and past usage, gas and electricity consumption, PV production, standby usage, and self-consumption rate. The application also provided a price forecast for the next 24 hours, enabling residents to shift their energy usage to cheaper timeslots coinciding with low energy traffic on the transformer (Reijnders et al., 2020; interviewees #4 & #5).

Additionally, there were 28 households in Heeten that are monitored but do not receive price forecasts (interviewee #5). They served as a reference group to compare behavior changes within the community (interviewees #2; #4 & #5). The project treats all households behind the transformer as a single community, allowing calculation of connection costs on a collective level (interviewee #5).

In the traditional Dutch energy system, consumers pay the network operator for their connection and energy transport based on an average energy usage of 3,500 kWh per year (Reijnders et al., 2020). However, in the GridFlex Heeten project, the connection costs were decoupled from the cost of energy transport (interviewee #5). Consumers paid for their connections individually, but the transport cost was calculated at the transformer level. Energy that remains within the community and does not pass through the transformer is not charged, promoting self-consumption within the neighborhood (interviewees #4 & #5). The price per kWh for transport depended on the total power demand of the community, increasing with higher demand on the transformer. This means that each resident paid the same price per kWh, but the price varied based on the collective behavior of the community (interviewees #3; #4 &#5; Reijnders et al., 2020)

To incentivize behavior changes and reduce transport costs, the pricing scheme defined three levels of demand on the transformer, each corresponding to different prices, so called 'traffic light model' (interviewee #2). The cost of transport for each household was calculated by multiplying their energy consumption by the price associated with the transformer's demand level (interviewee #4). Increasing demand levels resulted in higher prices per kWh. By utilizing batteries and shifting energy consumption, the community could effectively reduce transport costs (Reijnders et al., 2020; interviewees #2; #4 & #5)

The batteries operated automatically based on weather forecasts, past energy consumption, and neighborhood information.

The GridFlex Heeten pilot project aimed to reduce transport losses, decrease grid congestion, and minimize investments in the grid. The ultimate goal was to achieve zero transport of electricity over the transformer, effectively creating an islanded microgrid. The community in Heeten represented a collective generation and battery flexibility model (Reijnders, Gerards, Hurink & Smit, 2018).

Reducing peaks in energy consumption also benefits the network operator by slowing down asset aging, reducing maintenance and replacement costs, and potentially avoiding expensive transformer upgrades. As a result, the network operator can offer remuneration to the community, similar to the variable transport cost (Reijnders et al., 2018).

The potential to expand the Heeten setup into a general concept for energy communities is largely determined by the existing legislation. Currently, Dutch laws restrict some of the seven value propositions outlined in the Universal Smart Energy Framework (USEF) (USEF, 2019). This limitation is partly due to the composition of energy prices in the Netherlands, which includes grid tariffs, supply costs, taxes, and levies like in Figure 10. The fixed grid costs and regulated prices leave very little room for variation in electricity prices, making it difficult to provide incentives for customers to change their energy consumption patterns.

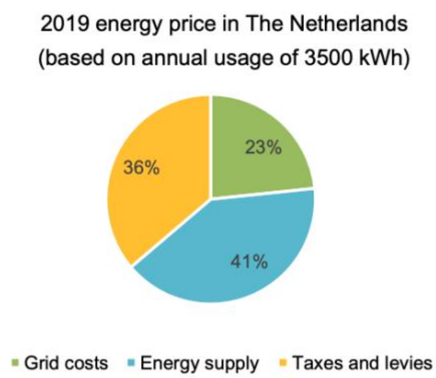

Figure 10 Energy price distribution in the Netherlands (Reijnders et al., 2020)

“Likewise, the tariffs for the network operators are regulated. This is all done to provide fair prices to all customers. However, the current system allows no incentives which can be given to customers to change their energy consumption pattern.” (Reijnders et al., 2020, p. 148). As a result, such approaches can only be tested in pilot projects.

