Success Factors of an Energy Community in an Urban Area

A Mixed Method Approach

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Resourcefully

TU Delft

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by

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A graduation project for the Master of Science in Management of Technology at the Delft University of Technology

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Preface

This thesis represents months of hard work and was for me the most enlightening part of my academic journey. I've always been deeply interested in the energy transition, so having the chance to research this topic in the city where I live was exciting. The experience was nothing like I expected, and for that, I am grateful. Much of this gratitude goes to the people who guided me through the process.

Learning was the most important aspect of my thesis journey. My first supervisor, Pieter Bots, complemented my weaknesses with his strengths, providing guidance that was always clear, though sometimes tough, which kept me on track and taught me valuable lessons. Pieter, your ability to understand my challenges made working together a pleasure.

I would also like to extend my thanks to my second supervisor, Rudi Hakvoort, for your sharp and sometimes amusing comments during our meetings. My gratitude also goes to Resourcefully, and specifically to Hugo Niesing, for a worthwhile and enjoyable internship. Discussing with Hugo was always enlightening, and your connections aided my thesis work. Access to the Liander grid data was a rare privilege, and I hope we can compare it with future datasets.

A heartfelt thank you to my family and friends for your support when my motivation was a little lower. To my girlfriend, Hanne, your love, support, and the wonderful breakfasts you prepared really made my mornings brighter as I tackled my thesis. Lastly, a shout-out to my roommates, whose good luck wishes every morning gave me an extra boost as I headed to the office.

Summary

As electrification intensifies with the increasing use of heat pumps, EVs, electric cooking, and other factors, household electricity consumption is rising, pushing low voltage electricity networks to their capacity limits. Expanding and enhancing the grid to make it more adaptable and intelligent is essential, but such transformations require substantial investment and time and cannot be achieved overnight. A practical solution to this challenge involves adjusting electricity consumption within residential areas. This can be facilitated through the formation of energy communities where households collectively manage their energy use to minimize peak load moments, thus alleviating pressure on the electricity network.

An energy community is typically a specific area or neighbourhood where households aim to produce and consume their electricity as much as possible within the neighbourhood itself. Additionally, households actively seek to modify their energy consumption patterns to avoid peak load moments, significantly reducing the need for additional investments in the electricity transport infrastructure. To encourage participation, a demand response program is utilized where households are financially rewarded for adjusting their electricity usage during peak times. This initiative not only helps manage the grid more efficiently but also offers rewards for the stakeholders who participate.

This research presents a case study from Sporenburg in Amsterdam, where the energy community is currently being implemented and tested. The study aims to explore the factors that contribute to the success of this energy community. Sporenburg is an exemplary case study because the transformer is equipped with a smart meter and Amsterdam has set more ambitious climate goals than the rest of the Netherlands, necessitating a higher rate of electrification in the area. While there are currently no congestion problems in Sporenburg, projections suggest that by 2050, Amsterdam's electricity demand will have increased threefold to fivefold compared to levels in 2022. The primary research question this study addresses is:

What are the critical factors, categorized into distinct groups, that contribute to the success of the energy community?

The research is structured into three sections, each focusing on different aspects of the energy community. It starts by analysing the **technical system**, where technical success factors are identified and explored. The examination continues with a study of the **organizational system**, where organizational success factors are pinpointed and discussed. Building on these insights, the **individual perspectives** of households are analyses, discussing these factors within the context of organizational success as well. Within these three sections the success factors are differentiated into two types: those that are critical conditions necessary for the success of the community, and those that contribute to success but are not essential. The table below visualizes these sections along with their corresponding sub-research questions.

Chapter 3 Technical system	*What is the current state of the technical system within the Sporenburg neighbourhood's energy community?*
Chapter 4 Organizational system	*What are the interests of the stakeholders involved in the energy community and what actions can they take?*
Chapter 5 Individual perspectives	*What are the varied perspectives of households regarding their participation in the energy community?*

Technical system

Characteristic	Important to know
Households	Owned-rented Heat pump/gas heated Electric cooking system
Cars	EV/hybrid-fossil fuel
Charging stations	Private public
Solar panels	Capacity
Utilities	Demand profile

To investigate the operational context and identifying technical characteristics that could influence the energy community a technical analysis of Sporenburg is employed using different analysis methodologies. With this analysis the technical characteristics of Sporenburg are identified and used to identify technical success factors. The most important characteristics are visualised in the table on the right.

When these were identified the dynamics within the energy community are researched using a Causal loop diagram (CLD). The CLD analysis can be used to identifying critical leverage points within the system. These leverage points significantly influence the selection of success factors. From the CLD energy sharing emerges as a crucial leverage point with significant implications. This practice not only reduces electricity bills for consumers but also decreases the amount of electricity fed back into the transformer station, leading to fewer peak moments in the transformer.

When the technical system characteristics and the dynamics within this system the current state and future state of the transformer station is analysed. Understanding what is connected to the transformer and predicting how the stat of the transformer might evolve in the future are key components of gaining a comprehensive understanding of the system. This clarity on the future can motivate households to participate, as the purpose of their involvement currently appears vague to them. The future analysis of the transformer shows that the scenario's for 2030 are close and some even exceed the max capacity of the transformer.

Organizational system

The involvement of the key stakeholders in the project is essential; without their active participation, the community is unlikely to succeed. The interests and actions of these stakeholders play a decisive role in determining the conditions that can positively influence the community. As such, conducting a stakeholder analysis becomes a fundamental step. From this analysis three key stakeholders arise.

Households are the one that adjust their energy usage and can impact the peak load moments of the transformer, therefore seen as a key stakeholder. Households equipped with EVs and/or solar panels have a more substantial impact, making it crucial to prioritize their involvement initially. Ease of use of the system emerged as a significant factor from the discussions, with automation playing a vital role. To keep households actively engaged, the outcomes of their adjustments must be transparent, allowing them to understand the purpose of their actions. This means providing clear information on how their adjustments contribute to CO2 reduction, reductions in electricity bills, and peak load mitigation.

Liander is increasingly recognizing the potential of local energy communities, which they initially overlooked due to their small size and minimal impact. The challenge lies in scaling their involvement; supporting hundreds of diverse communities isn't feasible without a standardized approach, therefore standardization is needed. Liander is pushing for a general strategy where the roles and responsibilities of all parties are well-defined. Furthermore, Liander is open to sharing data but emphasizes that it must be done responsibly to ensure that these community initiatives help alleviate rather than exacerbate the problem.

The municipality of Amsterdam set ambitious climate targets set for 2030, including a significant expansion of EV charging infrastructure and the city recognizes that energy communities can contribute to these goals. However, the municipality also has her thoughts about the project's immediate impact on solving congestion problems and noting that other congestion issues may require priority. Nevertheless, Amsterdam values the opportunity to experiment with household willingness to adjust electricity usage and to strengthen their ties with the neighbourhoods.

Individual perspectives

The last sections explores the varying perspectives of key stakeholder households regarding their participation in energy communities. A survey is developed with the theory of planned behaviour and value-belief-norm to measure these various perspectives where they got questions about the awareness of the problem, responsibility of who must help in solving these problems and motivational incentives to participate. The main findings reveal that financial and CO2 incentives for participation are ranked lower than anticipated. There is no strong preference for one incentive over another, suggesting that a variety of motivational incentives is necessary. The data also shows that the presence of friends and neighbours in the community significantly boosts willingness to participate, as does owning an electric car. Additionally, understanding the tangible impacts of household actions – such as financial savings, CO2 reduction, and peak load management - and having a strong leadership board are most important for the community's success

Succes factors

From the three sections different success factors are identified. The success factors for the energy community are best understood as critical conditions required for its success, categorized into two main phases: the formation of the community and its operational phase. While certain conditions, such as the presence of an EMS and the installation of smart meters in households, are critical, they are often straightforward and require no further advice on how to achieve these success factors. Therefore, only advice on how to achieve the critical organizational success factors is given and these conditions are visualised below.

System	Condition
Forming the community	Commitment and participations of key stakeholders Clear business case for key stakeholders Technical system must be clear
Operational community	Strong board that takes the lead Operational leadership Varied motivational incentives Clarity on the impact of participation Active community participation Active neighbourhood engagement

Advice

The essential conditions for the success of community energy initiatives are well recognized; however, the strategies to effectively achieve these conditions remain unclear. To address this gap, specific recommendations will be outlined, focusing on scaling these energy communities efficiently despite limited time and resources. The advice is categorized into several key areas: the technical system, the organizational system (which includes Liander, target group and automation & Engagement and leadership), and the financial aspects of energy communities.

The first step is to gain a clear understanding of the **technical system** of the neighbourhood, which is essential during the formation phase to develop strategies for managing the community and creating the EMS. The characteristics identified through the technical system analysis play an important in this process.

From an **organizational perspective**, it is essential that all key stakeholders are fully committed and actively participate. Currently, Liander, a crucial stakeholder, is not as committed as needed for the success of the energy community project. Therefore, it is vital for Resourcefully to develop a clear framework that outlines the organization of the energy community and defines Liander's specific role within it. Moreover, Resourcefully must also devise a strategy to manage data responsibly. By doing so, Resourcefully will be able to build trust and foster smoother collaboration with Liander and other stakeholders involved in the project.

When considering the individual perspectives of households which is connected to the organizational system, it's crucial to focus on their enjoyment within the community. This highlights the importance of ensuring that community experiments are clear, user-friendly, and engaging. If the process is not enjoyable, participation may decline. To address this, a business case should be developed in advance, detailing the impacts in terms of CO2 reduction, financial benefits, and effects on peak load. This prevents households from being unaware of the effects of their adjustments. The business case should be presented in a simple, easy-to-understand manner, as households suggested in the interviews.

Additionally, automation plays a significant role in enhancing community energy management. Focusing on applications that are uniform and easier to manage, such as thermostats and EV charging points, is important. Prioritizing appliances that consume the most electricity and affect peak load moments could lead to more immediate and significant reductions in peak load moments. Additionally, a notable finding from the survey showed that households with EVs scored 2.1 points higher in their willingness to participate. This increased inclination makes it easier to engage these households.

Furthermore, a strong board and a community facilitator are important in boosting participation within the energy community. The board could organize informing community events and organize reward events once certain levels of active community participation are achieved. Meanwhile, community facilitator(s) visit homes to provide information, persuades others to join the initiative, installs smart meters, assists households with their applications, and offers support when issues arise.

As energy communities continue to grow, securing financing for incentives, smart meters, the EMS, and other essential services becomes increasingly important. Liander, a key stakeholder, has been identified as a potential **financier** for these initiatives. This potential arises because household efforts to reduce peak loads can defer or eliminate the need for costly investments in transformers and help prevent power outages, thereby saving money for Liander. Furthermore, Liander gains access to valuable data collected from households. However, immediate funding from Liander may not be available, prompting Resourcefully to negotiate and present a solid business case that positions Liander as a financier. In the meantime, securing other sources of funding, such as subsidies and municipal support, will be crucial for successfully launching these initiatives.

To wrap up, the entire energy community has been thoroughly investigated, leading to the identification of various success factors and the provision of extensive advice. This project will serve as a solid foundation for the development of additional energy communities and facilitate more in-depth research in this field.

Content

List of figures

List of Tables

List of diagrams

Abbreviations

Abbreviation	Definition
EMS	Energy management system
DSO	Distribution system operator
CPO	Charge point operator
EV	Electric vehicle
MSR	Transformer
Transformer	Low voltage substation
CLD	Causal loop diagram

1 Introduction

By 2050, the European Union (EU) aims to achieve climate neutrality. This ambitious goal demands significant efforts, with urban areas playing an important role in this endeavour. Urban regions are major energy consumers, utilizing about 64% of available primary energy and generating approximately 70% of greenhouse gas emissions (IEA, 2016). This high level of consumption and emission is largely due to energy use in lighting, heating, cooling, and transportation. As cities continue to grow and their economies expand, their impact on energy consumption and emissions is expected to rise even further.

This trend highlights the crucial need for cities to be at the forefront of the global energy transition. To meet this challenge, a substantial shift in urban energy management and usage is necessary. Cities must strive for greater energy efficiency, improve energy security, and contribute to achieving international climate targets. The path towards climate neutrality by 2050 requires comprehensive strategies that address both the supply and demand sides of urban energy systems, making cities central to the global efforts in mitigating climate change and ensuring a sustainable future.

On the supply side, this goal necessitates a significant transition from a dependency on fossil fuels to the adoption of renewable energy sources. The challenge, however, lies in the existing electricity grid's design, which is optimized for consistent and predictable energy sources like fossil fuels, making it unsuitable for this transition. The grid needs to evolve to accommodate the variable and unpredictable nature of renewable energy sources, such as wind and solar power, which are anticipated to become primary energy providers. The intermittency of these sources presents notable challenges due to their reliance on weather conditions, leading to fluctuating energy outputs that challenge the grid's stability and reliability. Addressing these challenges is crucial for ensuring the successful integration of renewable energies into the urban energy mix and advancing towards a sustainable and climate-neutral future.

The trend towards electrification in activities such as cooking and heating, along with the increasing rising adoption of electric vehicles (EVs), has significantly raised electricity demand and peak loads. This transition introduces a complex new layer to energy management. For instance, the common practice of uncontrolled EV charging, where EVs are charged at full power as soon as they connect until fully charged, poses a significant challenge (Soares et al., 2022). This issue becomes particularly acute during peak times, such as mornings when people start their day or evenings when they return from work and begin to cook, resulting in a spike in electricity usage. At these times, there is also a high demand to charge EVs. Given that homes and charging stations are linked to low-voltage (LV) networks, this simultaneous demand can lead to grid congestion. This congestion risk escalates with the increasing number of EVs and the further electrification of neighbourhoods, highlighting the need of developing a more adaptable and intelligent grid system.

These challenges underscore the importance of expanding the grid system and making it more adaptable and intelligent. Such a system would be capable of meeting current needs while being flexible enough to evolve with future technological advancements and consumer trends (Martinot, 2016). Innovative energy storage and management techniques, coupled with improvements in the grid's fluctuation management capabilities, can provide critical solutions. Smart EMS are emerging as a vital element in this transition, facilitating the efficient use of renewable energy sources, reducing fossil fuel dependency, and ensuring a stable and reliable supply of energy.

1.1 Energy community

Expanding the grid system and making it more adaptable and intelligent is crucial, but such a transformation cannot happen overnight due to the high investments and extensive time required. Therefore, it is necessary to focus on what can be done right now. This involves investigating strategies that can relieve the pressure on the electricity network in the short term, utilizing the resources that are currently available. One practical approach is to adjust electricity consumption within residential areas to reduce the occurrence of peak loads. This can be done within energy communities. There are already several examples demonstrating the effectiveness of such programs in reducing peak occurrence in the electricity grid (Honarmand et al., 2021), and they can eventually be widely used in the future.

Imagine it is the year 2030. Neighbourhoods stand as vibrant examples of modern living environments, driven by the vision of a CO2-neutral community. They have a high capacity of solar panels, EVs in every driveway, and smart home technologies that regulate daily activities. However, due to accelerated climate goals and electrification, the transformer station is often pushed to its limits, especially during peak hours when electricity demand exceeds production capacity. The DSO is actively working to expand the electricity network and upgrade the transformer station stations, but due to limited staffing resources, the upgrade of the stations are still on the horizon.

On a chilly winter evening around 6:00 PM, as residents begin heating their homes, preparing dinner, and charging their EVs, the electrical load reaches a critical peak. Despite its robust design and advanced technology, the transformer station cannot cope with the heightened demand, leading to a neighbourhood-wide blackout—a scenario currently rare but expected to become inevitable in the future.

The concept of the energy community visualized in Figure 1 emerges as a potential solution. This initiative activates the neighbourhood's EMS, employing smart algorithms to analyse and prioritize energy consumption based on urgency and efficiency. Residents receive push notifications alerting them that energy demand is nearing the system's capacity. To encourage responsible energy use, they are urged to adopt measures such as delaying the charging of EVs, reducing heating slightly, and turning off high-energy appliances like ovens and dryers. In recognition of their efforts to maintain network stability, residents earn points for reducing their consumption. These points can later be converted into monetary rewards at the year's end, thus avoiding power disruptions and ensuring the network has sufficient capacity for vital services.

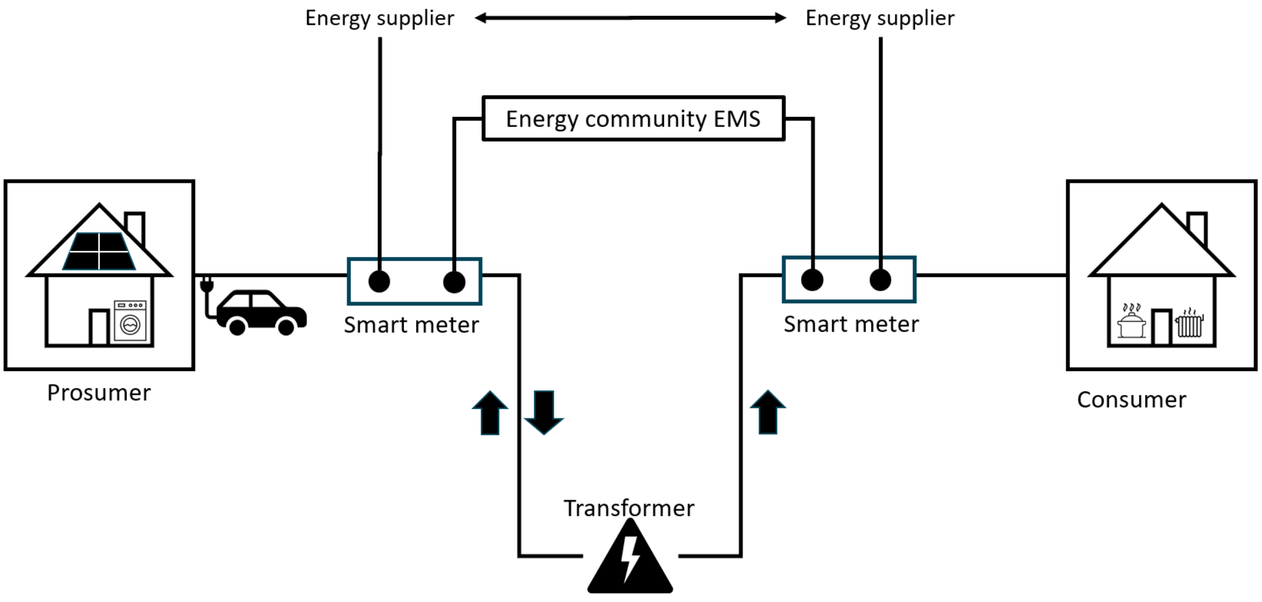


Figure 1: overview energy community

In times of scarcity, the community unites; public EV charging stations switch to slow charging and households adjust their electricity consumption to off-peak periods. This cooperative spirit fosters a sense of solidarity and shared responsibility, crucial for ensuring both the stability of the electrical grid and the uninterrupted availability of power.

1.2 Amsterdam as a case study

This research will focus on residential areas in Amsterdam, exploring the factors that contribute to the success of the energy community. Amsterdam has set an ambitious goal to cut its CO2 emissions by 55% by 2030 from 1990 levels, outpacing the national target by 5% (Gemeente Amsterdam, 2020). The city has unveiled a comprehensive strategy to achieve this objective, emphasizing the electrification of mobility and heating systems, as well as the expansion of solar energy (Gemeente Amsterdam, 2021). A key milestone includes transitioning all buildings to gas-free heating by 2040 and aiming for entirely emission-free mobility by 2030, with significant strides expected by 2025. Projections indicate that by 2050, Amsterdam's electricity demand will increase threefold to fivefold compared to 2022 (Tennet et al., 2022). The electrification initiatives, while crucial for reducing greenhouse gases, present a considerable challenge for Liander, the local grid operator.

In addition to the anticipated rise in electrification, Amsterdam's electricity grid is already at its maximum capacity. With the city's ambitious development plans, this situation is expected to further exacerbate, increasing the pressure on Liander (Tennet et al., 2022). Liander's limited capacity to rapidly implement necessary upgrades means that consumers may face delays in securing enhanced electricity connections. There might also be issues with feeding solar power back into the grid or even experiencing power outages (Bremmer & Zoelen). Therefore, it is important to explore what can be achieved with the current resources. Demand response programs, along with energy collaboration within neighbourhoods, is a viable option. By adopting these strategies, peak loads on the electricity network can be reduced, and the need for immediate upgrades to the electrical infrastructure can be delayed.

This research investigates the technical system where the energy community operates, examines the behaviour of various stakeholders, and identifies the various perspectives of households regarding their participation in the energy community. The community under study is the FlexCity project, where households in the Sporenburg area monitor their energy usage and receive incentives to adjust it during peak times (Reschool, 2023). Seventy households are prompted via an application, where successful adjustments earn them points. These points can be converted into cash at the end of the year. Sporenburg, composed of households, was selected for study because it is one of the few where the transformer is equipped with a smart meter.

Currently, the district experiences no congestion problems. This research project will be conducted as a graduate internship at Resourcefully, a consultant in driving the urban energy transition. Resourcefully is involved in a range of projects aimed at promoting clean electric mobility and increasing the self-use of renewable energy (Resourcefully, 2023).

1.3 Core concepts

This research focuses on demand response programs in energy communities connected to the lower voltage (residential) distribution grid. By first establishing a clear understanding of the study's core concepts, it becomes easier to identify and explore knowledge gaps. Therefore, it will be explained how demand response program's function, the workings of the Dutch electrical grid, and the differences between traditional energy communities and the specific community in this research.

1.3.1 Residential demand response program

A residential demand response program is an initiative designed to encourage individuals living in residential areas to adjust their electricity use during peak load moments (Paul et al., 2018). This strategy is employed by distribution system operators (DSOs) to enhance the stability of the electrical grid, lower energy costs, and diminish the environmental footprint of energy production. The essence of these programs lies in incentivizing households to decrease or shift their energy consumption at critical times, thereby reducing the overall strain on the grid. These programs often incorporate smart technology, such as programmable thermostats and home EMS, which enable users to automate their energy savings. There are two types of demand response programs: incentive-based programs (IBPs) and price-based programs (PBPs). Figure 2 (Avordeh et al., 2021) provides an overview of these programs, along with the various strategies employed within each category.