The current tax schemes for individuals and communities strongly incentivize investments in renewable generation but provide almost no added value for exploiting energy flexibility services (Reijnders et al., 2020; Interviewee #4). The GFH pilot project received an exemption from the law, enabling the implementation of dynamic grid tariffs. However, for such tariffs to be viable from the perspective of a network operator, the entire neighborhood behind a common connection point (i.e., transformer) needs to be part of the community, making it challenging to establish in existing neighborhoods to include all residents (Bauwens & Devine-Wright, 2018). The scalability of the GridFlex concept and similar initiatives depends heavily on coming legislation and the influence of pilot projects like GridFlex. The research by Reijnders et al. (2020) suggests specific aspects that should be integrated into future legislation to create better business cases for energy communities, including a defined legal position for citizen energy communities, grid tariff schemes that compensate higher community self-consumption and lower peak loads, energy pricing schemes that differentiate between internal community energy transfers and external exchanges, and taxation schemes that encourage real-time self-consumption rather than annual averages.

APPENDIX E GROENE MIENT

In this appendix all the additional GridFlex information is shown.

Rules-in-use results

Rules-in-use	Outcome/interpretation
Boundary rules	The initial 'smart grid' experiment was initiated in a project consortium with the Municipality of The Hague, DSO Stedin, Eneco Energy, working group Watt, energy cooperation SoS and knowledge institutions with a letter of intent. Spectral Energy came later for the development of the Smart Community Platform. RvO granted the exemption under the Experimentation Decree. The Province of South-Holland granted a subsidy. *Most important consortium partners/stakeholders:* - Energy cooperative Sterk op Stroom: legal entity needed to form an energy community to execute energy actions related to the establishment, development and implementation of the smart grid. - Houseowners association (Dutch: VvE) Groene Mient: as a legal entity they received the Exemption of the Electricity Act under the Experimentation Decree. - GMDH residents: all the decisions within Groene Mient are made sociocratically…(interviewee #7). - Municipality of The Hague: it's the local municipality where the project is located, so they have to be included in the project consortium and decision-making process. - DSO Stedin: is legally binded to the GMDH, because of the geographic location of the project in The Hague, which is within the operational field of this grid operator. - Province of South-Holland: It is the province where The Hague is located, which is the city where GMDH is located. So, they are one of the important stakeholders especially with its subsidy to GMDH. - Spectral Energy: System integrator → they built the SCP of the GMDH project and its smart grid. - Delft University of Technology & The Hague University of Applied Sciences: knowledge institutions with data science - RvO: this was the stakeholder that needed to grant the Exemption, also on behalf of the Minister of Economic Affairs & Climate Policy. - ACM: The Consumer & Market Authority (Dutch: Autoriteit Consument & Markt) is a Dutch independent public regulator that needs to approve price tariffs for electricity within the Exemption, it makes sure the electricity market is regulated and stays 'fair'. - Energy Supplier Eneco: The first energy supplier related to this project and one of the stakeholders of the initial declaration of intent (SOURCE). - AquaBattery: was a partner to arrange a sustainable and environmental friendly battery. - All-in-power: platform provider (future) energy sharing with dynamic energy prices, mainly for the future development of the smart grid. - Energie Samen: national federation of energy cooperatives in the Netherlands. A boundary rule which affects the degrees of freedom is the fact that GMDH residents kept their '**small consumer connection**', all together within the exemption they formed a '**grand experiment**', which uses the conventional grid operated and owned by the DSO at place.
Position rules	Housing association Groene Mient is on paper the 'owner' of the Exemption. In combination with energy Cooperation SoS they are the 'project leaders' and initiators for the smart grid project part of Groene Mient. The roles of Municipality of The Hague and DSO Stedin (physical network manager) could be described as very important and powerful project partners and natural allies, but the cooperation should be more and is lacking now due to several reasons, e.g., financial (Stedin), regulatory and interests (Municipality) issues. The Province of South-Holland its only role in the project so far is the one of financer. Knowledge institutions like the Delft University of Technology and The Hague University of Applied Science external data advisors. RvO & ACM act as external licensing authorities and possible funders. Spectral Energy is the smart grid digital technology provider with the SCP and data protector.
Choice rules	The municipality decides to sell the land to the Groene Mient and therefore a green community residential area can arise at that location. At a certain point in time a declaration of intent/project strategy is signed by Groene Mient association, Municipality, DSO Stedin, Eneco and an energy company to learn from this project. Energy cooperative Sterk op Stroom is founded to take over the sustainable/smart grid part of the housing owners association. DSO Stedin could not afford to actively invest in the Groene Mient smart grid, due to lack of money. SoS decided due to all the circumstances to leave the smart grid experiment for what it is, because is not feasible to develop and implement a community smart grid at this point in time. Therefore, the most important action as a conclusion of the Groene Mient smart grid project so far is that the Exemption under the Experimentation Decree is still not in place, due to several reasons. So, the energy cooperation SoS decided to let the smart grid ambitions be for what it is for now.