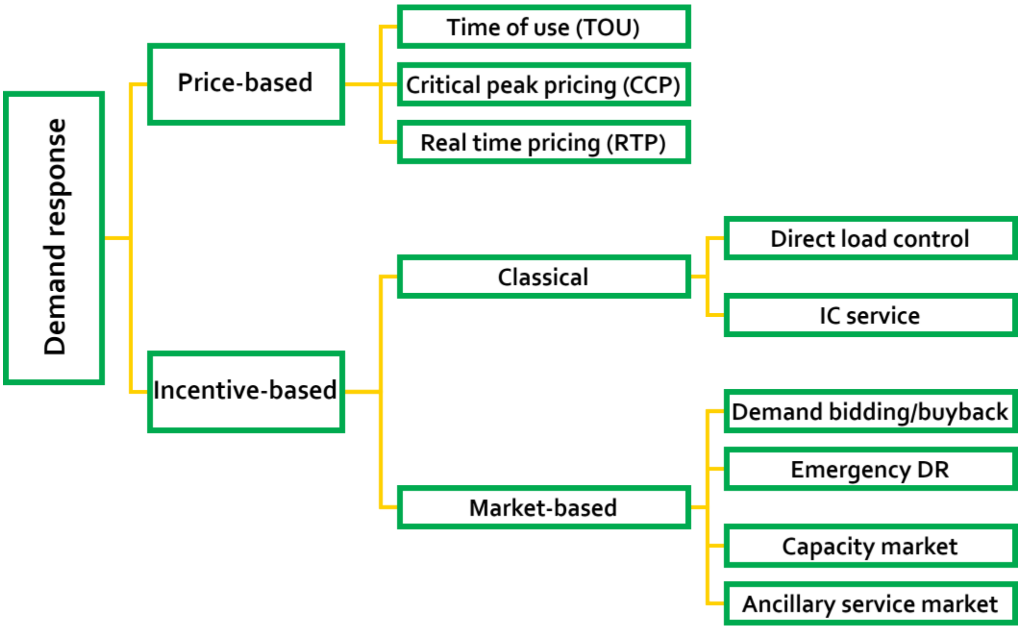


Figure 2: Demand and response overview

IBP reward consumers directly for reducing their energy usage during peak times, offering financial incentives such as cash payments or bill credits. In contrast, PBP adjust the cost of electricity based on demand, encouraging consumers to modify their usage through dynamic pricing models like time-of-use rates, critical peak pricing, or real-time pricing. The main difference lies in the approach: incentive-based programs motivate through direct rewards for specific behaviours, while price-based programs influence consumer behaviour indirectly by making electricity more expensive during high-demand periods and cheaper when demand is lower. Demand response programs maximize individual utility by motivating participants to modify their energy consumption in reaction to price signals, targeting personal cost reductions or financial incentives. This approach encourages individuals to synchronize their energy usage with the requirements of the energy grid, often overlooking the communal or long-term advantages.

The demand response program in this study where households earn points that can be exchanged for money based on reducing their electricity usage during peak times, fits best under the incentive-based demand response category. This type of program directly rewards consumers with financial incentives for their actions, rather than adjusting prices based on the time of use.

1.3.2 Residential distribution grid

In Figure 4 (Gemeente Amsterdam, 2022) the structure of the electricity network within the Netherlands is visualized: Tennet serves as the operator for the high-voltage network, while Liander is responsible for the medium and low-voltage networks in Amsterdam. In addition to these, there are five other network operators in charge of the medium and low-voltage networks throughout the country, as illustrated in Figure 3 (Energievergelijk, 2024). In residential neighbourhoods, connections to the low-voltage network include homes, utilities (like schools, supermarkets, shops, etc.), street lighting, sewage pumps, and public EV charging stations. Available to these connections are either 230 or 400 volts. Historically, 230 volts sufficed as cooking and heating were gas-based. However, with the transition to electric cooking and heating, as well as the introduction of EV charging stations, the need for 400 volts has become apparent.

Figure 3: DSO map

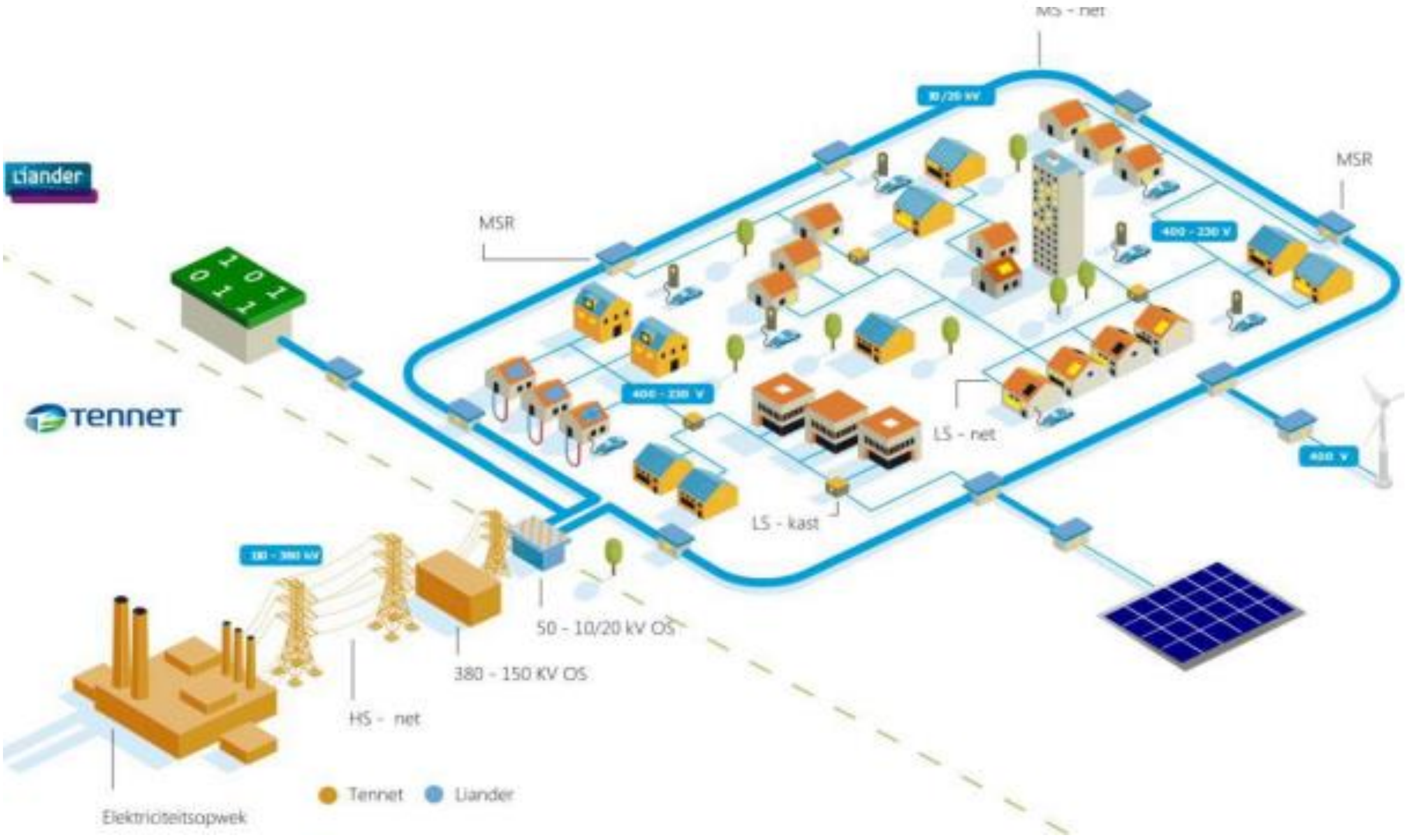


Figure 4: Infrastructure Dutch electrical grid

In neighbourhoods across the Netherlands, homes are connected to a medium voltage substation, known as transformers. A transformer, operated by Liander in the Netherlands, is a pivotal component of the electrical distribution network, playing an essential role in the transformation and distribution of electricity. It receives electricity at medium voltage levels (ranging from 10 kV to 35 kV) from the high-voltage transmission grid and steps it down to a lower voltage suitable for consumption by households, EV chargers, businesses, and industrial facilities (Reschool, 2023).

As previously mentioned, cooking and heating were predominantly powered by gas, and cars operated on fossil fuels. As a result, a 230V connection was sufficient, and peak electricity demand was considerably lower than it is today. This scenario had direct implications for the planning and capacity calculations of DSOs like Liander, who installed transformers based on low-capacity needs, without the necessity to accommodate high peak consumptions. Additionally, installing metering equipment at transformers was uncommon, given the consistent energy supply from gas and coal-fired power plants, and with solar energy still in its nascent stages, there was no pressing need for transformer metering.

However, the contemporary shift towards sustainability marks a significant transition. The move to electrify cooking, heating, and mobility is projected to cause a substantial increase in household electricity consumption. According to Milieu Centraal (2023), sustainability efforts are expected to triple the electricity usage of an average household. Moreover, incorporating the consumption of EVs, as detailed by CBS (2022) and shown in Diagram 1, could potentially quadruple this consumption. These changes demand a comprehensive re-evaluation of transformer capacity and management by DSOs, as peak consumption levels rise markedly, and the energy supply grows increasingly reliant on fluctuating sources like solar and wind energy.

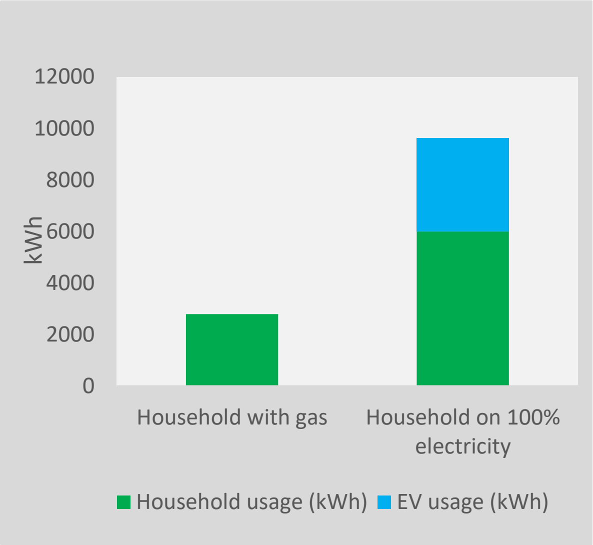


Diagram 1: Electricity usage households per year

1.3.3 Energy communities

Energy communities in general align with broader goals of energy transition and climate change mitigation by promoting the decentralization of energy systems, encouraging the uptake of renewable energy, and empowering citizens to take an active role in the energy landscape. They are supported by various policies and regulatory frameworks at the national and EU level, designed to facilitate their development and integration into the wider energy system (IEA, 2023). The energy community involves various stakeholders, including households, businesses, local authorities, and energy cooperatives.

A form of an energy community that is already widely deployed in the Netherlands is where stakeholders collaborate to invest in, develop, and manage local renewable energy projects, such as solar parks, wind farms, biomass energy systems, or small hydroelectric plants. The primary aim is to create a self-sustaining model of energy production and consumption that is less dependent on the traditional, centralized energy grid and fossil fuels, thereby contributing to carbon reduction and environmental sustainability (Honarmand et al., 2021). Members of the energy community benefit from reduced energy costs, increased energy security, and the potential for generating income through the sale of surplus energy back to the grid. These communities often leverage smart grid technologies and an EMS to optimize energy production and consumption, ensuring that energy is used efficiently and sustainably. Additionally, by fostering a sense of ownership and participation in local energy decisions, energy communities can strengthen local economies, support job creation, and enhance social cohesion.

The key distinction between traditional energy communities and the energy community in this study, centres on the approach to maximizing benefits. Traditional energy communities often focus on maximizing individual benefits, whereas the energy community in this study emphasizes collective benefits. This shift in focus involves collaboration among members to reduce peak loads and share energy resources. The overarching goal is to enhance sustainability, energy autonomy, and economic gains for the entire community.

The goals of the energy community in Sporenburg are to minimize the occurrence of peak load moments and synchronize electricity production with consumption. Achieving these objectives demands significant collaboration from both households and utility owners in the neighbourhood. Furthermore, an advanced EMS is essential, providing a comprehensive view of production, demand, and flexibility. The working of the energy community will be further explained in chapter 3.

1.4 Knowledge gap & research goal

The literature review, which is partially covered in section 1.3 and further detailed in appendix A Literature review, provides a comprehensive overview of existing work on residential demand response programs within energy communities. It elaborates on their value, various types, and the effects of coordinated approaches. Despite the extensive knowledge available, there remains a noticeable gap in academic research. Consequently, this study aims to address:

- **The role of various stakeholders:** While existing studies have primarily focused on demand response programs and the role of households, this research will broaden the analysis to include other stakeholders such a DSO and a municipality

- **Consumer participation factors:** Prior studies have focused on economic incentives or utilized simulations and assumptions. This research, however, will delve into factors influencing consumer participation, including the psychological aspects of consumer behaviour towards demand response. This focus is supported by the suggestions of Mohd Zahid & Aki (2024) and Sridhar et al. (2022) to investigate incentives more deeply.

- **Case study of Amsterdam:** This study will specifically leverage data from Amsterdam, examining demand response programs in the context of a complex urban environment. Amsterdam serves as a relevant case study due to its progressive strides towards a sustainable city and the goal of achieving climate-neutral transportation by 2030.

These gaps in knowledge lead to the formulation of the following research question:

What are the factors, categorized into distinct groups, that contribute to the success of the energy community?

1.5 Sub research questions

The main research question is organized into three distinct sub-questions. The report will tackle these sub-questions one by one, employing an exploratory approach that integrates both qualitative and quantitative data. Each sub-question is dedicated to a specific chapter, and through the process of addressing these questions, various types of success factors will be uncovered. The methodology for categorizing these success factors, as well as the overall structure of the research, will be more thoroughly explained in section 1.6.

Chapter 3 Technical system	*What is the current state of the technical system within the Sporenburg neighbourhood's energy community?*
Chapter 4 Organizational system	*What are the interests of the stakeholders involved in the energy community and what actions can they take?*
Chapter 5 Individual perspectives	*What are the varied perspectives of households regarding their participation in the energy community?*

Table 1: Thesis structure

1.6 Research approach

This study conducts a case study of the Sporenburg district in Amsterdam, employing an iterative approach to research. As new information and data become available, the initial analyses conducted at the start are continuously adjusted and improved throughout the research. For this case study, a mixed-methods approach is utilized, integrating both qualitative and quantitative research methods. Qualitative analysis explores the organizational system necessary for the successful establishment and operation of the energy community. Simultaneously, quantitative methods are applied to analyse the technical system and individual perspectives, ensuring a comprehensive understanding of all facets of the community.

As visualized in Table 1 the thesis structure is made up in three chapters where the factors for success are analysed in these different chapters. In Chapter 3, the focus is on analysing the technical system, where technical success factors are identified and explored. The examination continues in Chapter 4 with a study of the organizational system, where organizational success factors are pinpointed and discussed. Building on these insights, Chapter 5 focuses on the individual perspectives of households, discussing these factors within the context of organizational success as well.

The identified technical and organizational success factors are categorized into those that are critical - essential conditions necessary for the community's success - and those that contribute to success but are not essential. Moreover, this research outlines how these factors function within two main systems: the formation of the community and within the community itself. The specifics of these systems and their roles are detailed further in section 3.5.

In each chapter of this study, different methodologies and analyses are employed to help identify success factors. The following section will clearly outline the methodology for each chapter to ensure that they align with their respective objectives.

2 Research methods

In this section, the methodologies used in each part of the study will be explained, along with the reasons for their selection. To illustrate the logical progression of the sub-questions, as well as the methods of information collection, a Research Flow Diagram is presented in Figure 5. This diagram serves as a visual guide to the research design, clearly delineating the chapters of the Master Thesis and their corresponding sub-questions.

Chapter 3 – Technical system

This analysis is done to understand the operational context and identifying technical characteristics that could influence the energy community. Knowing these details is needed for comprehending the system, thereby enabling the determination of necessary technical conditions for success, and ultimately providing informed advice on how to achieve it.

It starts with examining the specific characteristics of the Sporenburg neighbourhood. An important component of this examination is understanding the transformer area, particularly the capacity of the transformer and the capacities of its cables. Additionally, it is important to identify which households, solar panels, charging points, supermarkets, and other entities are connected to the transformer. This awareness facilitates the identification of which assets can impact the transformer station, allowing for a more targeted and effective analysis.

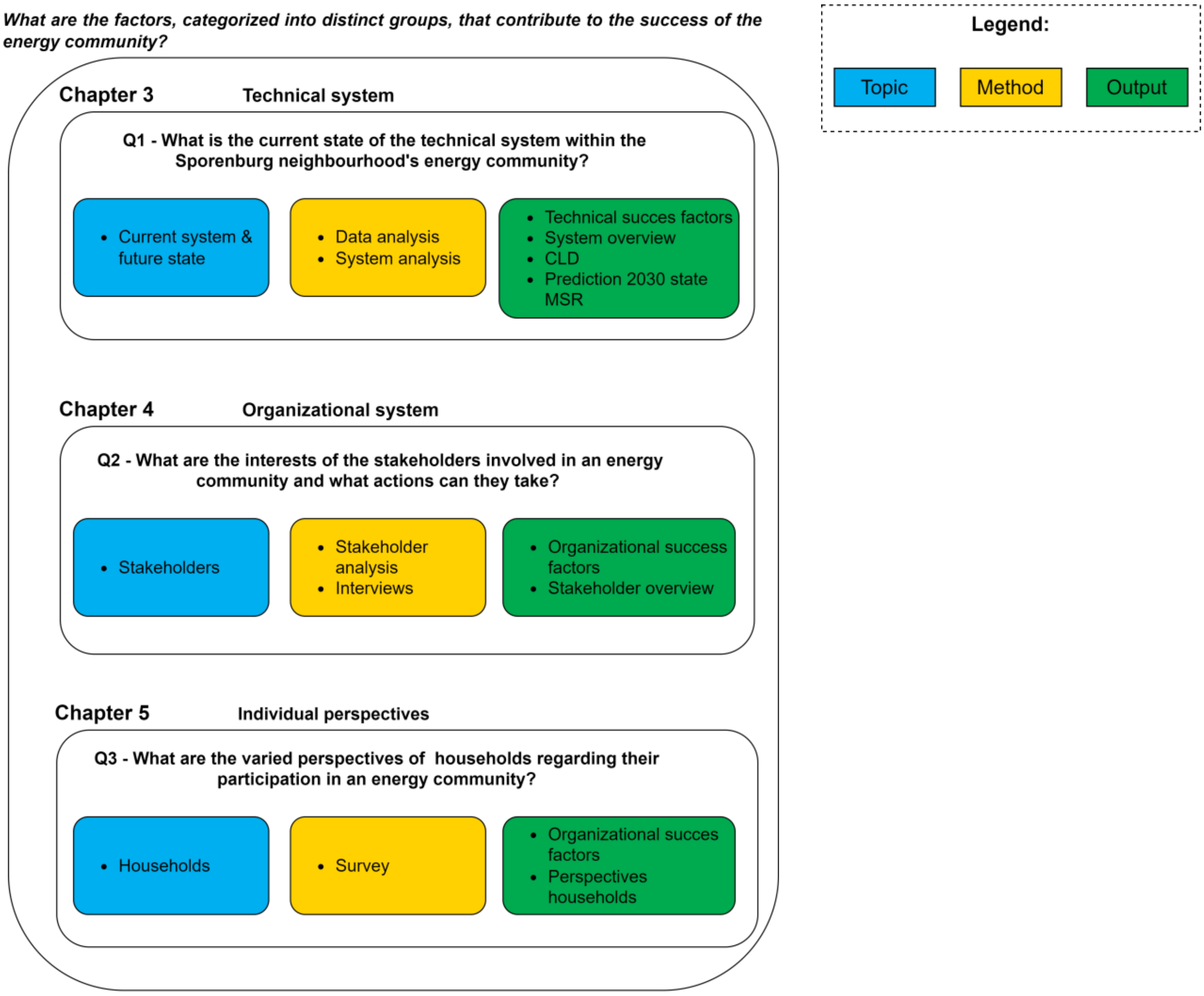
To enhance the comprehension of the operational context of the energy community's system, and specifically how the demand response program operates within this framework, a Unified Modelling Language (UML) analysis is conducted. While UML diagrams are typically used to visually represent the architecture, design, and behaviour of software systems (Torre et al., 2018), in this study, the UML diagram is employed to provide a clearer understanding of the technical system. It enhances the clarity and comprehensibility of interactions among multiple system components and stakeholders and facilitates the detailed representation of information flow and decision-making processes. This analysis sets a fundamental stage for further investigations, such as the causal loop diagram (CLD).

After discussing the system characteristics, it is necessary to explore how various elements such as policy, technology, household behaviour, and environmental factors are interconnected and influence each other. Understanding these dynamics can reveal key leverage points that enhance the community's success. A CLD will be utilized for this analysis (Enserink et al., 2022). The CLD will be instrumental in identifying the success factors of the energy community by visually mapping out the relationships and feedback loops between various system components. Such insights are useful when developing a survey for households, as they guide the inclusion of questions that delve into critical areas revealed by the CLD. These questions can explore attitudes towards the energy community and the factors that motivate household participation, providing deeper insights into the community dynamics.

To gain a deeper understanding of the need for energy communities, it is necessary to determine the state of electricity feed-in within the transformer. The transformer in Sporenburg is among the few that are measured, allowing data to be retrieved. This data is crucial for identifying peak times on the electricity grid and for formulating hypotheses about their causes. Understanding the current state of the transformer is important, but it is also crucial to consider how it might look in 2030, given the increased electricity usage due to higher demand from EVs and the rise in solar power production. Therefore, the projected demand and production for 2030 will be calculated and the Resourcefully energy transition model will be used to simulate different scenarios (Resourcefully model, 2024). Such analyses are vital as it underscores the practical and technical challenges that highlight the need for flexibility within the electricity grid. It connects directly to the operational aspects of the energy system, providing a clear view of both the current state and potential future state of the electricity network.

Chapter 4 – Organizational system

To better understand the organizational structure of the energy community, it is crucial to identify the involved stakeholders, understand their interests, assess their power, and determine the actions they can take. This understanding helps in pinpointing key stakeholders whose interests and actions play a significant role in identifying the necessary conditions for success. To achieve this, a stakeholder analysis will be conducted, involving the identification of stakeholders such as households, energy providers, and DSO, among others. Utilizing a power-interest matrix, this analysis will delve deeper into the dynamics among stakeholders, providing a structured method to assess their levels of influence and interest. Based on this analysis, assumptions about the stakeholders' interests and the potential actions they might take within the energy community will be formulated. Once these assumptions are established, all significant stakeholders will be invited for interviews. These interviews will serve to confirm the previously identified characteristics and to understand the motivations behind their participation in the energy community, as well as the barriers they face. This insight will also be useful in developing the questions for the survey.



Chapter 5 – Individual perspectives

Energy communities present a unique advantage as bottom-up initiatives, emerging from and propelled by the community itself. Yet, this advantage raises a pivotal question: do neighbourhoods possess the necessary willingness to fully embrace such a model? This question touches upon a deeper societal inquiry, are we individualistic, or is there a collective readiness to engage in collaborative efforts aimed at reducing congestion and enhancing sustainability? Understanding the factors that drive active community participation in these grassroots initiatives is crucial. Therefore, a survey will be developed to measure the behaviour of households within the energy community. This survey will be designed using theoretical models to predict behaviour and data sourced from interviews with diverse stakeholders.

3 Technical system

This chapter presents a technical system analysis of the energy community to understand its operational context and identify technical characteristics that influence its functionality. Understanding these details is crucial for determining the technical conditions necessary for the community's success and offering informed recommendations for achieving it. Additionally, it is essential to examine how various factors such as policy, technology, household behaviour, and environmental considerations are interconnected and impact each other. Recognizing these dynamics is key to identifying leverage points that can significantly improve the community's effectiveness. Finally, the necessity and impact of energy communities are further highlighted by assessing the state of electricity feed-in within the transformer. This section evaluates both the current situation and potential future scenarios of the transformer.

3.1 System characteristics

In the Sporenburg neighbourhood, 556 households and 13 houseboats are connected to the transformer station, with no significant load impact from industrial stakeholders or utilities like supermarkets or schools. Each household, on average, consists of 2.6 individuals, with the average disposable income being 70.000 euros and avergae household value amounting to 705.000 euros. (Gemeente Amsterdam, 2024). The households in the neighbourhood have made a significant investment in renewable energy, particularly solar panels, achieving a total production capacity of 465 kWp. The area is serviced by 18 public EV charging stations, and the number of private charging stations is not known. Liander provides a specific capacity of electricity to the public charging points from a Charging Point Operator (CPO). The CPO then determines how to distribute this capacity across their connections. Currently, 70 households participate in the FlexCity program, which offers real-time energy usage monitoring via smart meters. The Open Remote EMS is instrumental in this process, validating electricity data every fifteen minutes and facilitating advanced grid management and forecasting. This system issues challenges during anticipated peak load times as part of a demand response program to optimize energy consumption, a process further explained in 3.1.1. Participation in the energy community of Sporenburg is voluntary, offering households the chance to join and benefit from the additional advantages of the demand response program. Besides this demand response program, energy sharing is being explored, as explained in section 3.1.2. The charactaristics of Sporenburg are illustrated in Figure 6 and the overview of the neighbourhood is visualized in Figure 7.

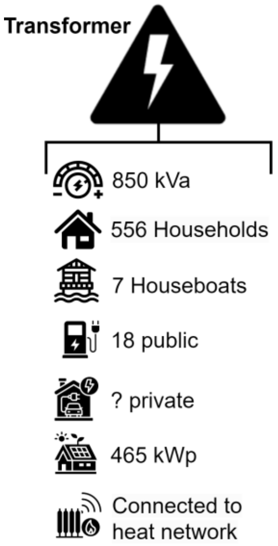


Figure 6: Connected to transformer

Figure 7: Sporenburg neighbourhood

*MSR = Transformer

3.1.1 Demand response

In Sporenburg, a demand response program empowers households to modulate their energy consumption in response to anticipated peak load times, which fluctuate throughout the day. Residents receive up-to-the-minute information regarding peak load moments, enabling them to adjust their energy usage and to reschedule tasks that consume a lot of energy to off-peak hours. An overview of how this program operates within the technical system of Sporenburg must be created to enhance understanding of the system. Understanding the interactions between the EMS, transformer, and households is crucial for determining the necessary conditions for a successful energy community.

To enhance the clarity and comprehensibility of interactions among the transformer, EMS, households, and the energy supplier a Unified Modelling Language (UML) diagram will be utilized. Although UML diagrams are typically used to visually represent the architecture of software systems (Torre et al., 2018), in this context, they will be employed to visualize the interactions within the demand response system. This approach will clarify how the system operates and facilitate a detailed representation of the information flow and decision-making processes. This diagram, along with a visualization of how the application operates, is included in appendix B Demand response.

3.1.2 Energy sharing

In practice, energy sharing is not yet permitted, but households physically share energy through cables: electricity from one neighbour (prosumer) can directly flow to another household (consumer) when produced and consumed simultaneously. However, this sharing isn’t formally accounted for on paper or contractually; this means there is no financial settlement for the simultaneous usage of electricity where prosumers produce, and consumers consume at the same time. Organizations like Energie Samen are lobbying the Dutch government because they view energy sharing is an important factor for more efficient energy usage (Interview, 2024).

Within the FlexCity project, the potential for energy sharing is being examined. In scenarios where a neighbour has excess solar power, they can sell this extra energy to another household also connected to the same transformer. The EMS is designed to forecast energy production and consumption, allowing participants to adjust their energy usage accordingly. This arrangement is financially beneficial for both parties: the selling neighbour can secure a price higher than the standard feed-in tariff offered by energy companies, whereas the purchasing neighbour can buy the energy at a cost lower than the current electricity rates. Ideally, this system would be automated, allowing for excess electricity from one household to automatically charge a neighbour's EV, rather than requiring households to respond manually to notifications on their phones to use extra electricity during periods of overproduction.

Besides that, energy sharing is not permitted yet, the existing 'net metering policy' can complicate the process as well. This regulation allows solar panel owners to deduct the electricity they feed into the grid from their electricity consumption, effectively equalizing the buy and sell prices. A household will only begin sharing energy if its total annual production exceeds its consumption. This arrangement reduces the financial incentive to sell energy directly to neighbours. In 2027, the net metering policy will end, making energy sharing more beneficial (Milieucentraal, 2024). Without the extensive benefits of net metering, solar panel owners might be more motivated to find alternative uses for their surplus energy, such as selling it to neighbours. They could do this more frequently and with greater enthusiasm. Such a shift could promote a more decentralized and community-oriented energy network, enhancing efficient electricity use and sustainability

3.2 Dynamics within the energy community

Now that the technical system is analysed it is necessary to analyse the dynamics within the energy community. Understanding how different elements such as policy, demand response, household behaviour, and environmental factors are interconnected and influence each other. This will support in uncovering key leverage points that can enhance the community's success. A Causal Loop Diagram (CLD) will be utilized for this analysis (Enserink et al., 2022). The CLD will be instrumental in identifying the success factors of the energy community by visually mapping out the relationships and feedback loops between various system components.

3.2.1 Method

The process of developing a CLD starts with a deep understanding of the key structures, processes, and drivers (Ruijgh et al., 2023). Therefore, a socio-technical analysis is conducted to establish this foundational knowledge. This understanding is further enriched by literature research. While the FlexCity project represents a unique case, insights from other energy communities have been examined and are utilized to determine the factors important for successful energy community operations. The results from the socio-technical analysis in combination with factors from the literature research, are presented in appendix C CLD method.

The next step is to write out the equations of the CLD. It provides a quantitative foundation to the qualitative insights derived from the diagram. This process enables the precise modelling of relationships between variables, facilitating simulations and predictive analysis. By converting the visual relationships into mathematical equations, the impact of changes in one variable on others can be systematically evaluated, enhancing the robustness and accuracy of the analysis. Consequently, the dynamics of the modelled system can be better understood, and "what if" scenarios can be simulated (Crielaard et al., 2022).

Finally, by systematically connecting the factors the CLD is created and visualised in figure 15. The diagram not only improves understanding of the current system but also simulates the potential impacts of changes within the community. It shapes the energy community and identifies key leverage points, enabling stakeholders to visualize outcomes and make informed decisions. The impacts of various actions and policies can be determined, helping align the efforts of different stakeholders towards shared goals of energy efficiency and reducing the peak loads. The equations and a detailed explanation of how the CLD works, can be found in appendix D Causal loop diagram.

3.2.2 Results

In Figure 8 the CLD is visualized If energy sharing were to be formalized on paper, it would significantly impact the system. Therefore, this mechanism is highlighted with red lines in to indicate that it is an important yet unimplemented aspect of the system.

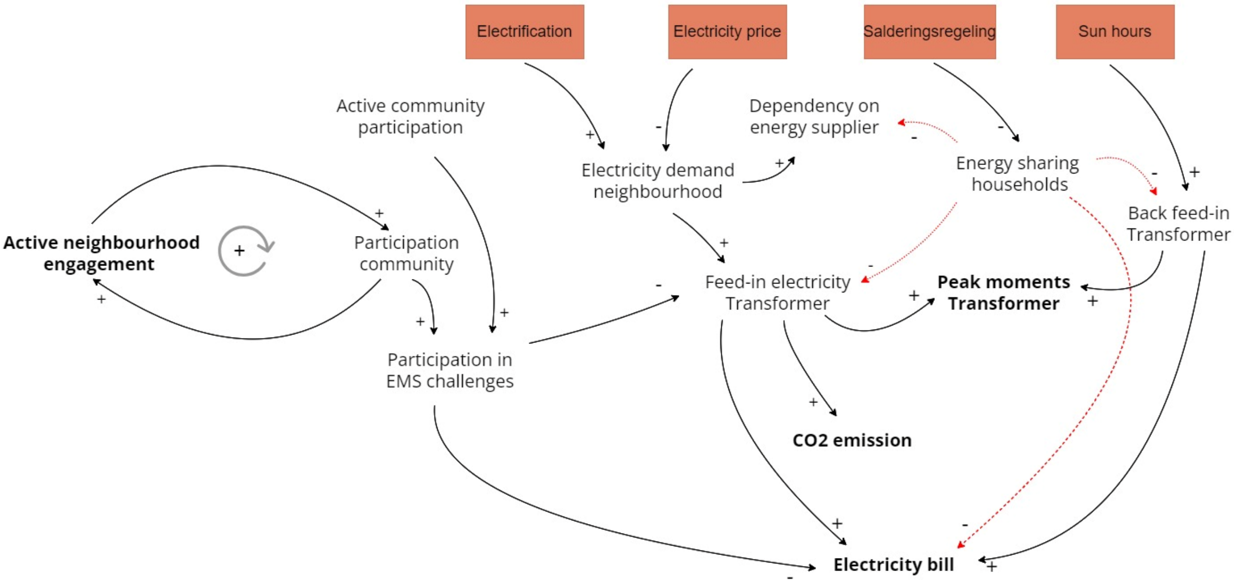


Figure 8: Causal loop diagram

The CLD reveals how different variables influence the performance indicators within the energy community.

The first observation is that both active neighbourhood engagement and active community participation are key factors in direct or indirectly increasing the participation in challenges and reducing peak load moments in the transformer. This means that these factors are essential for success of the community.

Performance indicators
Peak moments transformer
Electricity bill
Active neighbourhood engagement
CO2 emission

Table 2: Performance indicators CLD

Active community participation refers to the households that have joined the community and actively engage in various challenges as they arise. The decision to participate actively is influenced by several factors, such as the cost of the electricity bill, CO2 emissions, the occurrence of electricity peaks, the enjoyment derived from participating in experiments, and a desire to enhance neighbourhood engagement. While these motivating factors are not visualized in Figure 8, their impact on participation is significant.

Active neighbourhood engagement is the first phase of joining the community, indicating a positive attitude towards participation. As more households join and install the necessary equipment, the community gains greater recognition, which in turn encourages further engagement and participation. This results in a positive feedback loop.

Electrification, defined as the increased adoption of electric products and technologies such as EVs, heat pumps, and electric cooking appliances, significantly impacts household electricity demand. As illustrated in Diagram 1, EVs, electric cooking, and heat pumps contribute to this increased demand. Additionally, the amount of sunlight hours or seasonal weather patterns influences the back feed. Consequently, critical peak load moments that depend on feed-in are more likely to occur during the winter months, whereas peaks that depend on back feed tend to occur in the summer.

Energy sharing emerges as a crucial leverage point with significant implications. This practice not only reduces electricity bills for consumers but also decreases the amount of electricity fed back into the transformer station, leading to fewer peak moments in the transformer. Additionally, energy sharing reduces dependency on traditional energy suppliers, which poses a disadvantage for these suppliers since their revenue model primarily relies on trading energy. Consequently, it is unlikely that traditional energy suppliers will support a system that diminishes their role and affects their profits.

Some dynamics are not visualized in the CLD. The production from solar panels and the simultaneous consumption of the households with solar panels are not visualized. In the end it is calculated what the overproduction is from these solar panels. This means the electricity production from solar panels after own prosumers consumption and after sharing is the electricity back feed-in. For a detailed explanation of the CLD, appendix D Causal loop diagram should be consulted.

3.3 Current situation transformer

The transformer station situated in the Sporenburg neighbourhood is one of the nine stations monitored by Liander. The data collected allows to determine the amount of electricity delivered or returned every 5 minutes by entities connected to the transformer. This data is averaged over one-hour periods to provide a clearer view of energy usage and return patterns. Figure 9 visualizes a day where the highest peak load is recorded from February 2022 to August 2022. The maximum capacity is 850 kW and calculated in appendix E future situation. The peak at 18:00 can be seen as a day like December 19th, when the sun sets at 17:00 and solar power production is negligible. The peak occurs when most people return home and begin cooking and charging their EV's. The critical zone is defined at 850 kW, which implies that, with a demand peak of 460 kW from households, a maximum of 35 charging stations, each with an 11 kW capacity, can be used simultaneously without exceeding the maximum capacity. This number is relatively low considering that by 2030, all cars in Amsterdam must be emission-free. Currently, there are 366 cars in the Sporenburg transformer area, highlighting a potential capacity challenge as the transition progresses.

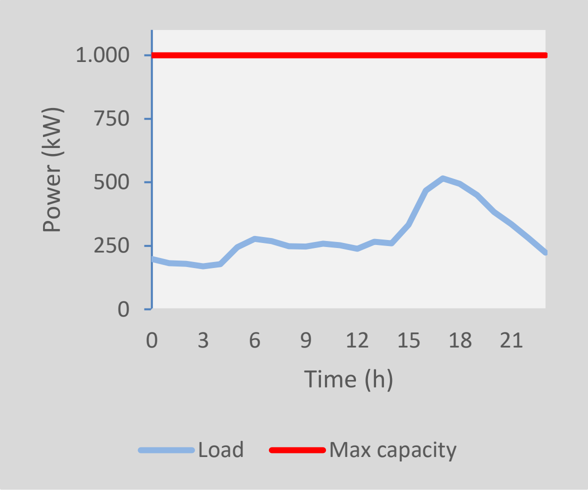


Figure 9: Max load electricity demand 2022

3.4 Future situation transformer

While not directly related to the primary research question, understanding the future state of the transformer station is important for the success of the community. This knowledge aids in developing strategies within the community and plays a vital role in shaping the community by providing Sporenburg with a realistic view of their neighbourhood. It also helps envision what the area could look like in 2030 under various scenarios. This clarity can significantly motivate households to participate, as the purpose of their involvement currently appears vague to them.

In 3.3 a quick calculation is made to determine how many charging station can be used simultaneously, but this has not considered the charging behaviour of households. To visualize what the situation in Sporenburg might look like by 2030, the model developed by Resourcefully can be utilized. This model is designed to predict the transformer profile, incorporating assumptions about household energy consumption, solar production, and the electricity demand of EVs. It includes charging profiles for both cars and households and will be used to simulate various scenarios. These simulations will provide insights into how different patterns of energy use and production affect the overall electricity demand in the area.

In these simulations, the focus is solely on the capacity of the transformer. Expert consultations have confirmed that the cables in Sporenburg are currently under capacity and are unlikely to face issues in the near future (Interview, 2024). Consequently, these simulations exclusively examine the load on the transformer and do not consider the load on the residential area’s cables.

The detailed calculations of the assumptions are presented in appendix E future situation. These calculations consider the unique characteristics of the neighbourhood as well as the goals set by the government and the municipality of Amsterdam. Given the ambitious targets for car electrification and solar panel installation, various scenarios have been developed. These scenarios estimate outcomes where the objectives are either 50% achieved or fully met by 100%. As a result, four scenarios for 2030 have been outlined, alongside one control scenario that depicts the expected state in 2023, all visualized in Table 3

Scenario		**Variable**	**2023**	**Unit**
0		Solar capacity	394.000	kWh
		Electricity demand EV	106.091	kWh
		Variable	**2030**	**Unit**
1	100% EV & 100% solar	Solar capacity	1.360.850	kWh
		Electricity demand EV	680.610	kWh
2	50% EV & 100% solar	Solar capacity	1.360.850	kWh
		Electricity demand EV	340.305	kWh
3	100% EV & 50% solar	Solar capacity	680.000	kWh
		Electricity demand EV	680.610	kWh
4	50% EV & 50% solar	Solar capacity	680.000	kWh
		Electricity demand EV	340.305	kWh

Table 3: Scenario's

Figure 10 illustrates the net grid interaction from a peak day for different scenarios throughout the year. The maximum capacity of the transformer station is marked with a red line. The data collected allows to determine the amount of electricity delivered or returned every 15 minutes by entities connected to the transformer. No hourly averages are calculated. A peak day could occur on dates like December 19th, when solar power generation is low and electricity demand for cooking and EVs is high. In Scenario 3, the demand exceeds the transformer's limit, and in Scenario 4, it approaches its maximum capacity, indicating potential future issues with the transformer station. This underscores the need for solutions such as energy communities, which help reduce peak loads and alleviate stress on the grid infrastructure.

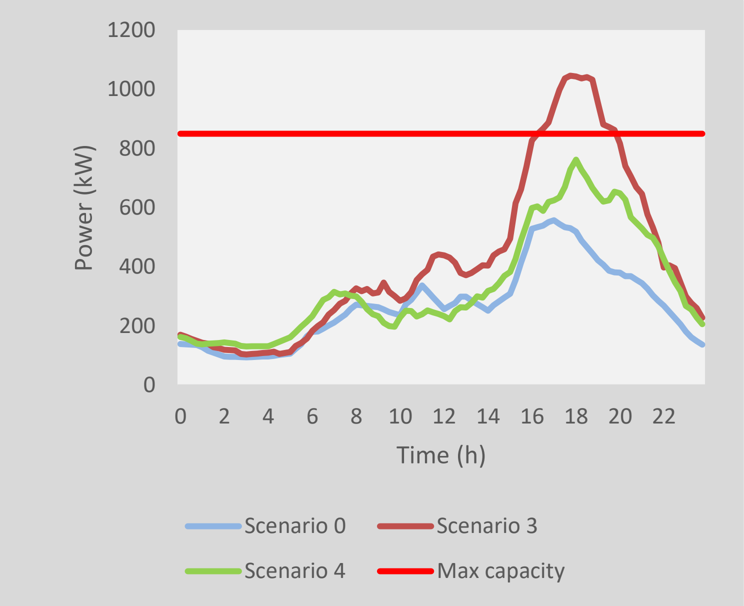


Figure 10: Scenarios electricity peak

Figure 11 shows a day in June when the maximum amount of electricity that can be back feed into the grid from solar production is reached. The line shown represents the net grid interaction and it indicates that the maximum capacity is exceeded. However, such a scenario is unlikely to occur in practice because the transformers in solar panels are engineered to automatically shut off if the network voltage becomes too high. Despite these precautions, real-world exceptions do occur, as evidenced by the situation in Biddinghuizen, where households often experience power outages due to peaks in solar panel power (Omroep Flevoland in 2024)

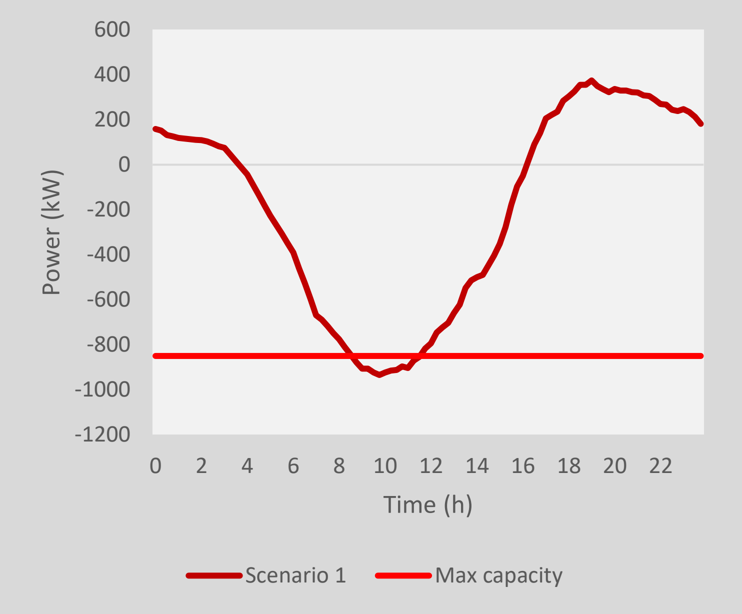


Figure 11: Max electricity back feed in

3.5 Technical success factors

In the research approach outlined, it is proposed that after each chapter, it will be concluded which conditions are critical or non-critical for the success of the energy community. Before delving into these conditions their respective categories will be analysed.

Categories

A socio-technical analysis is an approach used to understand complex systems by emphasizing the interdependent relationship between social and technological elements. This concept, which originated from workplace efficiency and human factors research in the mid-20th century, has evolved to encompass modern systems that integrate human, processual, and technological dimensions. The theory advocates that for a system to achieve optimal effectiveness and sustainability - both its social components, such as people, culture, policies, and organizational structures - and its technological components - including tools, machinery, software, and operational processes- must be designed and harmonized to work in concert (Ruijgh et al., 2023). The premise is that the best outcomes are realized when the system's social and technical elements are considered cohesively. Therefore, a distinction between two types of success factors will be made: technical, which includes the technical components, and organizational, which encompasses the social and organizational components.

Besides the socio-technical analysis, this research evaluates two distinct systems within the realm of energy communities. The first system focuses on the operational aspects of the energy community, which aims to address high peak load moments at the transformer station by striving to balance electricity consumption. The second system pertains to the foundational elements of the energy community, where stakeholders are engaged in crafting the rules and structure of the community. Key figures in this process include Resourcefully, the company spearheading the project, and Jasper from Kantelingen, who specializes in developing energy communities. These stakeholders are instrumental in forming the energy community, but their capacity to directly influence peak load management at the transformer station is limited. The primary focus of the analysis is on the operational aspects of the community. However, the study will provide insights and recommendations for both systems in the stakeholder analysis and the conclusion.

The factors influencing the energy community are categorized into critical and non-critical. Critical factors are essential for the community's existence; without them, the energy community cannot sustain itself and would fail. On the other hand, non-critical factors are those that contribute to the success and thriving of the energy community.