Information rules	The information that SoS/Groene Mient had when the initial project plan/goals were set up was not sufficient to reach the implementation of a smart grid yet. An example of this is that their technology (e.g., smart assets) is not smart grid ready, heat pumps from an older generation without an Internet of Things connection etc. (interviewee #6 & #7). Another important information rules concerns data collection and data handling. Who is responsible for this and who may store the data. The General Data Protection Regulation (GDPR) constrains data handling, for instance for the DSO in the order of data protection and the right to privacy for consumers (Cuijpers & Koops, 2013). Interviewee (#6): Personal data (vs. science) that you may use within science, but there must be necessity to it and a realistic use, if this is not happening soon, the data must be destroyed. Overall, the information available to participants of the project consortium was sufficient. On the other hand how different stakeholders handled the information was lacking. From the interview (#6) is it clear that some knowledge institutions could not fulfill their promises mostly related to data (handling), although there has been scientific research done with the Groene Mient data. For now mainly Spectral Energy of the SCP and All-in-power are concerned with the consumer electricity data and other smart grid data handling and protection. Knowledge institutions like universities are not doing as much with the data as possible, e.g., with the data the houses of the Groene Mient provide with the smart meters in place (interviewee #6).
Aggregation rules	The decision-making process initially was with all the involved stakeholders and with consent. But due to lack of further involvement of for example the Municipality of The Hague (interviewee #6), the Groene Mient project and SoS felt left behind and were not as motivated as before to make the smart grid successful. *Groene Mient internal decisions are made by all 33 households*
Payoff rules	The net costs and benefits of the project are not well established. The only subsidy the project got was €75,000 of the province. The project and the energy cooperative need more money from subsidies to attain their initial goals. The interviewee (#6) said that the data collection they have is already worth four times (350k) its initial subsidy value (75k). Knowledge institutions (e.g., universities) could subsidies the project more if they have access to the data for scientific analysis in collaboration with the Groene Mient association, energy cooperative SoS, Spectral Energy and All-in-power. However, what the accessibility of the data is for knowledge institutions is not known for now.
Scope rules	The final status of the outcome, as described in the status quo section, the smart grid is not in place, the Exemption under the Experimentation Decree is not operational at the moment. The initial project scope (rule) was broadened several times because of the ambition to implement sustainable batteries (in cooperation with AquaBattery) and (share) electric vehicles. Both are not in place yet but energy cooperative SoS has several ideas for the Groene Mient and the surrounding Vruchtenbuurt neighborhood especially with the electric vehicles and a smart charging station. The rule thing that limits the scope of outcomes is that the Exemption is only intended for the Groene Mient households (Mient 327 - 351 (odd numbers) and Limoenhof 1 – 20) (RvO, 2018). Then along the way of the project technical solutions are limited because of smart grid asset development/the assets Groene Mient has. Within Groene Mient (with DSO Stedin) together with GFH they are currently doing experiment(s) regarding good grid management: grid management and grid management tariffs and comparable things, only after this the Groene Mient and SoS is continuing actions with the Exemption they have under the Experimentation Decree. The set of possible outcomes decreases because the subsidy from the province is fully used, has already become worth more than four times as much as it was due to high valuable data (interviewee #6). Another reason the possible outcomes decreased over time is because the collaboration between the Groene Mient/Sos and the relevant knowledge institutions was lacking which resulted and was caused by the high valuable data was not used properly by the knowledge institutions according to the interviewee (#6). *(Put in technical challenges from GMDH interview??)*

Additional Information

Infrastructural, building and demographical characteristics

Sustainable Housing: The neighborhood consists of 33 energy-efficient homes that are built with sustainable materials and incorporate renewable energy systems. The houses are designed to reduce energy consumption and promote a low-carbon lifestyle.