Factors

Technical	Prioritization
Households have smart meters installed	Critical
Households have application installed	Critical
Liander has installed smart meter on the transformer	Critical
A sufficient amount of EVs in the neighbourhood	Critical
EMS system must be developed	Critical
Data availability	Critical
Demand response program must be developed	Critical
Enough solar panels in the neighbourhood	Non-critical
Cybersecurity measures	Non-critical
Households use heat pumps or other electric heating solutions	Non-critical
Households use electric cooking	Non-critical
Cybersecurity measures	Non-critical
Scalable system	Non-critical

Table 4: Succes factors technical analysis

4 Organizational

To identify the organizational success factors of the energy community, it is crucial to understand who the key stakeholders are. Their involvement in the project is essential; without their active participation, the community is unlikely to succeed. The interests and actions of these stakeholders play a decisive role in determining the conditions that can positively influence the community. As such, conducting a stakeholder analysis becomes a fundamental step. This analysis assists in mapping out the roles of individuals, organizations, and institutions, determining how their interests align with or conflict with the goals of the community. By identifying these dynamics, Resourcefully can engage more effectively with each stakeholder, fostering cooperation and mitigating conflicts.

First, a formal map analysis will be conducted to identify the relationships and roles of the various stakeholders involved, providing a clear overview of their interconnections and responsibilities. This will form the basis for the power interest grid that delves deeper into the individual characteristics, influences, and dynamics of each stakeholder. Subsequently, the results of interviews conducted with the key stakeholders will be analysed.

4.1 Formal map

A formal map helps by systematically outlining the structured relationships and roles within the stakeholder network. This is useful in the complex environment of the energy community where multiple stakeholders interact, as it helps in understanding how each stakeholder fits into the overall system and how they influence one another. This mapping begins by identifying and documenting formal institutions and their relations, which are typically easier to delineate through available documentation such as organizational charts, laws, and regulatory frameworks. It helps to clarify roles, responsibilities, and hierarchical relationships that dictate how decisions are made and how power is distributed among various stakeholders such as government bodies, energy providers, and community members. This is particularly important in energy communities where the interplay between public policy, business interests, and active community participation shapes the effectiveness and sustainability of energy initiatives. The formal map, visualized in Figure 12, will form the basis for the power interest grid.

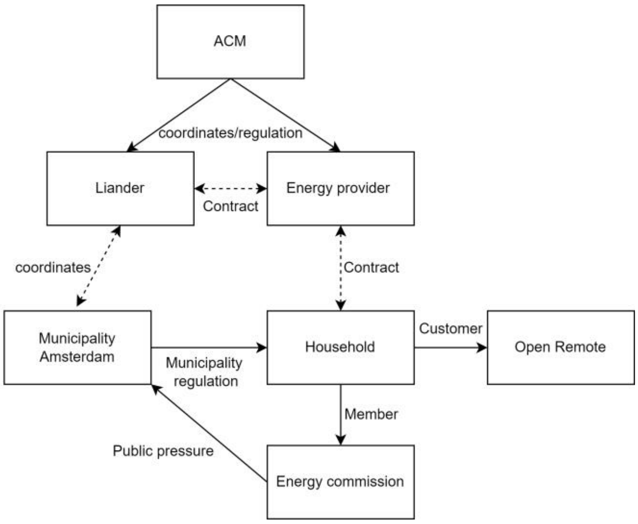


Figure 12: Formal map

4.2 Power interest grid

An exploration was initiated to uncover the pivotal stakeholders within the energy community, employing a stakeholder scan. The findings are illustrated in a power-interest grid which categorizes stakeholders along two critical dimensions: their level of interest in the organization’s operations and their ability to impact its outcomes.

4.2.1 Method

The matrix divides stakeholders into four quadrants, each representing a distinct stakeholder category. Stakeholders with high power and high interest are considered key players whose engagement is critical for the project’s success. These stakeholders require close management and frequent communication to ensure their ongoing support and involvement. Conversely, stakeholders with high power but low interest possess the ability to influence the organization yet are not deeply engaged in its day-to-day operations. The strategy for this group involves keeping them satisfied and adequately informed to garner their support, when necessary, without overwhelming them with excessive information.

In contrast, stakeholders with low power but high interest, despite their limited ability to influence organizational outcomes, exhibit a keen interest in the organization’s activities. Engaging this group through regular communication can turn them into valuable allies, especially in public relations and active community participation efforts. Lastly, stakeholders categorized as having low power and low interest have minimal influence and engagement with the organization. Monitoring and passive communication are often sufficient for this group, aiming to prevent potential issues due to lack of awareness.

Households in the energy community can be divided into 2 types and can have different characteristics. The one who joined the community and the one who didn’t join the community. In this analysis only the households who joined are taken into consideration. Households can have different characteristics and influence on the community. Characteristics like having solar panels, an EV or a variable or fixed energy contract can have influence on the energy community. In the power and interest grid the households are assembled as one stakeholder.

The initial power interest grid analysis, which is only about the operational system, is presented in appendix F Power interest grid. It is developed through assumptions, a literature review and two interviews with Jasper Klapwijk of Kantelingen and David Plomp of Resourcefully. Once these assumptions were established, all significant stakeholders were invited for interviews to confirm these characteristics and to understand their motivations for joining the energy community, as well as the barriers they face. The results of the interviews are detailed in Section 4.3, and the power-interest grids, updated based on these interviews, are visualized in the following section.

4.2.2 Results

As previously discussed in 3.5, there are two distinct phases within the energy community. After the interviews were conducted, two power interest grids are developed. The formation phase is represented by Figure 13, and the operational phase is visualized in Figure 14. It is important to note that there is a thin line between these two systems. Factors that are crucial for forming the community may also remain significant when the community is up and running, indicating an overlap in the needs and strategies across both phases. Therefore, in further analysis of the interviews the stakeholders will not be analysed in 2 different systems and there will be just one general analysis. Later, in the conclusion the success factors are categorized into these two systems.

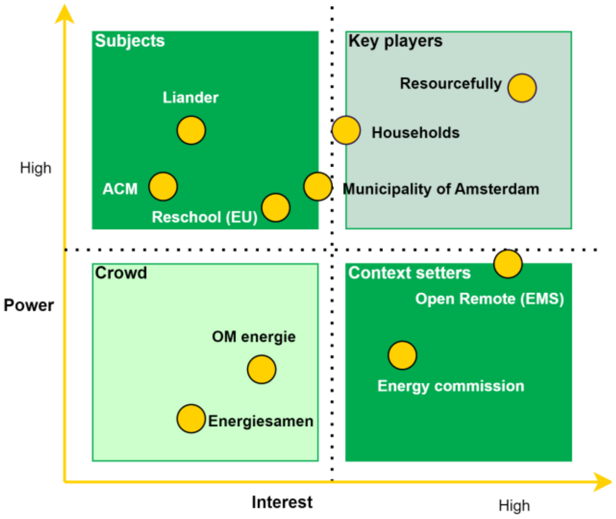


Figure 13: Formation phase

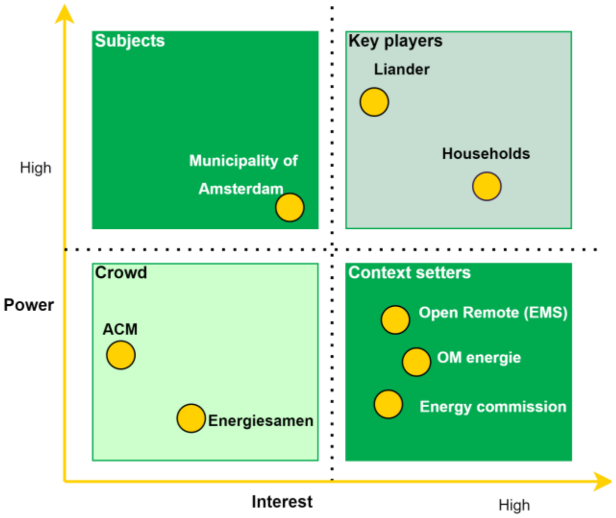


Figure 14: Operational phase

From the power-interest grid analysis, Households, Liander, and the Municipality of Amsterdam are the key stakeholders to consider in the energy community. Therefore, they will be further analysed in 4.4 using the information retrieved from the interviews.

4.3 Interviews

For the interviews, all stakeholders from the power-interest grid, except Reschool and the ACM, were invited to discuss their interests and potential actions. Understanding the interests and actions of these stakeholders is crucial in determining the conditions that can positively influence the community.

4.3.1 Method

For the expert interviews, a semi-structured interviewing approach was chosen. This method facilitates a guided conversation while also allowing the interviewee to elaborate extensively on certain topics or even introduce entirely new subjects, potentially leading to unexpected insights that had not initially been considered. For the start of the interview, it is essential to understand the backgrounds of the interviewees and the departments they represent. For instance, in the case of Liander and the Municipality of Amsterdam, various departments with differing interests could influence their responses. The department of EV charging is more likely to have interest in the EV charging capacity and infrastructure. The stakeholders identified in Figure 13 as ‘key players’ are the primary focus for these interviews and therefore more persons of that organizations are interviewed.

In advance, it was anticipated that contacting everyone for interviews would not be straightforward, especially in the case of Liander. Securing an interview with Liander proved particularly challenging and time-consuming. However, This issue was and thus scheduled these interviews well in advance. The event called Hieropgewekt proved to be particularly helpful, where successfully arranged an interview with Liander was arranged. During the interview, the contact from Liander referred me to two other individuals within the company. Thanks to Resourcefully’s extensive network, contacting and organizing interviews with other stakeholders was comparatively straightforward.

In total, 13 interviews were conducted with 14 individuals from 7 different stakeholders. Interviews were conducted with Liander, households, the Municipality of Amsterdam, Energie Samen, cooperation the Energy Commission, Open Remote, and OM Energie. To make the project more comprehensible, a specific stakeholder slide deck was created for each participant, accommodating for their varying levels of project knowledge. Assumptions about their interests and possible actions they could take were explored during these interviews. When responses from the stakeholders did not yield new insights and merely echoed the pre-assumed viewpoints, They were presented different scenarios to gauge their agreement or disagreement. Additionally, examples were included alongside the questions to clarify what was being asked, which proved useful in eliciting more than just general responses. Potential barriers and success factors were also discussed. The questions were drafted in a general format but were tailored specifically for each stakeholder with relevant examples. This approach is detailed and visualized in appendix G Interview questions. For every stakeholder there were also stakeholder specific questions, but they are not shown in this table. The most important factors that came out of the interviews are visualized in Table 5.

4.3.2 Results

In Table 5, key factors derived from the interviews are visualized, highlighting the main themes. These themes will be used in developing the survey and in identifying and prioritizing success factors. It is important to note that the main themes were not explicitly asked about, if a factor does not have a checkmark next to a stakeholder's name, it does not necessarily mean they do not find it important. The comprehensive analysis of the stakeholders and the interview results are illustrated in H Stakeholder analysis.

Actor	Organisational structure	Motivational incentive	Transparancy of information	Ease of use	Reliability on the system	Awareness	Commitment
Liander 1	x				x		x
Liander 2	x	x			x		
Municipality Amsterdam 1		x	x		x		x
Municipality Amsterdam 2	x	x			x		
Household 1	x	x		x	x	x	
Household 2	x	x					x
Household 3	x	x	x				x
Household 4		x		x	x	x	
Open Remote		x	x				
Energy Commission		x				x	
Energie Samen			x	x	x		
OM Energie	x	x	x				

Table 5: Interview results

Energie Samen pointed out that automating the adjustment of energy usage could lead to greater participation in challenges, as this would simplify the process and make it more user-friendly. Additionally, the reliability and commitment were underscored by stakeholders such as Liander, the municipality, and Energie Samen. It is essential for all major stakeholders to engage fully with the community, establish strict agreements, and adhere to these rules diligently. For instance, it is crucial to have clear protocols in place for scenarios where systems do not function as planned. One solution, as proposed by Open Remote, is to calculate potential issues in advance and limit the number of households participating in challenges. These measures are crucial to ensuring reliability and avoiding unnecessary costs, thereby fostering a trustworthy and effective community.

Open Remote emphasized the importance of having a clear business case for every stakeholder involved in the energy community. They highlighted that for a project to be scalable and appealing, it must offer tangible benefits that make participation worthwhile for all parties. If a solid business case is established, stakeholders will be more committed, and there is a greater potential for the communities to expand effectively.

OM Energie stressed the need for transparency concerning grid data and network congestion. They advocate for increased involvement of grid operators, which would enhance understanding of local grid dynamics and pinpoint congestion issues. This knowledge is important for distributing energy efficiently and allows other stakeholders to provide more targeted and effective support. Moreover, the Energy Commission mentioned increased awareness of the FlexCity project. They noted that many people are still unaware of the project, signalling a need to enhance visibility and understanding among the community.

4.4 Key stakeholders’ analyses

From the power-interest grid analysis, Households, Liander, and the Municipality of Amsterdam are the key stakeholders to consider in the energy community. Therefore, they will be further analysed in this section

Households

Households play a crucial role within energy communities, with the potential to significantly impact the peak load moments from the transformer. Key actions that households can undertake include installing renewable energy solutions such as solar panels and battery storage, investing in EVs, and adjusting their electricity consumption patterns. Their primary interests lie in reducing energy costs and minimizing their carbon footprint, while also enhancing the sense of community within their neighbourhood. Additionally, households show a keen interest in participating in experimental projects within the energy community.

The interviews provided deeper insights into the interests and potential actions that households can undertake within the energy community, as well as the barriers to participation. It was underscored that commitment from the neighbourhood is crucial for organizing the community. Currently, Resourcefully is taking a leading role in organizing the events and setting up the board. However, in the future, this responsibility should be taken on by the residents themselves. Volunteers, primarily elderly individuals, are essential for leading and motivating households to join, as younger members often have familial and career commitments that limit their involvement.

The discussions also highlighted the importance of sustained engagement in community activities for households that join. The systems they interact with need to be user-friendly to maintain initial enthusiasm for new experiments and ideas. There is also a significant focus on the need for systems that enable easy adjustments to energy consumption. While households currently manually reduce their usage in response to challenges, there is a consensus on the benefits of automating this process through a simple action in an application.

Moreover, for the community to be attractive and retain participants, a compelling business case offering clear, tangible benefits is essential. These benefits should include measurable reductions in peak electricity loads, decreases in CO2 emissions, and direct financial savings, clearly demonstrating the value of joining and staying active within the community to all members.

Lastly, while households recognize their responsible role in managing the electricity grid, there is disappointment that Liander, the DSO, is not involved in the project yet. Participants believe that the DSO’s involvement would significantly boost the project’s effectiveness. They recognize that the challenges of peak loads are not only a concern for the households but also for Liander, who is responsible for maintaining the electricity grid that households pay to use.

The decisions households make about participating in the energy community and changing their consumption behaviours reflect a balance between the effort involved and various motivations such as economic considerations, environmental values, and social values.

Liander

Liander serves as the exclusive electricity network operator in Amsterdam, tasked with maintaining and developing the city's electrical grid. The organization holds the authority to upgrade the transformer to enhance its capacity, potentially reducing the need for grid flexibility. Liander is also responsible for approving new connections, including those for households and EV charging points. They have the capability to monitor the transformer station and gather data on the electricity network, which supports the implementation of smart grid technologies. The primary goal of Liander is to ensure the stability and reliability of the grid, a commitment that is contractually guaranteed to their customers. Failure to meet these obligations can result in financial penalties. Additionally, Liander aims to expand the grid to ensure equitable access to grid resources for all users, ranging from residential neighbourhoods to businesses and charging stations. In this expansion, they have the opportunity to prioritize connections that offer the greatest societal benefit, aligning with broader environmental and community goals.

The interviews provided deeper insights into the activities of Liander and outlined potential actions they can take regarding the formation of energy communities. Currently, Liander is exploring a demand response program that encourages households to adjust their energy usage during peak times through variable rate pricing. One potential approach involves a time-of-use tariff that accounts for network congestion. However, implementing such programs poses challenges because households are not direct customers of Liander. Instead, the costs to use the electricity network are calculated and collected via energy suppliers, creating an intermediary layer between Liander and the households. This arrangement complicates Liander's ability to directly influence household behaviour. Moreover, managing demand is crucial not only during peak times but also in neighbourhoods where solar production can cause grid congestion. To address this, Liander might incentivize behaviours such as encouraging EV owners to charge their cars during off-peak hours, specifically between 12 PM and 6 PM on sunny days. This strategy ensures that electricity is used directly and helps prevent overloading the transformer station.

Liander is also conducting research into stakeholder management to determine its appropriate role in initiatives such as energy communities. A challenge they face is the substantial costs associated with allocating manpower to support all energy community initiatives. There is uncertainty whether the benefits derived from these initiatives will be sufficient to offset these costs.

Lastly, Liander recognizes the necessity for efficient use of their electricity network and has incorporated flexibility into their operations. While households typically enjoy the contractual freedom to utilize their full capacity at any time, problems arise when multiple households in a neighbourhood simultaneously draw on their maximum capacity, potentially leading to grid congestion. To prevent such scenarios, Liander actively employs data analytics to calculate and predict the capacity for new connections and to identify potential congestion points across the grid. This proactive approach allows them to anticipate and address issues before they escalate.

To further enhance grid management, Liander is also exploring innovative contract terms for new connections. They are considering agreements that would limit a customer to using only 20% of their capacity during a few critical times of the year. This measure is designed to mitigate congestion during peak periods. Importantly, this limitation would only apply for a few moments each year, ensuring that outside of these times, consumers can use electricity as usual. Through these strategies, Liander not only aims to manage the electricity grid more effectively but also ensures that consumers maintain access to the energy they need, when they need it, with minimal restrictions.

Liander focuses on strategic operational and development decisions that ensure the grid remains accessible for new connections and can accommodate renewable energy sources. Simultaneously, they prioritize maintaining the reliability of the electricity grid. This dual focus demands a careful balancing act.

Municipality of Amsterdam

The municipality of Amsterdam can play a significant role in influencing energy communities by organizing events to inform households about the benefits of joining energy communities. They also provide subsidies and advice on energy efficiency projects, such as the installation of EV charging points and solar panels. Additionally, the municipality manages and installs public assets like street lights and public buildings, which are connected to the transformer, with a focus on sustainability, economic growth, and ensuring equitable access to energy. A key aspect of Amsterdam's commitment to sustainability is its ambitious plan to achieve the 2030 climate goals. These goals include initiatives for zero-emission mobility, which necessitate increasing the number of charging points from 10,000 in 2020 to 65,000. Moreover, managing power capacity is important not only to support economic vitality within high-demand sectors - currently, 350 companies are on the waiting list for an electricity network connection (Liander, 2023) - but also to guarantee fair energy distribution

The interviews highlighted that one of the reasons is that Amsterdam actively supports community initiatives is to strengthen the relationship between citizens and the municipality, particularly in response to past strains. The primary goal of these efforts is not just to alleviate net congestion but also to explore how willing households are to adjust their electricity usage. The city can enhance these initiatives with its extensive knowledge and network, including CPOs and energy experts.

Municipal authorities have emphasized that community formation must prioritize safety, ensuring that energy meter data cannot be exploited to determine whether a household is occupied, which could potentially aid thieves. Furthermore, they stress that energy contracts and the willingness of large consumers to participate are important in shaping these communities. For example, a supermarket with a fixed, inexpensive energy contract may lack the incentive to join an energy community. Consider a supermarket covering 1,000 square meters with an energy usage of 463 kWh/m²/year; its consumption could exceed that of 100 households in a year (Save consortium, 2018). This scenario underscores the importance of clear connection architecture to a transformer and identifying who most significantly impacts peak consumption. If key influencers lack incentives and willingness to participate, the adjustments made by households will have a minimal effect on reducing peaks in the electricity grid.

The Amsterdam city municipality can significantly influence the formation of the energy community through its collaboration with Liander. Together, they are planning and developing the electricity grid for 2035 (Gemeente Amsterdam, 2022). Should Amsterdam be satisfied with the project's progress, the municipality might pressure Liander to join if they show reluctance. This scenario illustrates a mutual dependence on each other to participate in the project. The municipality recognizes that such communities will only receive support if they are influential enough and have commitment from key partners like Liander.

The municipality's decisions on policy, supporting energy communities and infrastructure improvements are driven by a desire to harmonize sustainability targets with economic growth and social equity.

4.5 Common pool resource

Within the energy community, stakeholders are integrally involved with the electricity grid, where the transformer station operates as a common pool resource. This resource is freely accessible and shared among users but faces the risk of depletion, leading to collective disadvantages. Looking ahead to 2030 for the Sporenburg area, this scenario could lead to the electricity network becoming overloaded due to behaviour driven primarily by individual benefits. Such circumstances might trigger power outages and create a scarcity of essential connections, such as those required for EV charging stations Insights from common pool resource theory are valuable in this context, offering strategies to effectively manage the transformer station and pinpoint the factors critical for the success of an energy community. By understanding and applying these lessons, stakeholders can devise mechanisms that discourage overuse and promote sustainable management, ensuring the network remains robust and capable of supporting the community's needs.

Ostrom’s (1990) research into common-pool resources (CPRs) and the ‘tragedy of the commons’, first introduced by Hardin (1968), provides essential insights for managing shared resources, such as the transformer station within the energy community. Hardin described a scenario where individuals, motivated by self-interest regarding a freely accessible, shared resource, could deplete it, leading to a collective disadvantage. Hardin suggested that this dilemma could only be averted through stringent regulation or privatization by external authorities.

Ostrom illustrated that communities have the capacity to develop sustainable management strategies for CPRs without the need for intervention by external authorities. Her field studies unearthed eight principles that underpin successful communal resource management, including collective choices and effective oversight. Energy communities, with their focus on sustainable energy production and consumption, exemplify how local governance and collective action can efficiently and sustainably manage the electricity network. This collaborative approach prevents the ‘tragedy of the commons’ through shared responsibility.

To effectively summarize Ostrom’s principles, the application of restorative leadership is crucial. This involves establishing a strong leadership board that guides the community while ensuring that all members actively participate in managing and making decisions about the efficient use of the transformer. This inclusive approach fosters a sense of ownership and accountability among the members. Additionally, it is essential that the transformer is monitored by an EMS and that this system provides motivational incentives to prevent overuse. Furthermore, collaboration with local governments, energy providers, DSO’s and other relevant stakeholders is important. These partnerships provide access to additional resources and expertise, which are vital for enhancing the effectiveness of the energy community.

4.6 Free riders

In the energy community, it should not be assumed that all stakeholders and households will participate actively, and it is possible that some may even act against the community’s interests. In terms of common pool resources, this situation often introduces the challenge of “free riders.” Free riders are individuals or entities that enjoy the benefits of a resource like the transformer, without contributing equitably to its upkeep or sustainability. These shared resources are vulnerable to overexploitation because it might seem advantageous for individual users to maximize their usage without considering the long-term sustainability or collective needs of the community (Ostrom, 1990)

The impact of free riders can be significant. For example, the municipality of Amsterdam has noted cases like a supermarket that, due to a cheap electricity contract, has no incentive to modify its energy consumption patterns. In the case of Sporenburg, however, no significant free riders have been identified, so this issue does not need to be addressed. The concept of free riders and potential free riders is elaborated further in appendix I Free riders.