Shared Facilities: The Groene Mient emphasizes communal living and resource sharing. The neighborhood has shared facilities such as a community center (the ‘Ei’ building), a big common garden which promotes the community feeling. These shared spaces are designed in such a way to promote interaction, collaboration, and create a sense of community among residents. The garden is an example of a such a community shared space without any fences. The community garden includes biodiversity conservation, and regenerative land management practices (interviewee #7).

Community Participation: The project actively involves residents in decision-making processes and encourages their participation in various sustainable initiatives. Residents have a say in the management of shared spaces, collective projects, and the overall development of the direct surroundings of the Groene Mient project area.

Learning and Innovation: The Groene Mient project serves as a living lab for learning and experimentation. It provides opportunities to test and develop and test innovative solutions related to sustainable living, energy efficiency, and community development. Lessons learned from the project can potentially inspire and inform future sustainable initiatives.

Stakeholder overview

Groene Mient association, Energy Cooperative SoS, Residents, All-in-power (platform energy sharing), Aqua Battery (sustainable battery provider company), DSO Stedin, Municipality of The Hague, Province of South-Holland, knowledge institutions (e.g., Delft University of Technology and The Hague University of Applied Science), Spectral Energy (System Integrator), Solar Engineers, Energie Samen (national federation of energy cooperatives in the Netherlands), RVO and ACM (Energy Consumer & Market Authority).

Experimentation Decree including Smart Grid assets

In November 2018, owners association (Dutch: Vereniging van Eigenaren(VvE)) Groene Mient and energy cooperative SoS obtained an Exemption of the Electricity Act under the Experimentation Decree, a so-called Grand Experiment Electricity Act (RvO, 2018). This allows SoS to experiment smart grid applications for a ten years period. This is a condition for, e.g., using a smart grid and energy sharing in the Vruchtenbuurt neighborhood (Working group Watt & Sterk op Stroom, 2022).

The Smart Community Platform (SCP), which was created by Spectral Energy and placed in the Groene Mient homes in 2020, monitors energy flows and gathers data. Through the SCP's dashboard, this information is made available to the Groene Mient households. Additionally, the ability to operate heat pumps and boilers depends on this data. However, as stated by the interviewees (#6 & #7) the assets they use are not smart grid ready at all. The heat pumps do not have any Internet of Things (IoT) connection (interviewee #6) so those cannot be controlled by any smart grid algorithm/SCP. Therefore, the main purpose of ‘smart grid’ Groene Mient is flexibility in consumer behavior (like GFH). This is the main reason why the Exemption is not in place yet even almost five years after it was granted to the Groene Mient. This is strange because the other two projects (SSA and GFH) needed to make sure their operational date was maximum one year after the Exemption was granted to the project (RvO, 2015; RvO, 2016).

Stakeholders Collaboration for GMDH’s Smart Grid

The next section is stated by Working group Watt & Sterk op Stroom (2022):

To develop an experimental smart grid for the Vruchtenbuurt, a multitude of partners, including the Municipality of The Hague, DSO Stedin, Spectral Energy, an energy supplier, and knowledge institutions such as Delft University of Technology and The Hague University of Applied Sciences, were involved. Substantial grant money was also secured for this project. SoS facilitated numerous partner meetings from 2019 to 2022 to establish a solid foundation for the creation of the experimental smart grid. Through collaborations with partners like the municipality of The Hague, Eneco, GreenChoice, Spectral Energy, AquaBattery (a sustainable neighborhood battery provider), etc., efforts were made to form innovative coalitions. Various knowledge institutions were consulted to ensure effective data analysis and its availability for non-profit use. Additional funding was sought from green investment funds to cover the costs associated with developing the smart grid. Policymakers and partners strongly believe that a smart grid can significantly contribute to the energy transition and reduction of CO2 emissions. Influential figures within DSO Stedin have emphasized the importance of citizen initiatives in this context. The final partner meeting took place on September 22, 2022, for SoS marking the completion of the experimental phase of the Smart Grid project. Eventually, the intended innovative coalitions were not successfully formed.