4.7 Organizational success factors

Organizational	
Active community participation*	Critical
Active neighbourhood engagement*	Critical
Key stakeholders Liander, Households and the Municipality must be involved*	Critical
Clear business case for all key stakeholders*	Critical
Varied motivational incentives*	Critical
Operational leadership*	Critical
Educational and training programs	Non-critical
Possibility for energy sharing	Non-critical
Free riders must be limited	Non-critical
Energy sharing is possible	Non-critical

Table 6: Succes factors organizational

* These factors are further explained in section 6.2

5 Individual perspectives

A leverage point within the CLD is active neighbourhood engagement, which has a positive influence on peak moments on the transformer. Therefore, neighbourhood engagement is a critical factor to consider for the success of the energy community. This general condition can be further explained by delving into the engagement of Sporenburg through a survey. The survey would explore the attitudes, motivations, and barriers related to participating in the energy community. Understanding these aspects allows for identification of factors to enhance neighbourhood engagement.

From the interviews, insights were gained into what motivates households to participate in energy communities, the barriers they face, and their attitudes towards these communities. This information, combined with findings from the literature review and behaviour theories, will be used to develop the survey.

5.1 Method

In the survey, the behaviour of households will be measured. To accurately measure and analyse this behaviour, several theories have been considered. For example, the theory of Rational Choice suggests that individuals make decisions by evaluating alternatives and selecting the one that maximizes their satisfaction or utility (Becker, 1976). However, this theory is often criticized for assuming that all decision-making is entirely rational and for not considering the roles of emotions, irrational beliefs, and social influences. The Diffusion of Innovations Theory, developed by Everett Rogers (1962), aims to explain how, why, and at what rate new ideas and technology spread through cultures. This theory identifies factors that influence the adoption of an innovation and categorizes individuals based on their adoption timing. However, categorizing households into different groups was challenging since the FlexCity project is in its early stages, with only early adopters or people who have not yet joined. This limitation can restrict the ability to fully utilize the theory for analysis or predictive insights. Ultimately, a combination of theories was chosen: the Theory of Planned Behaviour and the Value-Belief-Norm Theory.

The Theory of Planned Behaviour (TPB) is a theoretical model developed by Icek Ajzen (1991) to predict and explain human behaviour. This model is useful for understanding specific behaviours in contexts where freedom of choice prevails, such as in the FlexCity energy community. The TPB suggests that behaviour is primarily influenced by the intention to perform that behaviour, which is determined by three factors: attitudes, subjective norms, and perceived behavioural control.

The Value-Belief-Norm (VBN) theory, developed by Stern et al. (1999), is a psychological model that explains human behaviour towards environmental issues. It integrates values, beliefs, and norms to predict individuals’ pro-environmental behavioural intentions and actions. According to this theory, altruistic, selfish, and biocentric values determine basic beliefs about the consequences of environmental degradation and one’s own effectiveness in reducing it. These beliefs, in turn, inform personal norms for action.

To apply the VBN theory in a survey, it is important to ask questions aimed at determining a person’s values, beliefs about environmental impact, and the urgency and need for personal contribution. This approach measures the extent to which someone is inclined towards environmentally conscious behaviour. By doing so, it identifies the driving forces behind environmentally friendly decision-making and actions. The structure of the survey is formed using both the TPB and the VBN theory.

5.2 Structure

The survey is structured in several phases. The theories previously explained, which are used to analyse behaviour, informed the development of the survey questions. Here, ‘behaviour’ refers to the willingness to adjust electricity usage or to participate in the energy community. The questions of the survey are listed in appendix J Survey questions, and their structure is explained in this section.

Introduction

On the first screen, respondents are introduced to the survey. This introduction briefly describes the survey’s purpose and goals and provides concise instructions on how to proceed. Minimal information is given to prevent biasing the respondents or overwhelming them with details. Additionally, the terms regarding the collection and use of information are outlined. If a respondent does not agree with these conditions, they are not required to complete the survey. It is also noted that the survey is available in two languages to ensure that the entire neighbourhood can participate.

Filter questions

The survey is divided into two parts: one for households that are already familiar with the FlexCity project and the energy community, and another for those who have never heard of it or don’t really understand what it represents. Households unfamiliar with the project were asked questions about their awareness, while those who have installed the smart meter and application were asked about their experiences with the program so far and the factors, they consider important for its success. These sections can be found in appendix J Survey questions, labelled as ‘Awareness’ and ‘Joined’.

Awareness

Here, the awareness of the problem of high peaks in the electricity network, as well as awareness of the consequences (VBN) resulting from this issue is assessed. This to find out how well people know about the problem and the consequences.

Attitude

The attitude refers to the personal stance someone holds toward the behaviour in question. In this survey, attitudes are indirectly measured by asking households about their perceptions of the current electricity network issues, including whose problem it is and who should be responsible for resolving these issues.

Motivation

The motivation of the energy community is assessed by asking households to rank various statements based on what they consider most important for joining and actively participating in the energy community. This method allows for the measurement of egoistic, altruistic, and biospheric values through different statements. Initially, it was considered to measure these statements using a Likert scale, but this method has limitations such as response bias, acquiescence bias, and a general tendency to agree with the statements as presented, as noted by Robert et al. (2021). It became necessary to determine which motivations households would prioritize over others. Consequently, a ranking method was chosen instead. Although point allocation was considered, it proved too time-consuming and complicated to implement in Qualtrics. Consequently, the ranking method was used, allowing to see which motivations households prioritize over others.

Subjective norms

Subjective norms involve the perceived pressure from others to either engage in or avoid certain behaviours. Within energy communities, this is examined by determining how strongly respondents feel that important people in their lives (like neighbours, family, and friends) expect them to join such initiatives. Specifically, respondents were asked if they knew any neighbours or friends who were involved in the FlexCity project or similar community projects.

Perceived behavioural control

This refers to the degree to which individuals feel capable of performing a specific behaviour. In the context of energy communities, this aspect can be investigated by asking about various factors, such as the availability of resources, knowledge of how to contribute, and perceptions of whether the effort required is excessive, either for oneself or others, or concerns about trust within the community.

Important factors to consider
For those who have installed the smart meter and application, there was a request to rank the important factors for the success of the energy community. These households have previous experience in the energy community and have received some information about how the community operates. Consequently, they are equipped to provide insights on what they believe are crucial for the community's success. This input will assist in identifying the success factors of the community

Intention
The question regarding the intention relates to the motivational factors that influence behaviour; it examines how prepared and willing someone is to perform the behaviour.

5.3 Analysis

The study initially aimed to collect comprehensive data from a target population of 556 individuals. Despite time constraints and external influences affecting the participants, the response rate reached was 18.3%, which is considered quite high. However, with only 92 respondents and as few as 29 answers on some questions, the amount of data collected was not substantial. Therefore, the focus was primarily on gathering descriptive statistics, rather than conducting extensive inferential analysis. This decision was influenced by the understanding that the small number of respondents could lead to reduced representativeness of the sample and an increased margin of error. With such a limited pool of responses, the variability within the sample may not accurately mirror the variability in the entire population, potentially leading to biased estimates. Furthermore, the small sample size diminishes the statistical power of any analysis performed, making it challenging to detect true effects and increasing the likelihood of Type II errors, where real effects go undetected. Consequently, it is expected that many effects will not reach statistical significance, rendering conclusions drawn from this data less reliable and less generalizable to the broader population.

Initially, the data must be analysed and, where necessary, transformed. However, it is important to minimize these transformations to maintain the data's integrity. Excessive or inappropriate transformations can change the underlying characteristics of the data, potentially affecting the validity and reliability of the conclusions drawn from it. The aim is to preserve the original accuracy of the data as much as possible while still preparing it for effective analysis. For instance, dummy coding will be applied to variables such as car choices, where there are three options.

5.4 Statistics

The goal of the survey was to assess the awareness, attitude, motivation, subjective norms, experience, and intention of households regarding the energy community. The survey was conducted from June 2nd to June 4th and remained open for respondents until June 14th. To distribute the survey, flyers were utilized. On a Sunday afternoon, a team of three people visited households, ringing doorbells. To distribute the survey, flyers were employed. A team of three individuals visited households on a Sunday afternoon, ringing doorbells. If no one was home, they placed a flyer in the mailbox. The team returned to the neighbourhood on the following Monday and Tuesday evenings to reach houses that were missed on Sunday. There was a large flat with about 100 households that was inaccessible, so flyers were placed next to the doorbells. Details of this distribution overview can be found in appendix K Survey distribution.

The flyer was designed to make it easy for respondents to scan the QR code and included a picture of me to make it appear more trustworthy and alleviate concerns about scams. Despite these efforts, some residents expressed fears of fraud, asking if scanning the QR code might lead to a bank scam, due to recent news about online bank fraud (Schellevis, 2024). This fear likely reduced the number of people willing to scan the QR code when they found it in their mailboxes.

Using Cochran’s (1977) formula, it was calculated that a sample size of 384 was sufficient to achieve a 95% confidence level with a 5% margin of error. However, after applying the finite population correction formula suggested by Krejcie and Morgan (1970), it was determined that a sample size of 228 would be adequate. Recognizing that even this number was not feasible, the decision was made to adjust the margin of error to 10%, accepting a higher error rate. This adjustment means that 82 respondents are sufficient. A 10% margin of error in the survey research implies that the true proportion of the population that shares the observed opinion could vary by as much as 10 percentage points either above or below the survey results.

In total, 400 flyers were distributed. Forty people scanned the flyer immediately and didn’t need a physical copy. Some individuals took the flyer, stating they would scan it later. Most people were open to participating in the survey, but some refused to talk or fill it out. This is challenging, as it is valuable to capture the opinions of those who have negative views about such communities.

The survey distribution resulted in a total of 102 respondents. Among the initial 103 respondents, 10 were excluded from the dataset due to incomplete survey submissions. Additionally, one respondent, although completing the entire survey, was omitted from the dataset because he finished it in less than 150 seconds. Consequently, the refined dataset consists of 92 respondents.

The expected average time for completing the survey, identified from the pilot testing, was 286 seconds (4 minutes and 46 seconds). However, the average time for completing the survey in the dataset was found to be 437 seconds (7 minutes and 17 seconds). This was slightly higher than expected but understandable since the pilot test included only people who worked at Resourcefully and some family members. To further investigate, a box plot was used to identify any outliers in the completion times. The box plot revealed that there were indeed outliers, with the most extreme case taking 4592 seconds (1 hour, 16 minutes, and 32 seconds). One plausible reason for the unusually long duration could be that respondents initially opened the survey but chose to finish it later. After removing the outliers, the average time needed to complete the survey was 387 seconds (6 minutes and 27 seconds), which is closer to the expected time. The outliers were only excluded for calculating the average completion time, not for analysing the data collected from the surveys.

The survey was designed to minimize biases in the responses by allowing the questions to be completed without necessarily reading the explanations. Additionally, the survey settings required respondents to answer each question before moving on to the next, and they were unable to return to previous questions. This restriction, which could not be adjusted in the Qualtrics settings, was clearly stated in the introduction to avoid any confusion. For the rating questions, an example was provided to demonstrate how to correctly assign a unique number to each statement, ensuring that households understood how to respond properly. Despite these measures, four households did not complete the survey upon reaching the rating questions. It is assumed that they discontinued either due to the effort required or because they did not comprehend how to proceed with the rating format.

5.5 Results

In this paragraph, the results of the survey are analysed. The analysis is conducted using Excel and SPSS, both of which are good tools for statistical analyses. A total of 92 households participated in the survey. However, not every question was answered by every household. This discrepancy is due to the presence of filter questions, which directed respondents to different subsequent questions based on their previous answers. Therefore, when only a subset of households responded to a particular question, the specific number of respondents (N) is indicated in the upper right corner of the corresponding diagram. If no such indication is provided, it means that every household answered that question.

Sociodemographic

As illustrated in Diagram 2, a significant proportion of the neighbourhood's population consists of older individuals who already have children who are no longer young. This demographic profile aligns with data from CBS, confirming the trend of aging populations in the area. Additionally, the average household size in Sporenburg, as visualized in Diagram 3, is 2.6. This figure is slightly higher than the CBS (2024) data, which reported an average household size of 2.4.

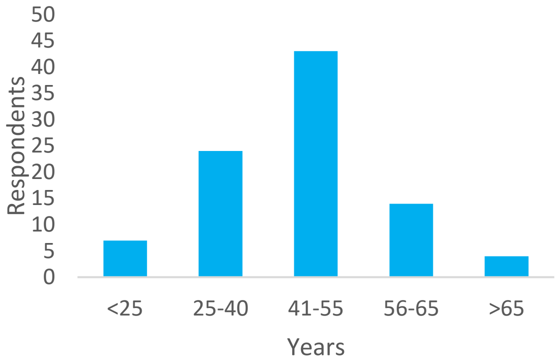


Diagram 2: age

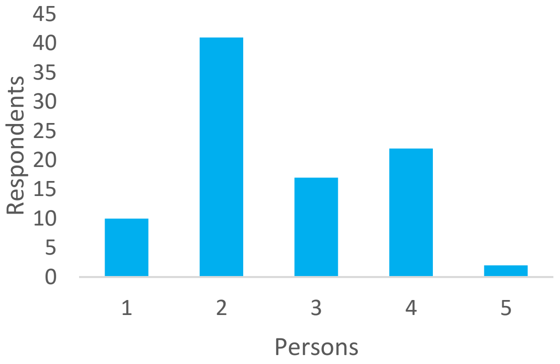


Diagram 3: Household size

As depicted in Diagram 6, 50% of the respondent households currently have solar panels installed. This figure is substantial, suggesting a solid foundation for expanding solar energy use. However, the goal to double or even quadruple this capacity by 2030, as outlined in the scenario formulation, poses a significant challenge. The data also suggests a correlation between solar panel ownership and increased likelihood of joining the energy community, reflecting a pre-existing commitment to sustainable practices among these households.

Furthermore, most respondents are homeowners, a factor that significantly influences their willingness to participate in community energy initiatives. Homeownership tends to instil a stronger sense of responsibility and long-term investment in property enhancements, including sustainability efforts. In contrast, renters may feel less involvement or ability to make permanent changes, which can affect their motivation to engage in such practices.

Additionally, Diagram 4 reveals that one-third of the vehicles owned by respondents are electric or hybrid. Households with such vehicles demonstrate a proactive stance on environmental responsibility and are likely to be more receptive to initiatives that further their ability to impact sustainability positively.

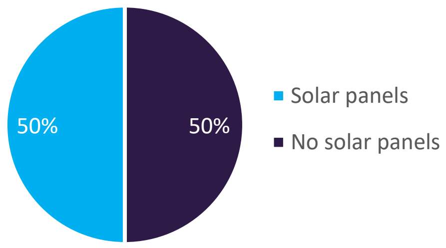


Diagram 6: Solar panels

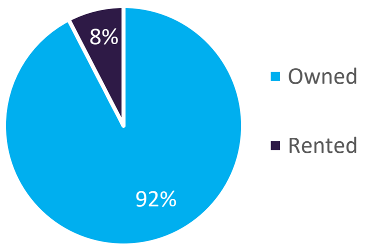


Diagram 5: Type of house

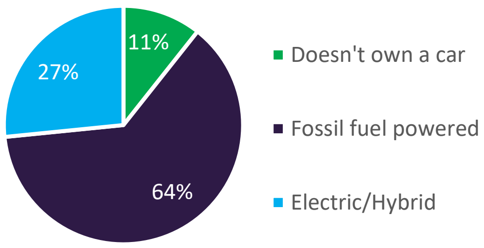


Diagram 4: Type of car

These households not only contribute to reducing emissions but also play a crucial role in energy management within the community by potentially adjusting their vehicle charging behaviours to help balance electricity demand peaks. Another notable finding from the survey is that the average car ownership in Sporenburg is significantly higher than reported by CBS data for 2024. According to CBS, the average car ownership in the area is 0.64 per household. However, the survey results show an average of 0.89 cars per household, which is substantially higher. This discrepancy is significant, especially considering that EVs have the most impact on the transformer during peak times. Overall, this collected data set can be seen as a representative sample group.

Awareness

The awareness questions were only asked to households that were either unfamiliar with the FlexCity project or had merely heard of its name. It is presumed that those already participating in the FlexCity project are well-informed on these matters. The findings from 58 respondents, depicted in Diagram 7, revealed remarkably high levels of awareness of the electricity grid problems, with all groups reporting awareness above 79%. This high level of awareness implies that it may be unnecessary for further investigations into whether this awareness significantly influences their willingness to participate in the project or affects other variables. Consequently, it is not deemed cost-effective for Resourcefully to invest additional resources in raising awareness about the issues affecting the electricity grid.

Although it was not deemed necessary to explore the effect of awareness in depth, a linear regression analysis was conducted to explore the potential impact of this awareness on various behaviours or attitudes. Unfortunately, this analysis did not yield statistically significant results. Therefore, it is not assumed that awareness influences the willingness to participate. Interestingly, despite the high awareness of electricity issues, about 21% of the households were not aware that these problems are related to simultaneous electricity usage.

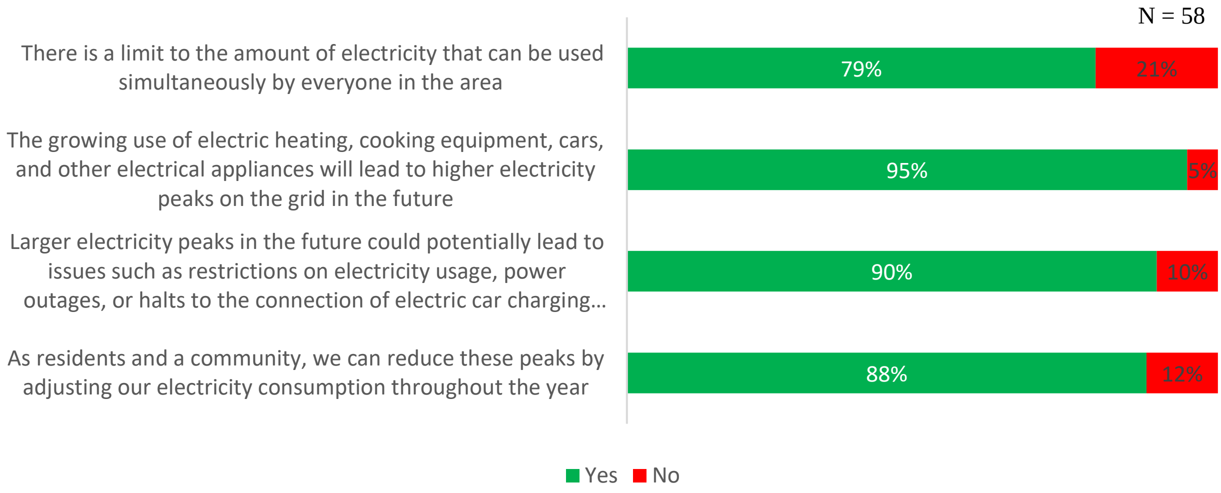


Diagram 7: Awareness

Responsibility

Diagram 8 reveals that a significant proportion of households acknowledge that while the electricity grid issues are primarily Liander's responsibility to resolve, they also recognize their own role in addressing these challenges. Notably, 64% of households agree or strongly agree that they can contribute to solving these problems, closely aligning with the average willingness (6.8 out of 10) to participate in the energy community.

The results of the independent t-test, visualized in appendix L Survey results, show there is a statistically significant difference between the group that has joined the community and the group that has not yet joined. On average, the group that hasn't joined the community scores 0.58 points lower on the scale that measures the concern about electricity grid problems are a concern for the users. Here a 5-point scale from "strongly disagree" to "strongly agree" is used. They also score 0.6 points higher on attributing the responsibility for solving these problems to Liander on the same scale.

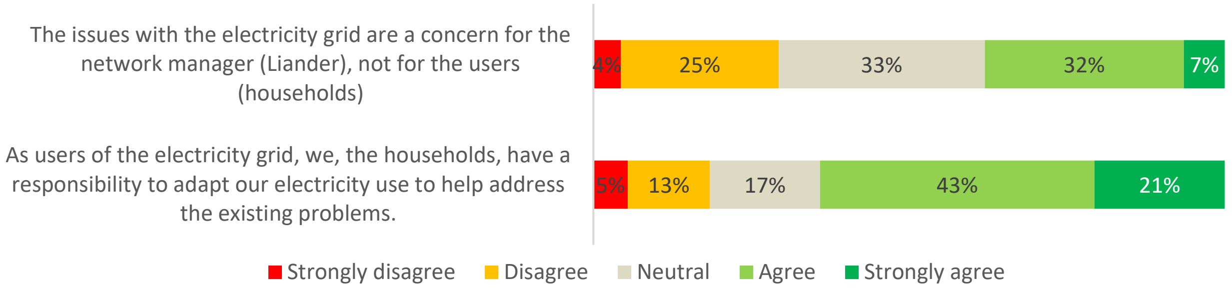


Diagram 8: Responsibility

Motivations

In Diagram 9, the average motivations for joining the energy community are visually represented, with data gathered from 92 respondents. Each household was given the opportunity to rank their motivations on a scale from 1 to 5. These rankings were then converted into scores, with a higher score indicating stronger motivation and greater importance attributed to that factor by the household. The scores for this data range from 1 to 5. A whisker plot was not selected for this analysis because every motivation score achieves both extreme values of 1 and 5. The distribution includes all possible scores, making a whisker plot less informative for observing variations or outliers within the data. Instead, the diagram visualizes the standard deviation, which provides a clearer indication of the variability within the data. The results show a relatively narrow range of motivation levels, with only a 0.62 difference between the lowest and highest average scores.

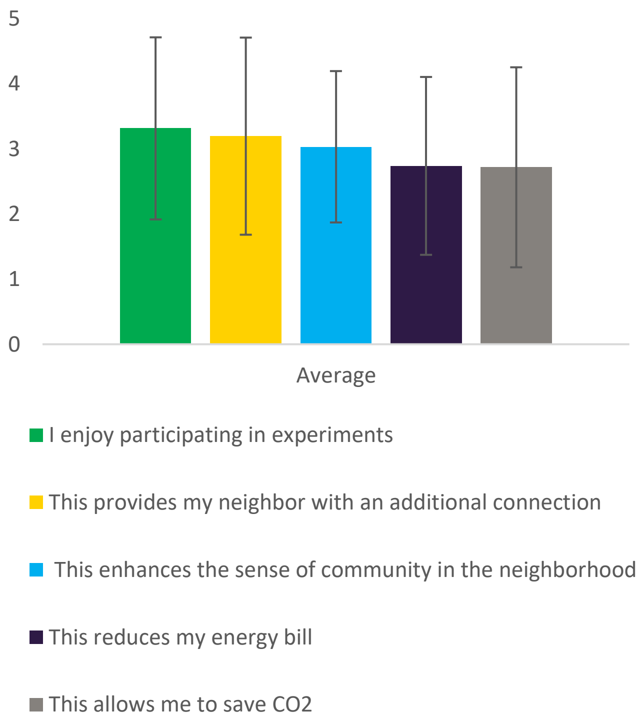


Diagram 9: Motivations

The motivation that ranked highest is the enjoyment derived from participating in experiments. This highlights the importance of ensuring that the community experiments are clear, user-friendly, and engaging. If the process is not enjoyable, participation may decline. On the other hand, the motivations related to reducing CO2 emissions and financial incentives received the lowest rankings. This suggests that the main fous should not be on these aspects. The additional connection factor is also highly ranked, indicating that households are motivated by the opportunity to do something extra for their neighbours. This suggests that households are more willing to participate when the need for the community is greater. Currently, the energy community is not essential for creating this additional connection, but it will certainly become important in the future. Companies in the Netherlands are already fostering additional connections for households by ensuring flexibility in their energy consumption, and households have the opportunity to do the same (van Engen, 2024).

When analyzing the motivations of households that have not yet joined the energy community, the findings closely align with the overall results, showing no statistical difference. This test is detailed in appendix L Survey results. The variation in their motivation levels is quite high, especially for motivations related to CO2 savings and providing an additional connection for neighbors, both of which have a standard deviation above 1.5. This indicates that the motivational incentives vary widely among respondents. The similarity in ranking perceptions between members and non-members suggests that while the specific motivations vary widely, the overall prioritization of motivations is consistent across both groups.

Barriers

The investigation into barriers reveals that although most households have confidence in the community's efforts, their confidence is moderate rather than strong. Diagram 10 shows that the lack of participation by others does not hinder individual households from getting involved. Additionally, it seems that implementing automation to adjust electricity usage could potentially increase satisfaction for 40% of the households. This automation might particularly appeal to those who find manually adjusting their electricity usage one or two times per week too much effort. However, it remains uncertain whether these same households would find the initial setup, joining the community, installing a smart meter, and using an application. This situation indicates that while technological solutions might boost participation rates, they might not fully resolve the deeper issues related to engagement and taking responsibility.

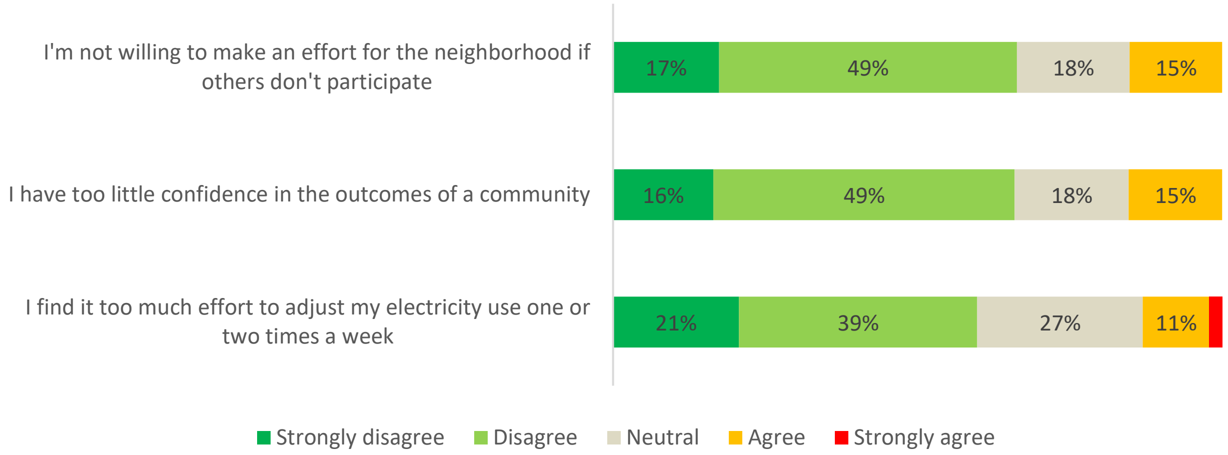


Diagram 10: Barriers

When the dataset is divided into households that have joined the community and those that have not, there is found significant statistical differences in responses to two questions: “effort for adjusting electricity” and “effort if others don’t participate.” For the question about adjusting electricity usage, households that did not join the community scored, on average, 0.78 points higher. This indicates that these households are less willing to make an effort to adjust their electricity usage one or two times a week. Similarly, for the question about making an effort if others don’t participate, non-joining households scored, on average, 0.89 points higher. This suggests that they are also less willing to make an effort if others are not participating.

For households unwilling to make efforts for adjusting energy settings twice a week, automation may offer a solution. This raises an important question: If these households are reluctant to engage frequently, how likely are they to join the community in the first place? To attract more members, a motivational feature could be introduced. This feature would reward households with extra points for promoting the community and successfully encouraging others to join. As the community grows, the collective effort required from each member decreases, as well lowering the barriers for “effort if others don’t participate.”

Experience

Diagram 11 & 12 shows the results of the section of the survey that was completed exclusively by the 29 households that have installed smart meters and applications, providing a focused insight into their motivations and understanding of the system. According to Diagram 11, a significant number of these households are currently not sufficiently motivated by financial incentives to participate actively, which can pose a barrier to their involvement in the challenges. However, this may not be a major issue because, as shown in Diagram 9, financial incentives are ranked among the lowest in terms of motivation. Therefore, it should not be considered the highest priority in this context, but it is interesting to further investigate.

It would be interesting to see if households who ranked financial motivation as their first or second priority answered the question “I’m currently financially motivated enough to participate in challenges” differently compared to those who ranked it lower. If the two groups answered differently, it would suggest that increasing financial incentives for the first group could be beneficial since they consider financial motivation important but currently feel insufficiently motivated.

To explore this, a correlation and linear regression analyses is conducted, which are detailed in appendix L Survey results. However, both analyses showed no statistically significant effect. This means it is not possible to conclude that the households differ in their responses to the financial motivation question based on how highly they prioritize financial incentives.

Furthermore, there is a general understanding among most of the households about how points can be earned, indicating that the system’s mechanics are clear to them. However, for 14% of the respondents, the method of earning points remains unclear, and this also leads that of these 14%, 3/5 respondents remain neutral or disagree about whether financial incentives are sufficient motivation.

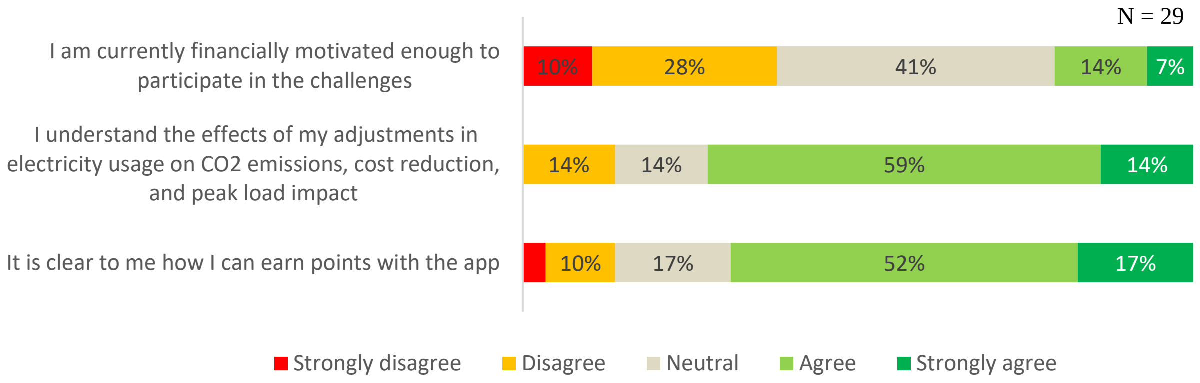


Diagram 11: Experience

Households that have joined the community were asked to rank the factors they believe are most crucial for the community's success. These scores can range between 1 and 4, with the highest score indicating that the factor is considered most important. Although no single factor significantly stood out, it is evident that financial incentives are considered the least important. Conversely, clarity regarding the impacts of participation received the highest ranking, highlighting an essential area for focus. Consequently, it is crucial that Resourcefully takes this into account when further developing the application.

Households need clear information about the environmental impact, specifically the CO2 reduction, the financial benefits quantified beyond mere points, and the effect on peak load management. Currently, the conversion of points into monetary value is not transparent, leaving households uncertain about what these points translate to in financial terms. Additionally, the impact on peak electricity loads has not been visualized, a feature that could further motivate households to participate. By quantifying and clearly communicating the CO2 savings, Resourcefully can attract more households and enhance participation in the community.

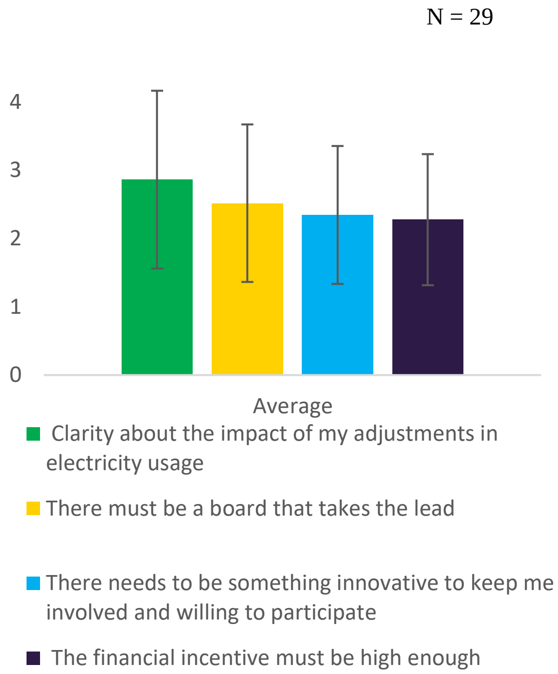


Diagram 12: Succes factors

The variation in motivation levels for the factors "something innovative that keeps me involved" and "financial incentives must be high enough" have a standard deviation of 1 or lower. This indicates a medium variability in the spread of the rankings for these motivations. In contrast, for factors like "the board that takes the lead" and "clarity about the impact of my adjustments," the variation is greater than 1.1. This suggests that the motivational incentives for these factors vary widely among respondents.

5.6 Multilinear regression

Following the initial transformations, all variables will be examined to determine if they correlate with each other and the extent of these correlations. These findings will then be analysed and utilized in the multilinear regression model to further understand the relationships within the data. In Table 7, the results of a linear regression analysis are presented, where estimations that are not statistically significant are highlighted in red. The dependent variable in this analysis is the willingness to participate in the energy community, which is rated on a scale from 0 to 10. The constant represents the baseline willingness to participate for households without cars, solar panels, or neighbours who have joined any community or project. The willingness to participate can be calculated by:

$$W = Constant + EV \times \alpha + BE * \partial + FNC \times \beta + FNP \times \gamma + FV \times \delta + S \times \varepsilon$$

N=92

Parameter	Estimate effect	Std. Error	t-value	p-value
Constant	5,556	0.651	8.534	<0.001
Electric car (EV)	2.139 (α)	0.727	2.940	0.004
Barrier too much effort (BE)	- 4.053 (∂)	0.576	-7.035	<0.001
Friend/neighbour joined community (FNC)	1.123 (β)	0.446	2.518	0.014
Friend/neighbour joined any type of project (FNP)	0.341 (γ)	0.438	0.780	0.438
Fossil fuel car (FV)	0.794 (δ)	0.634	1.253	0.214
Solar panels (S)	-0.046 (ε)	0.411	-0.113	0.911

Table 7: Multilinear regression

The presence of an electric car significantly enhances the willingness to participate in the energy community, which logically aligns with the notion that individuals who invest in EVs are more inclined towards sustainable practices and are eager to join such initiatives. Additionally, their participation is crucial as they have a considerable impact on managing peak power demands. Moreover, it has been observed that the involvement of friends or neighbours in the community markedly boosts one's willingness to participate. This phenomenon underscores the role of subjective norms in shaping individuals' decisions to engage in community initiatives.

There are factors that negatively affect households' willingness to participate, particularly when they express that adjusting their energy usage twice per week is too much effort. This suggests that automation can play a crucial role in enhancing participation.

The analysis did not reveal any significant effect of household size or age on the willingness to participate in the energy community. The correlation between household size and willingness to participate is notably low and statistically insignificant, indicating that these factors do not play a substantial role in influencing participation decisions.

The initial simple regression analysis suggested a strong positive effect of solar panels on the willingness to participate. However, when electric cars and the presence of friends or neighbours who have already joined the community are included in a multiple regression model, the impact of solar panels becomes less distinct and even negative. This indicates that households with electric cars or those connected to active community members are also likely to have solar panels, contributing to their higher willingness to participate. Thus, while solar panels still show a significant effect in the simple regression, their influence is not statistically significant in the multiple regression. This underscores the importance of considering multiple predictors to accurately assess their individual contributions and understand the interdependencies among various factors influencing active community participation.

5.7 Succes factors

Technical	Prioritization
A sufficient amount of EVs in the neighbourhood	Critical
More of the households are of the type owned	Non-critical
Automation on adjusting electricity usage	Non-critical

Organizational	
Clarity on the impact of participation*	Critical
Strong board that takes the lead*	Critical
Financial incentives must be high enough	Non-critical
Something innovative within the community to keep households involved	Non-critical

Table 8: success factors individual

* These factors are further explained in section 6.2

6 Conclusions and advice

This section begins with the key findings from which the factors contributing to success are derived. Utilizing results from technical analysis, organizational analysis, and survey data, the sub-research questions are addressed. Based on these findings, success factors are identified and recommendations are provided to Resourcefully to enhance the project's success. Additionally, this chapter discusses the limitations of the current research and suggests directions for future research.

6.1 Key findings

The dynamic relationship between the community's social agreements and its technical systems is central to driving energy communities toward their goals of sustainability, reducing peak loads, and ensuring affordable energy costs. Therefore, both aspects are crucial to consider when investigating the factors for success. Initially, the technical findings will be analysed, followed by an examination of the social agreements.

Technical system	*What is the current state of the technical system within the Sporenburg neighbourhood's energy community?*
Organizational system	*What are the interests of the stakeholders involved in the energy community and what actions can they take?*
Individual perspectives	*What are the varied perspectives of households regarding their participation in the energy community?*

Technical system

The current state analysis of Sporenburg is presented and visualized in Section 3.1. This section will further clarify the important characteristics of an energy community and highlights what should be considered in future planning and development. It will also be explained why these characteristics are crucial and how they can be identified for an effective development of an energy community.

For the success of the energy community, conducting both a current system analysis and a future system analysis is crucial. Understanding what is connected to the transformer and predicting how the transformer might evolve in the future are key components of gaining a comprehensive understanding of the system. This knowledge aids in developing strategies within the community and plays a vital role in shaping the community by providing Sporenburg with a realistic view of their neighbourhood. It also helps envision what the area could look like in 2030 under various scenarios. This clarity can significantly motivate households to participate, as the purpose of their involvement currently appears vague to them.

Implementing such analyses from the start of projects like FlexCity could enhance awareness and a sense of responsibility among community members, potentially leading to higher participation rates. The necessary data for these analyses is outlined in Table 9. In addition to knowing specific quantities, such as the number of households, understanding the diversity in types and features is also crucial. This includes the form of electrification in households and the type of ownership, as these factors significantly influence the community's energy dynamics and strategic planning.

Understanding the number of households is important to assessing the impact on the transformer. The average consumption data is accessible on the Liander website, providing a foundation for such analyses.

Ownership type plays a significant role in the willingness to participate in the energy community. This is attributed to a stronger sense of ownership and responsibility compared to renting households.

In Sporenburg, every household was connected to a heating network and utilized electric cooking systems. Notably, heat pumps were not installed. Devices like these are high electricity demand products, which significantly increase the neighbourhood's overall electricity consumption but also offer opportunities for flexibility in energy usage. Therefore, it is an important characteristic to consider when assessing the energy dynamics and potential strategies for managing and optimizing energy use in the community.

Characteristic	Important to know
Households	Owned-rented Heat pump/gas heated Electric cooking system
Cars	EV/hybrid-fossil fuel
Charging stations	Private public
Solar panels	Capacity
Utilities	Demand profile

Table 9: Characteristics

Understanding the capacity of solar panels is critical for assessing their potential to feed energy back into the grid, which could lead to a reduced demand on the transformer station. Currently, there is no general data available on the capacity of the solar panels operating within the transformer's network, but this information can be estimated as detailed in appendix E future situation.

To predict the peak load moments from the transformer the amount and type of cars and charging stations is needed. With this information, an estimate of the number of simultaneous charging sessions can be made, providing a clearer understanding of the potential energy demand during peak load moments. While there is information available on public charging stations, data on private charging stations is lacking. The survey was a good opportunity to gather more information about private charging stations, particularly since 27% of the participants own EVs or hybrid vehicles, but this question was unfortunately overlooked.

The presence of large-scale commercial or industrial utilities simplifies managing energy usage within the community, making planning and implementation more straightforward. Managing one large consumer, equivalent to the demand of 100 households, is generally easier because controlling a single significant load can be more efficient than coordinating 100 separate households with diverse consumption patterns. However, if the large consumer does not cooperate, reducing peak load moments becomes more challenging. This situation highlights the trade-offs in energy management: the complexity of handling many small consumers versus the efficiency gains from managing a few large ones.

While some neighbourhood data is available online, accessing this information is challenging, especially when specific data for a particular part of the neighbourhood is needed. Additionally, transformers are not categorized by neighbourhood, which complicates the data collection process. A critical piece of information that is not available online is the number of private charging stations. Having detailed data on the quantity of charging stations and ownership of private stations would greatly simplify the management of the energy community.

From the CLD it is clear that Energy sharing emerges as a leverage point with significant implications. This practice not only reduces electricity bills for consumers but also decreases the amount of electricity fed back into the transformer station, leading to fewer peak moments in the transformer. Moreover, energy sharing reduces dependency on traditional energy suppliers, which poses a disadvantage for these suppliers since their revenue model primarily relies on trading energy. As a result, traditional energy suppliers are unlikely to support a system that undermines their role and impacts their profits, as acknowledged by OM energie (Interview, 2024)

Organizational system

Households are pivotal stakeholders within energy communities, and specific measures are necessary to encourage their participation, maintain their engagement, and ensure their continued connection to the community. Households equipped with EVs and/or solar panels have a more substantial impact, making it crucial to prioritize their involvement initially. Ease of use of the system emerged as a significant factor from the discussions, with automation playing a vital role. The responsibility for automation is shared; partly it lies with the households and partly with the development of the EMS. An EMS needs to be designed to connect smart IoT devices, thermostats and smart plugs. Households are responsible for installing these devices and connecting high-energy-consuming appliances like EV charging points and washing machines to the system. Resourcefully can offer support by providing information on how to automate this. To keep households actively engaged, the outcomes of their adjustments must be transparent, allowing them to understand the purpose of their actions. This means providing clear information on how their adjustments contribute to CO2 reduction, reductions in electricity bills, and peak load mitigation.

Liander is increasingly recognizing the potential of local energy communities, which they initially overlooked due to their small size and seemingly minimal impact. These communities are actively addressing grid congestion that Liander is also striving to solve. The communities have demonstrated that people are willing to modify their energy usage behaviours to reduce peak loads on the electricity grid. While it is clear that Liander is becoming more receptive to supporting such projects, though they advocate for standardization. The challenge lies in scaling their involvement; supporting hundreds of diverse communities isn’t feasible without a standardized approach. Therefore, Liander is pushing for a general strategy where the roles and responsibilities of all parties are well-defined.

Furthermore, Liander is open to sharing data but emphasizes that it must be done responsibly to ensure that these community initiatives help alleviate rather than exacerbate the problem. A company like Resourcefully should not simply take the data and independently decide to lower the peak based on what they think is best for the electricity grid. Instead, these actions must be carried out with consensus. This is particularly crucial because solving congestion at the lower grid level could inadvertently increase congestion on the medium or high voltage sections of the grid. Effective cooperation among all stakeholders is essential, highlighting the crucial role Liander plays in this evolving landscape.

The Municipality of Amsterdam plays a pivotal role in fostering energy communities by organizing educational events and offering subsidies to promote sustainability and equitable energy access. It possesses the necessary knowledge and resources to support such initiatives effectively. When a municipality participates in energy projects, it sends a strong signal of trust to the DSO and households alike. This involvement typically boosts confidence in the initiative, making both the DSO and local residents more likely to engage actively. With ambitious climate targets set for 2030, including a significant expansion of EV charging infrastructure, the city recognizes that energy communities can contribute to these goals. However, the municipality also has her thoughts about the project’s immediate impact on solving congestion problems and noting that other congestion issues may require priority. Nevertheless, Amsterdam values the opportunity to experiment with household willingness to adjust electricity usage and to strengthen their ties with the neighbourhoods. For the project’s success, it is crucial that Liander participates, if not, the municipality fears that the project may not achieve its full potential and they would draw back as well.

Individual perspectives

The results of individual perspectives are detailed in Section 5.7. The main findings reveal that financial and CO2 incentives for participation are ranked lower than anticipated. There is no strong preference for one incentive over another, suggesting that a variety of motivational incentives is necessary. The data also shows that the presence of friends and neighbours in the community significantly boosts willingness to participate, as does owning an electric car. Additionally, understanding the tangible impacts of household actions - such as financial savings, CO2 reduction, and peak load management - and having a strong leadership board are most important for the community’s success

6.2 Succes factors

The success factors for the energy community are best understood as critical conditions required for its success, categorized into two main phases: the formation of the community and its operational phase. While certain conditions, such as the presence of an EMS and the installation of smart meters in households, are critical, they are often straightforward and require no further explanation; these are visualized in appendix M Success factors. This analysis will concentrate on the organizational necessary conditions

Performance indicators
Critical peak load moments
Energy bill
Community enjoyment
Stakeholders’ involvement

Table 10: Performance indicators

The conditions in Table 11 must positively influence one of the performance indicators, as detailed in Table 10. This approach ensures that the factors discussed are not only necessary for the foundational and operational stages of the community but are also directly tied to measurable outcomes that enhance the community’s overall performance and success.

System	Condition
Forming the community	Commitment and participations of key stakeholders Clear business case for key stakeholders Technical system must be clear
Operational community	Strong board that takes the lead Operational leadership Varied motivational incentives Clarity on the impact of participation Active community participation Active neighbourhood engagement

Table 11: Succes factors

For the successful formation of the community, it is crucial that key stakeholders such as Liander, the households, and the municipality are fully committed and actively participate. While all stakeholders play vital roles, the most critical are the households and Liander. Households are essential as they adjust their energy usage, directly impacting the community’s energy dynamics. Liander, on the other hand, is pivotal because it possesses data on which assets are connected to the transformer, manages electricity feed-in data, and has the capacity to finance the demand response program.

A clear business case must be established for all stakeholders, which may include benefits such as peak load reduction, financial incentives, and enhancing community enjoyment through participation.

The technical system must be thoroughly understood. This includes identifying the type of neighbourhood: determining if there are utilities with significant energy consumption that could impact the transformer substantially, assessing the number of charging points, the prevalence of EVs, and the installation of solar panels - details that are outlined in Table 9. Understanding these elements is fundamental in shaping the strategies for forming the community and ensuring its operational effectiveness.

For the community itself, it is essential to establish a robust leadership board, likely consisting of approximately five members. This board would ideally include some elderly individuals who have the time and willingness to dedicate their efforts to the project. Additionally, there should be a diverse range of incentives available to the community members, rather than focusing solely on one type. The survey results have provided a close ranking of these incentives, indicating that all are considered nearly equally important by the community.

Operational leadership is also important for the success of the energy community. This requires the board to take an active leadership role and focus on the growth of the community, ensuring that households who join receive guidance and assistance with their enrolment and any arising issues. Additionally, a "community facilitator" plays a vital role in this dynamic. This is an individual who actively engages with the community. This person visits homes to provide information, persuades others to join the initiative, installs smart meters, assists households with their applications, and offers support when issues arise. The community facilitator can be a member of the board or another resident within the neighbourhood.

Another key finding from the survey is the crucial role of clarity regarding the impacts of energy adjustments. Therefore, it is vital to ensure that the impacts of adjusting electricity usage are clearly communicated to foster active and informed participation in the community. This approach not only motivates current members but also attracts new participants by demonstrating the tangible benefits of their involvement.

Active community participation and neighbourhood engagement are essential conditions for the success of the energy community. Community participation ensures that households within the community actively engage in the various challenges and initiatives put forth. Meanwhile, neighbourhood engagement is crucial for increasing the overall participation rate among households. Together, these elements work hand-in-hand to build a cohesive and effective energy community

In addition to the necessary conditions, several external factors play a crucial role in stimulating adaptation. These include the process of electrification, the fluctuating prices of electricity, regulations surrounding net metering, and the variability in the number of sunlight hours. The impact of these factors is clearly visualized in the CLD in Figure 8.

6.3 Advice

The essential conditions for the success of community energy initiatives are well recognized; however, the strategies to effectively achieve these conditions remain unclear. To address this gap, specific recommendations will be outlined, focusing on scaling these energy communities efficiently despite limited time and resources. The advice is categorized into several key areas: the technical system, the organizational system (which includes Liander, target groups and automation & Engagement and leadership), and the financial aspects of energy communities. Each recommendation will be grounded in practicality and feasibility, ensuring that the advice is both pragmatic and effective for the growth and long-term success of energy communities.

Technical system

The first step is to gain a clear understanding of the technical system of the neighbourhood, which is essential during the formation phase to develop strategies for managing the community and creating the EMS. Important factors are detailed in Table 9 and further discussed to explain their significance. Resourcefully should create a format to provide a comprehensive overview of neighbourhood characteristics. It is essential that the sources of information used in this format are clear and standardized to ensure that future energy communities can be developed quickly and efficiently. This standardization will facilitate the replication of successful strategies and the smooth scaling of energy projects across different neighbourhoods.

Additionally, While energy sharing is currently not feasible under the new Energy Act, future implementation is expected due to EU mandates (Entrnce, 2024). Therefore, it is advisable to incorporate this possibility into strategic planning for the technical system. Engaging with energy providers or municipalities to initiate pilot projects is recommended. Ultimately, implementing energy sharing could deliver significant benefits for all key stakeholders.

Liander

From the stakeholder perspective, it is clear that Liander's involvement is crucial for the success of the energy community project. Throughout the interviews and the course of this research, Liander has shown increasing openness to collaboration and participation. However, they still have several concerns that need to be addressed. These include how data management will be handled, the role they should play within the community, and strategies to mitigate issues like peak shifting that could lead to congestion in the medium voltage network.
Consequently, it is vital for Resourcefully to develop a clear framework that outlines how the energy community is organized and defines Liander's specific role within it. Although Liander is conducting its own research, Resourcefully possesses a deeper understanding of how their efforts can be most effectively utilized. This study serves as a robust example that can be presented to Liander to illustrate effective energy community systems and provide a foundation for organization.

Furthermore, the data held by Liander is incredibly valuable, yet their reluctance to share this information presents a significant challenge. As a result, Resourcefully must develop a strategy to manage the data responsibly. This strategy should ensure that concerns about potential misuse of the data and issues of data security are thoroughly addressed. By doing so, Resourcefully can build trust and facilitate smoother collaboration with Liander and other stakeholders involved in the project.

Target group and automation

The survey reveals that 40% of participants, who are either neutral or agree, find it too much effort to adjust their electricity usage twice a week. This and the results from the interviews has led to considerations of automation as a potential solution. One potential solution is the installation of smart plugs for households. These devices primarily function to turn appliances on or off, but they do not resume operation from the previous state; instead, they act more like a reset button for most products. Future developments are expected to improve the automation of household appliances, making it more user-friendly and integrated. Currently, the automation technology in large electricity-consuming appliances is not yet sufficiently advanced. Many household appliances, such as dishwashers, washing machines, and heat pumps, vary greatly in their capabilities, with only some being remotely controllable. Therefore, Open Remote suggests in their interview that it is now more practical to focus on applications that are uniform and are easier to manage like thermostats, and EV charging points.

Prioritizing appliances that consume the most electricity and affect peak load moments could lead to more immediate and significant reductions in peak load moments. Additionally, a notable finding from the survey showed that households with EVs scored 2.1 points higher in their willingness to participate. This increased inclination makes it easier to engage these households, providing an extra incentive to focus on EV owners.

A limitation of this approach is that it might not be fair to participants who do not own EVs, charging points, or heat pumps, as they would not benefit equally. It is essential that all participants have the opportunity to engage and earn rewards proportional to their adjustments in electricity usage. This situation presents a dilemma: whether to treat everyone equally and potentially achieve a moderate decrease in peak loads, or to incentivize larger electricity consumers more aggressively, resulting in greater reductions but less equality. One possible approach is to communicate to households that the overall benefits will increase if larger consumers are more motivated, which could also serve as an incentive for further electrification, for example an extra charging point connection for the neighbour. While this challenge might lessen as electrification becomes more widespread in the future, it remains an important issue that needs immediate attention.

Engagement and leadership

Active community participation and neighbourhood engagement are crucial goals, but it is challenging to provide a single piece of advice on how to achieve them. This is because participation is influenced by various factors, such as motivational incentives like helping a neighbour, enjoying experiments, financial benefits, and reducing CO2 emissions. Therefore, multiple recommendations are provided here to address these diverse motivations.

The survey revealed that households are primarily motivated by the enjoyment of experiments. This highlights the importance of ensuring that community experiments are clear, user-friendly, and engaging. If the process is not enjoyable, participation may decline. Clarity was ranked as the most important success factor for households already participating. Therefore, a business case should be developed in advance, detailing the impacts in terms of CO2 reduction, financial benefits, and effects on peak load. This prevents households from being unaware of the effects of their adjustments. The business case should be presented in a simple, easy-to-understand manner, as households suggested in the interviews. One effective strategy that could be implemented is allowing households to see the impact of their adjustments on their own average peak load, rather than just being informed about a general reduction such as 0.1% in the community peak load. Presenting personalized results can significantly enhance motivation, giving households a tangible sense of contribution and achievement.

Furthermore, a strong board and a community facilitator are important in boosting participation within the energy community. The board could organize community events, such as neighbourhood barbecues once certain levels of active community participation are achieved. Integrating a visual diagram in the application that tracks progress towards these community rewards can motivate households to reach these milestones. This setup introduces a gamification element to the energy community, making participation more engaging and enjoyable, which is a high priority for households, as indicated by the survey results. Meanwhile, community facilitator(s) visit homes to provide information, persuades others to join the initiative, installs smart meters, assists households with their applications, and offers support when issues arise.

Finally, the reward system should be expanded to include incentives for community building. Households that successfully encourage their friends or neighbours to join the community should receive additional points or other benefits. This approach not only fosters community growth but also enhances individual commitment to the initiative. Notably, households with a friend or neighbour already in the community score 1.4 points higher in their willingness to participate.

Financial

Currently, the demand response program implemented in the FlexCity project is financed by Reschool as part of a pilot project to evaluate the outcomes. However, as these communities scale up in the future, financing for incentives, as well as for smart meters, the EMS, and other services, will need to be sourced from elsewhere. Liander is identified as a key stakeholder who could potentially finance these initiatives. This is because the efforts of households to lower peak load can result in delayed or unnecessary investments in the transformer and potentially preventing power outages which saves money for Liander. Additionally, Liander benefits from valuable data collected from households, which further justifies their involvement in funding the demand response program.

Liander is currently exploring variable network tariffs, as revealed through interviews, indicating their proactive research in this area. While Liander appears to be the appropriate party to finance the necessary products and the demand response program, immediate funding from them may not be forthcoming. Initially, other sources such as subsidies and support from municipalities will be essential to launch these initiatives successfully. This multi-source funding approach will help establish the groundwork during the early phases of energy communities.

6.4 Limitations

The scope of this study focused specifically on key factors within Sporenburg's current organizational and technological environment, excluding external changes in the future such as economic shifts, regulatory updates, or technological advancements. These external elements, while impactful, were outside the study's parameters. Therefore, the success of the energy community in Sporenburg hinges on these identified factors and the stability of the current situation. If these conditions are maintained and no significant external changes occur, the community is well-positioned to succeed. However, any changes in the external environment would necessitate a reassessment and potential adjustment of strategies.

Another limitation arises from the reliance on different stakeholders for interviews and data collection. For instance, Liander, a crucial stakeholder, is not currently involved in the project. This absence posed a challenge in obtaining up-to-date data from the transformer station. Only data from 2022 was received, and not from 2023. Having the 2023 data would be valuable as it would provide insights into the changes in energy usage and the impact of the increased presence of EVs in the neighbourhood.

Additionally, the research acknowledges the limitations inherent in any case study analysis. The neighbourhood of Sporenburg was not randomly chosen; it is one of the ten neighbourhoods where the transformer is measured for data collection. This selection allows for the measurement of eventual impacts on electricity behaviour and the overall impact of the energy community. However, Sporenburg is not representative of a typical Amsterdam neighbourhood. The success factors identified are based on a set of assumptions that may not hold true for another neighbourhood.

From the current system analysis, it was evident that this neighbourhood was an ideal test pilot ground. The households are all connected to a heating network, use electric cooking systems, and have no utilities that significantly impact the transformer. The characteristics of the neighbourhood were quite uniform, making it easier to manage and guide. Additionally, this neighbourhood has an average household price of €700,000, which means that residents have the mental bandwidth to consider and address this problem without being preoccupied with other issues. Therefore, it is less likely that the implementation of these communities will fail here. Therefore, these factors should be viewed as tools for discussion and exploration rather than definitive predictions.

Lastly, a disadvantage of the CLD is that it does not inherently provide information on the magnitude or timing of changes. This means that while CLDs can illustrate how variables are interconnected and influence each other, they do not quantify how much a variable will change or how quickly these changes will occur. To address this limitation, further quantitative methods, such as system dynamics modelling or the use of differential equations, are required to accurately simulate and predict the behaviour of the system over time. With these methods, it is possible to quantify critical factors like the level of active neighbourhood engagement and the necessary number of EVs in the neighbourhood. Currently, the available information does not provide specific numbers required to guarantee the community's success.

6.5 Future research

Future research should explore a variety of neighbourhood types where the technical systems differ from those in Sporenburg. This includes neighbourhoods with a higher proportion of rental households, lower-income households, or areas where significant electricity consumers, such as large utilities, are present beyond residential settings. Each of these scenarios may necessitate tailored strategies. Additionally, while energy sharing among individual households is not yet feasible, it is possible between homeowner associations (VvEs). This aspect of energy sharing presents a valuable opportunity for exploration in future projects.

Furthermore, the creation of the CLD and equations sets the stage for the next step, which is to build a model. This model will allow for an analysis of the impacts of different measures or regulations. With this approach, the outcomes can be quantitatively assessed, providing precise data on the effects of various interventions. This methodical progression from theoretical framework to practical application is crucial for understanding and enhancing the effectiveness of energy management strategies in diverse settings.

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A Literature review

The literature review aims to identify knowledge gaps within this study. It begins with an outline of the methodology used to select relevant literature. The review then examines the chosen literature and delves into the main themes found within these sources. This structured approach highlights areas needing further research and provides a clear understanding of the current knowledge landscape. This analysis corresponds with section 1.4 of the document.

The literature review focuses on gaining a deeper understanding of demand response programs in residential areas, with a particular emphasis on their application in the Netherlands, especially Amsterdam. This section is dedicated to thoroughly analysing the current state of knowledge in this domain. This analysis will highlight the existing gaps in understanding and pinpoint the primary research question that needs to be addressed. This literature review is divided into three subsections. First, the methodology of the literature review is explained and what role it plays in this thesis project. Second, the core concepts and background knowledge regarding this research field will be explained. Lastly, the review and overview of relevant literature is given, where selected papers are discussed, findings laid out and properties and features of past studies are compared. This subsection concludes with the description of the knowledge gap motivating the research and the main research question.

This literature review draws upon insights from the municipality of Amsterdam, Liander and Resourcefully, supplemented by various literary sources. Discussions with Hugo Niesing and David Plomp from Resourcefully and Jasper Klapwijk from Kantelingen highlighted the significance of this issue. From this starting point, the direction of the research was established and will now be further developed through an extensive literature review. It will form the basis of the data gathering in the next steps. After this, literature review data will be gathered and analysed, interviews will be conducted, and surveys will be conducted.

Methodology

Various tactics were used in the literature review and employed in the selection process. To gather relevant references, two distinct databases were utilized: Google Scholar and Scopus. Apart from this the TU Delft Library was also used to access additional journals and articles. Within these databases, two search strings were used. Initial article selection was conducted focusing on titles, subheadings, and abstracts. In cases of uncertainty, concepts were investigated in greater depth within the research article. This approach led to the identification of more than 98 articles initially deemed relevant. Further refinement was achieved through a more detailed review of these articles, including their introductions and conclusions. The articles under consideration were published between 2015 and 2024, with a notable increase in relevant publications post-2021. While developing the search string, it was revealed that some demand response programs incorporate thermal energy, either alone or alongside electricity. Additionally, the research often combined residential and commercial sectors; however, this thesis specifically targets residential areas, leading to the exclusion of mixed-sector studies. The details of the search strings are provided below.

The following keywords were used in permutation and combination to search for the relevant literature. Keywords: “Residential,” “Community,” “Demand response,” “Electricity,” “Thermal” and “Commercial” In addition to this search strategy, reports from the Municipality of Amsterdam, Liander, and Tennet were also obtained. This approach, when integrated with specific search terms in online databases, resulted in a large number of findings, necessitating significant filtering. The outcomes of this process are illustrated in Figure 16.

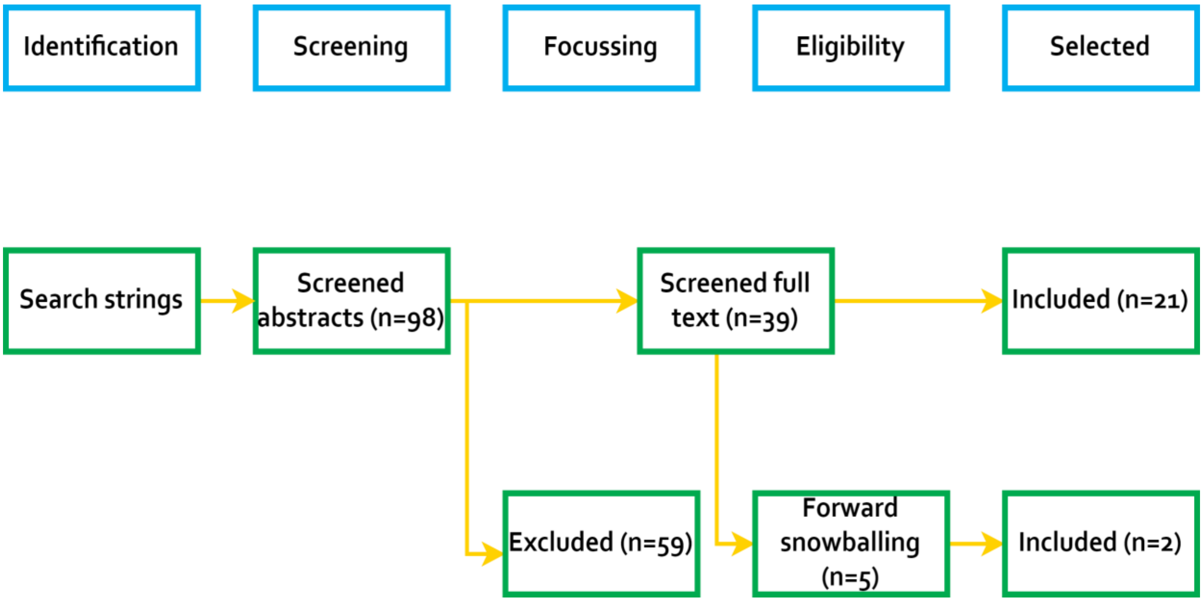

Figure 16: A Selection process

Figure 16 provides an overview of the literature search process. Initially, 98 articles were screened, resulting in 59 being excluded. Forward snowballing was then applied to the remaining articles, examining publications that cited the initial set, which uncovered 5 new references. After an eligibility check, the literature review comprised 23 references. In addition to this, reports from Liander and the municipality of Amsterdam were also utilized but are not discussed in the literature review. In selecting literature, the focus was primarily on articles discussing price-based demand response programs tested with a wide array of assets like EVs, washing machines, solar panels, etc. There were noticeably fewer articles available on incentive-based programs. Additionally, articles that explored forms of neighbourhood collaboration were also considered. This dual focus aimed to capture both the technological and community aspects of demand response initiatives.

Combining the keywords and adding Boolean operators has led to the following search terms:

Residential AND Demand response AND Electricity AND NOT Thermal OR Commercial
Community AND Residential AND Demand response AND Electricity AND NOT Thermal OR Commercial

Selected Literature

Table 12 presents various studies, detailing their methodology, measured effects, primary features, and whether any form of cooperation is included. The research will be analysed and discussed to eventually determine the knowledge gap and the main research question.

Source	**Method**	**Measured effects**	**Main feature** *DR = demand response	**Cooperating**
Al Zahr et al. (2021)	Combination	Profitability Peak load	Coordinated DR	Yes
Bakare et al. (2023)	Combination	Peak load	Challenges associated with DR	-
Chen et al. (2023)	TOU	Profitability Peak load	Community energy aggregators Peak load shifting	Yes
Chung et al. (2023)	TOU	Profitability Peak load	Model for monthly electricity usage and peak-hour usage ratio	No
Enrich et al. (2024)	TOU	Peak load	Effect from TOU	No
Fouladfar et al. (2019)	Combination	Profitability CO2	EMS Framework	No
Hofmann & Lindberg (2024)	PB	Energy savings	Incentives from households based on EMS	Yes
Hu et al. (2021)	-	Profitability Peak load	Neighbourhood level coordination and negotiation techniques	Yes
Manembu et al. (2023)	-	-	Overview load-shifting methods	Yes
Mohd Zahid & Aki (2024)	PB	Profitability	Participation in DR	No
Muratori & Rizzoni, (2016)	PB	Profitability Peak load	Rebound peaks	Yes
Nan et al. (2018)	TOU	Profitability Peak load	Optimal scheduling scheme	Yes
Nijhuis et al. (2015)	Combination	Profitability Peak load	Social welfare maximization DR	No
O’Reilly et al. (2024)	-	Profitability Peak load	Devices to control in DR	Yes
Pal & Kumar (2018)	PB	Profitability Peak load	EV strategy in DR	Yes
Parrish et al. (2020)	Combination	Profitability Peak load CO2	Motivations to participate in DR	No
Paul et al. (2018)	Combination	Profitability	Overview DR	Yes
Rana & Gróf (2024)	PB	Profitability	Local energy trading	Yes
Rong et al. (2023)	PB	Profitability	Privacy aware	No
Schwabeneder et al. (2021)	PB	Profitability	BUCA multiple markets	No
Sridhar et al. (2022)	PB	Profitability CO2	Finnish case study	No
Tuunanen et al. (2016)	Combination	Profitability Peak load	Benefits between DSO and markets	Yes
Weck et al. (2017)	PB	Profitability Peak	NL case study	No

Table 12: A Selected literature

Literature themes

Demand response strategies and their structure

demand response is a strategic approach where consumers intentionally adjust their electricity usage, especially during times when prices are high. This strategic adjustment helps consumers to save money on their energy bills, as highlighted by Pal & Kumar in 2018. Beyond individual savings, research by Enrich et al. (2024) and Fouladfar et al. (2019) demonstrates broader benefits such as reductions in CO2 emissions and the mitigation of peak load demands on the energy grid. However, implementing these strategies is not always straightforward and can sometimes lead to discomfort for users. The model introduced by Nan et al. (2018) stands out by offering a solution that effectively reduces the electricity costs for consumers and diminishes the peak load and peak-valley differences in residential load profiles. Remarkably, it achieves this without compromising the comfort of the users, thereby facilitating a more efficient and participatory approach to demand response within residential communities.

Demand response strategies, outlined by Paul et al. (2018), encompass a variety of approaches. A significant portion of these strategies relies on price-based methods, where households adjust their energy consumption in response to electricity pricing, thereby reducing their monthly energy expenses. Manembu et al. (2023) and Enrich et al. (2024) further explore this concept, demonstrating how various algorithms can be employed to fine-tune these strategies.

In the field of demand response programs, the emphasis on varying architectures and the specific appliances they target is crucial. Manembu et al. (2023) differentiate appliances into two categories: controllable and uncontrollable, highlighting the importance of this distinction for decision-making and policy development in demand response program design. This differentiation is key to crafting strategies that effectively manage energy consumption and efficiency. Building on this conversation, O’Reilly et al. (2024) explore ten specific appliances that can be controlled throughout Europe, with EVs highlighted due to their considerable electricity consumption. Despite their substantial energy consumption, EVs also present an opportunity to serve as economic assets for households, a potential detailed by Pal & Kumar (2018). This comprehensive approach to appliance management within demand response programs is vital for addressing the challenges of energy use while capitalizing on the economic benefits available to households.

An EMS is crucial for the effective operation of demand response programs. The study by Enrich et al. (2019) has been instrumental in advancing EMS by developing a new architecture that enhances the system’s efficiency. Moreover, there’s a noticeable variation in the focus of different studies regarding which appliances are managed by EMS. For example, Chung et al. (2023) specifically explores the management of washing machines and clothes dryers. In contrast, Pal & Kumar (2018) broaden their investigation to include EVs and other devices. Additionally, these studies differ on whether households have the capability to share their self-generated or stored energy, indicating the wide range of strategies and capabilities considered in the design of EMS in demand response.

Demand response challenges

Demand Response programs are designed to manage energy consumption effectively, but they face several challenges, as identified by Bakare et al. (2023) and Weck et al. (2017). These challenges include technical, economic, and regulatory issues. One challenge is the occurrence of “peak load shifts” or “peak rebounds,” a phenomenon where customers’ similar responses to time-of-use electricity pricing inadvertently create new demand peaks, as discussed by Muratori & Rizzoni (2016).

In response to these complexities, Chen et al. (2023) introduced an innovative approach to smartly manage electricity usage, focusing on tailoring energy savings to individual preferences and comfort levels while minimizing inconvenience. Their model leverages the concept of Community Energy Aggregators (CEAs), which act as neighbourhood coordinators. These CEAs gather the energy preferences of the community and negotiate with the power grid on their behalf, ensuring energy usage is optimized without overwhelming residents with the technicalities of energy management. This method not only makes energy saving more personal and effective but also streamlines the process by acting as a bridge between consumers and the power company.

Moreover, Bakare et al. (2023) argue that a singular strategy is insufficient for addressing the complexities of Demand-Side Management (DSM) due to poor performance and slow convergence rates. They recommend the use of multiple algorithms to enhance the system's efficiency. Privacy concerns within demand response programs are also addressed by Rong et al. (2023), who suggest enhancing user privacy using rechargeable batteries and smart home appliances. This approach not only safeguards privacy but also enhances the overall effectiveness and efficiency of demand response initiatives.

Cooperation and incentives

The study conducted by Rana & Grof (2024) delves into the innovative concept of intra-household energy trading, facilitated using a demand management system. This research highlights a two-fold advantage of the system: Firstly, it showcases that local trading of energy within a neighbourhood can significantly increase profits beyond the savings achieved from reduced energy consumption during peak hours. Secondly, it describes a model where this energy trading is executed "behind the meter," thus eliminating the need for grid operator involvement in the transactions. The findings illustrate a collaborative framework among households, leveraging this cooperation to further enhance their financial gains. This approach not only proposes a novel method for energy management but also emphasizes the potential for community-based strategies to increase economic benefits while promoting sustainable energy practices.

The paper by Hu et al. (2021) provides a comprehensive review and summary of the classifications, technologies, architectures, and techniques for neighbourhood-level coordination and negotiation within residential neighbourhoods. It underscores the importance of achieving harmonized coordination among different entities to ensure both grid reliability and economic benefits, while also noting that such coordination can mitigate peak rebounds. Despite the encouragement for residential consumers to participate in demand response programs, the paper points out that uncoordinated efforts are likely to fall short of anticipated benefits, potentially leading to issues such as rebound peaks. Al Zahr et al. (2021) further illustrates this point by comparing collaborative scenarios within smart neighbourhoods, which, despite slightly increasing costs by about 1.06% to 2.75%, can significantly reduce peak load moments by approximately 42 to 46%.

In contrast, the study conducted by Hofmann & Lindberg (2024) observes that, on average, households do not show a significant short-term price response to daily or hourly price variations. However, notable exceptions exist among subgroups, particularly those that actively monitor hourly prices through real-time information channels and those with automated smart charging for EVs. These groups demonstrated a higher propensity for reducing load during peak price hours and shifting their energy use to periods of lower prices, indicating the presence of some incentives for participation.

Parrish et al. (2020) delve into the motivations for participation in demand response programs, as well as the barriers and enablers to engagement, including aspects such as familiarity and trust, perceived risk and control, complexity and effort, and consumer characteristics and routines. This highlights the nuanced nature of consumer participation in these programs.

Mohd Zahid & Aki (2024) argue against the optimistic assumption that all consumers will participate in demand response programs, noting real-life challenges such as insufficient incentives, response fatigue, or emergencies that preclude participation. This variability in consumer engagement directly impacts the flexibility available to the system and its economic efficiency, emphasizing the need for realistic expectations and strategies to enhance participation in demand response initiatives.

Value

Demand response programs present a variety of benefits and considerations for different stakeholders. Sridhar et al. (2022) offers comprehensive insights into various demand response strategies and their potential trade-offs, empowering consumers to make informed decisions about their participation. Weck et al. (2017) identify price-based demand response and direct load control as the two most promising options for households within smart grids, although they acknowledge barriers to their adoption, noting that these programs might not always align with the interests of market players or DSOs.

Tuunanen et al. (2016) propose a methodology for implementing profitable demand response programs, focusing on the equitable distribution of benefits among DSOs and market participants. A key finding of their study is the necessity for collaboration among different market stakeholders to foster an active demand response market, which would require the introduction of new pricing models to establish a viable business case. They also suggest the possibility of introducing new pricing strategies to customers, such as providing a monthly financial incentive for participation in demand response programs.

Nijhuis et al. (2015) explore the nuanced perspectives of various stakeholders towards demand response programs, highlighting how a barrier perceived by one party might be seen as beneficial by another. Their study contrasts a demand response program from an energy supplier, which focuses on electricity pricing, with one from a network operator, which is based on network load management. The benefits of these programs can vary significantly depending on the grid topology. For example, demand response from an energy supplier's viewpoint might cause under-voltages, necessitating grid reinforcements, while load shifting from a network operator's perspective could lead to higher electricity costs. This analysis, encapsulated in a case study from the Netherlands, underscores the complexity of implementing demand response programs and the importance of considering the diverse impacts on different stakeholders.

B Demand response

In this section, the demand response program is clearly explained using a UML diagram. This diagram enhances understanding by detailing the information flow and decision-making processes. Additionally, the EMS application is visualized and described to show how households receive messages. This analysis corresponds with section 3.1.1 of the document.

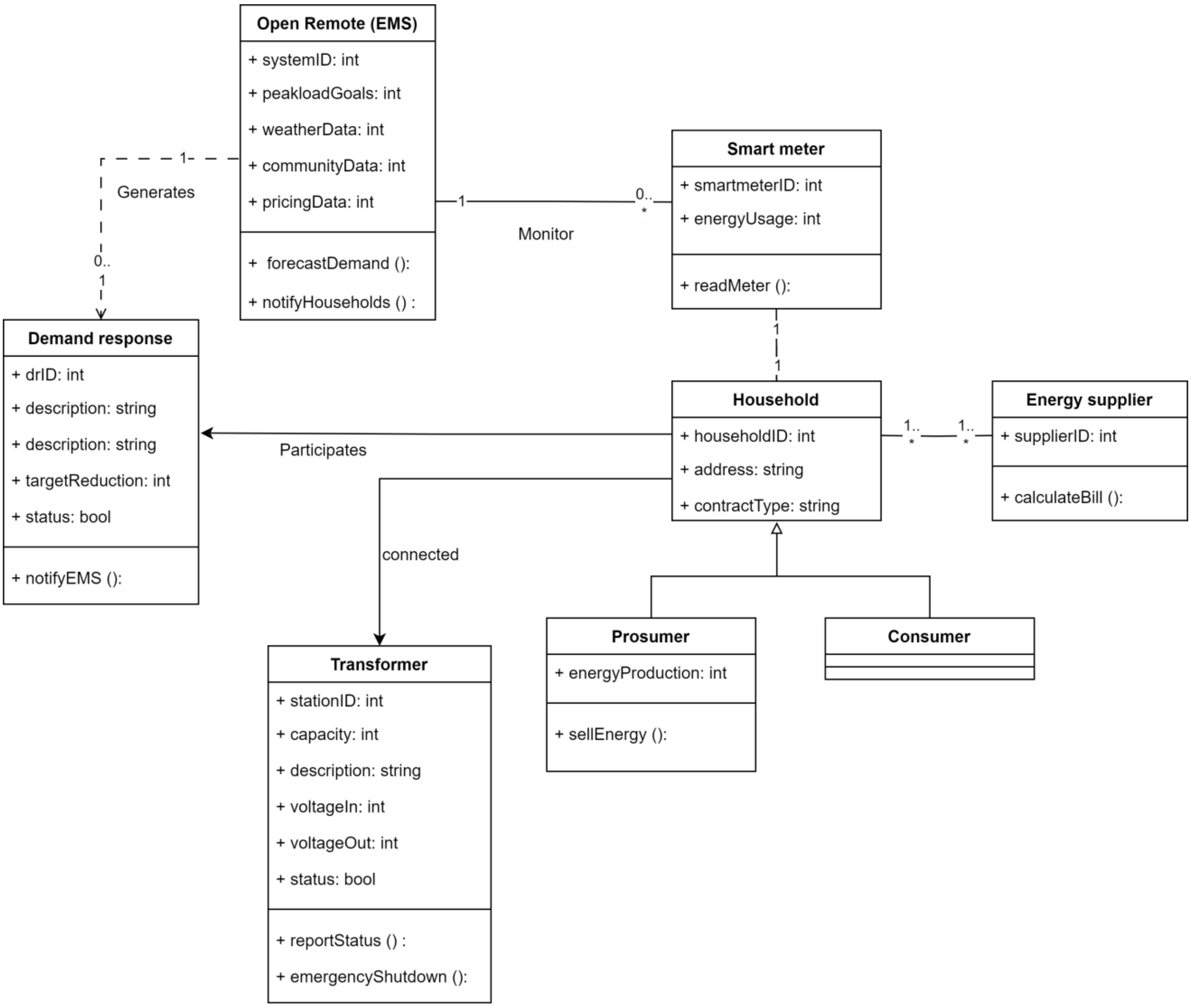

Figure 17: B UML diagram

In Figure 18 the application from the EMS system is visualized. During periods of high demand on the electrical grid, an app challenges participants to reduce their energy consumption, a strategy outlined in Step 1. This includes actions such as turning off non-essential appliances like dishwashers or washing machines and postponing energy-intensive activities such as EV charging, cooking, or heating, as detailed in Step 2. After completing the challenge, participants earn points that can be exchanged for money at the year's end, as seen in Step 3 (Open Remote, 2024). This method lies at the heart of an incentive-based demand response program designed to balance energy supply and demand efficiently during peak times.

1

1563

Watt

Onze wijk zit in piekbelasting!

Help mee door nu energie te besparen. Gebruik tijdens deze challenge maximaal **600 watt**

16:00 tot 17:00

maximaal 10 punten

2

485

Watt

600W max

4/10 punten

Onze wijk zit in piekbelasting!

Help mee door nu energie te besparen. Gebruik tijdens deze challenge maximaal **600 watt per minuut.**

Tips

Manieren om energie te besparen

3

Uitdaging voltooid!

Bedankt voor het deelnemen aan deze uitdaging.

Je hebt in totaal **453kWh bespaard** en **4 punten verdiend**

Figure 18: B Application EMS

C CLD method

For the CLD, first a socio-technical analysis is made to create a better understanding of the key structures, processes, and drivers of an energy community. After that, literature research is conducted to identify the factors that contribute to the success of an energy community, and this knowledge is finally combined into a CLD. In this appendix, both the socio-technical analysis and the literature research is visualised. This analysis corresponds with section 3.2 of the document.

In energy communities, the seamless interplay of processes, structures, and drivers is important for their development and functionality (Ruijgh et al., 2023) . Processes enable the community to achieve its goals through a series of actions and interactions, while structures provide the necessary organizational and physical framework. Drivers motivate the community towards these goals, influenced by both external pressures and internal aspirations. Achieving success relies on the balance between technical aspects, such as solar panels and wind turbines, and social constructs, like governance models and energy-sharing agreements. This balance supports vital operations like energy generation, storage, and distribution, all directed towards sustainability. The dynamic relationship between the community's social agreements and its technical systems is central to propelling energy communities towards their goals of sustainability, reducing peak loads, ensuring affordable energy costs, and attaining self-sufficiency.

Key structures	**Explanation**
Renewable energy installations	Physical infrastructure for generating renewable energy, such as solar farms from cooperations or individual rooftop solar panels.
Smart grid technology	Sophisticated grid infrastructures that facilitate efficient energy distribution, smart metering, and real-time monitoring. Examples of smart grid technologies include smart meters, IoT devices, and EMS
Governance framework	Organizational structures outlining roles, responsibilities, and decision-making protocols within the community, as detailed in the community agreement
Legal & Regulatory framework	The policies and regulations that govern energy production, consumption, and sharing in the community
Community platform	Digital or physical spaces that enable communication, collaboration, and knowledge sharing among members. The Open Remote application serves as the digital space, while the rented meeting room used for annual gatherings represents the physical space
Important processes	**Explanation**
Energy generation	The creation of energy using renewable sources
Demand response challenge	The launch of a demand response challenge where households are encouraged to participate.
Energy sharing & trading	The mechanisms through which community members share excess energy or trade it within and beyond the community boundaries
Decision-making	Collective decision-making processes that involve community members in governance, operational choices, and strategic planning
Primary drivers	**Explanation**
Sustainability goals	The collective aim to reduce carbon footprints, utilize renewable energy sources, and minimize environmental impact.
Economic incentives	The desire to achieve cost savings, energy independence, and generate income through energy trading.

Technological advancements	Innovations in renewable energy technology and smart grid systems that make sustainable community energy systems feasible and efficient
Social cohesion & empowerment	The drive to create a resilient community bound by shared goals, mutual support, and collective efforts toward energy sustainability, where the participation of neighbours encourages others to join the community more readily
Policy and regulatory support	Support from governmental and regulatory bodies, manifested through incentives, subsidies, and policies favourable to renewable energy initiatives, exemplified by the Reschool funding and the potential future option for households to share energy

Table 13: C Socio technical analysis

Factor	Explanation	Source
CO2 emission	Achieving a clear and measurable reduction in the carbon footprint, with established targets and transparent reporting methods to monitor and report CO2 emissions reductions effectively	Zardi,2015
Solar power capacity	A strong focus on harnessing renewable energy resources like solar panels to produce local energy	-
Energy sharing	Facilitating energy sharing among community members, which benefits all both consumer and prosumer, this means maximizing the use of energy when it is produced	-
Economic value	Ensuring the economic model provides profitability and advantages for all stakeholders within the energy community, maintaining overall satisfaction and support	Zardi,2015
Adoption rate	Monitoring the rate at which households join the community, including the installation of smart meters and downloading of relevant applications	-
User-friendliness	Design technology and systems that are user-friendly, ensuring that all community members can effortlessly install smart meters, use the application, and participate in the challenges	Madriz-Vargas et al., 2015
Active neighbourhood engagement	Direct participation of households and stakeholders, fostering a neighbour influence effect that encourages wider involvement. This can include educational initiatives aimed at informing community members about the initiative's goals and how it operates	Zardi, 2015
Scalability	Capacity for the system to scale up and modify as the community's requirements expand	-
Privacy	Robust data management protocols to safeguard the privacy and integrity of consumption data	Rong et al., 2023
Participation in challenges	The rate at which households participate in challenges issued by the EMS system	-
Effect on the transformer	How participation in these challenges impacts the peak loads managed by the transformer	-
Regulatory adherence	Ensuring compliance with all relevant legal regulations, including environmental laws and construction codes	Ahlemeyer et al., 2022
Government support	Active support from governmental bodies, underpinned by enabling subsidies and regulatory frameworks	Ahlemeyer et al., 2022
Restorative leadership	Organizing group decision-making processes, monitoring, and enforcing rules, resolving conflicts, and adapting to environmental changes	Ostrom, 1990

Table 14: C Main factors

In Table 17 the main factors are visualized in bold text, and the subfactors that fall under these main factors are visualized in regular text.

D Causal loop diagram

In this section, the CLD is elaborated using both formulas and additional textual explanations. The explanation aims to provide a deeper understanding of the dynamics captured by the CLD. Additionally, a visualization of the CLD without energy sharing is presented at the end of the section to illustrate the system’s behaviour in this specific scenario. This section corresponds with section 3.2 of the document.

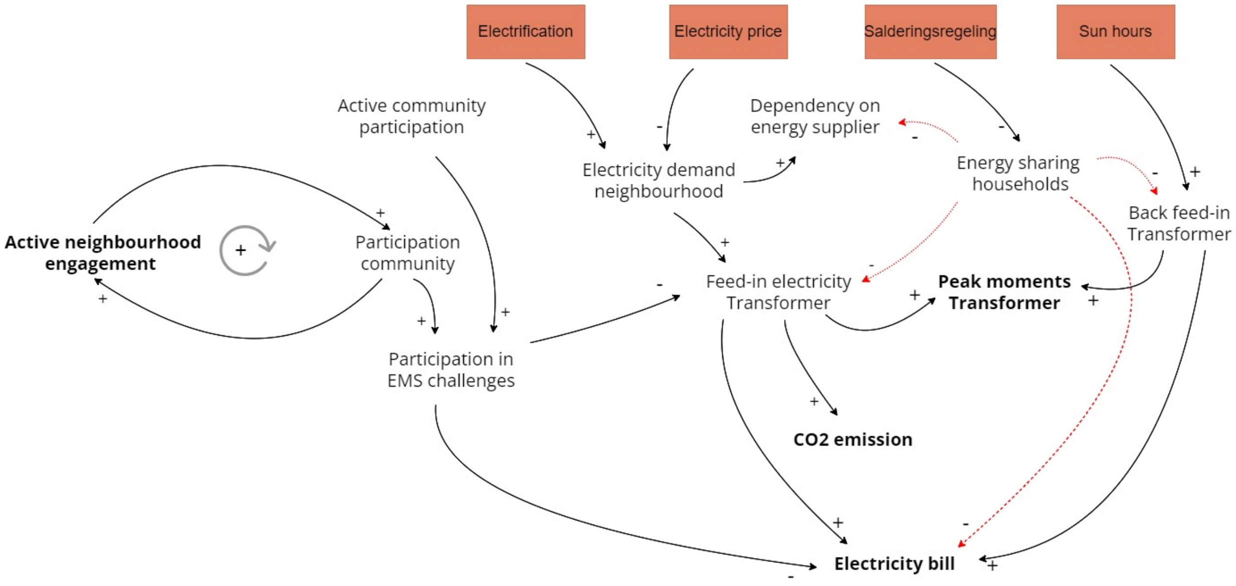

Figure 19: D CLD with energy sharing

Causal Loop Diagram explained

The CLD presented is designed at a higher level of abstraction to enhance clarity and comprehension. Consequently, while the diagram illustrates how variables influence each other, it’s important to note that some of these influences are indirect. There are intermediary steps required to fully understand the dynamics at play. These intermediary steps and the specific mechanisms through which variables interact are detailed in the equation table below. This approach ensures a more comprehensive understanding of the system’s interactions and the causal relationships within the energy community. The factors are a categorized variable

Equations within CLD	Explanation	Unit
$F = \frac{N_{Activeneighbourhood}}{N_{Households}} \times (J+1) \times \rho$	$F =$ *Active neighbourhood engagement* $N_{Activeneighbourhood} =$ *Households active in neighbourhood* $N_{Households} =$ *Households in Sporenburg* $J =$ *Participation community* $\rho =$ *Recovery factor participation*	– *Number* *Number* *Factor* *Factor*
$J = \frac{N_{join}}{N_{households}} \times (F+1) \times \gamma$	$J =$ *Participation community* $N_{Join} =$ *Households joined the community* $\gamma =$ *Recovery factor active community engagement*	*Ratio* *Number* *Factor*
$N_{participate} = J \times N_{households} \times U \times \delta$	$N_{participate} =$ *Household participation in EMS challenges* $U =$ *Active community participation* $\delta =$ *Average households home at time the challenge was isseud*	*Number* *Ratio* *Factor*
$U = \frac{N_{Activecommunity}}{N_{Join}}$	U = *Active community participation* $N_{Activecommunity} =$ *Households active in community*	*Ratio* *Number*
$B = E_{feedin} \times P - E_{shared} \times M_{sharing} - E_{backfeed} \times M_{Backfeed} - N_{participate} \times M_{challenge}$	$B =$ *Electricity bill* $E_{feedin} =$ *Feedin electricity MSR* $P =$ *Average electricity price* $E_{backfeed} =$ *Backfeed electricity MSR* $M_{backfeed} =$ *Average selling price backfeed in* $E_{shared} =$ *Energy shared by households* $M_{sharing} =$ *Average money earned with sharing* $M_{challenge} =$ *Average money earned challenges*	*€* *kWh* *€/kWh* *kWh* *€/kWh* *kWh* *€/kWh* *€/part*
$E_{feedin} = E_{demand} - E_{shared} - N_{participate} * E_{challenge}$	$E_{demand} =$ *Electricity demand neighbourhood* $E_{challenge} =$ *Average energy savings challenges*	*kWh* *kWh*
$E_{demand} = \sum_{i=1}^{n} E_{demandh} \times \partial \times \forall$	$E_{demandh} =$ *Average electricity demand household* $\partial =$ *Electrification* $\forall =$ *Electricity price*	*kWh* *Factor* *Factor*
$E_{shared} = \sum_{t} \min\left(E_{oversolar}(t), (E_{demandsynch}(t) \times \in)\right)$	$E_{oversolar} =$ *Overproduction solar* $E_{demandsynch} =$ *Electricity demand neighbourhood simultaniously* $\in =$ *Net metering regulation*	*kWh* *kWh* *Factor*
$E_{oversolar} = E_{produced} - E_{consumedsolar}$	$E_{produced} =$ *Electricity produced solar panels households* $E_{consumedsolar} =$ *Electricity consumed solar panels households*	*kWh* *kWh*
$E_{consumedsolar} = \sum_{t} \sum_{i=1}^{n} \min(E_{producedh}(t), E_{demandsolarh}(t))$	$E_{demandsolar} =$ *Electricity demand household with solar panels*	*kWh*
$E_{produced} = \sum_{i=1}^{n} E_{producedh}$	$E_{producedh} =$ *Electricity produced solar panels household*	*kWh*
$E_{producedh} = S \times \mu \times Z$	$S =$ *Covered surface solar panels* $\mu =$ *Efficiency factor* $Z =$ *Sunhours*	*m2* *kW/m2* *h*
$E_{backfeed} = E_{oversolar} - E_{shared}$		
$A = \frac{(E_{consumedsolar} + E_{shared})}{E_{demand}}$		
$CO2 = E_{feedin} \times \emptyset$	$CO2 =$ *CO2 emissions* $\emptyset =$ *CO2 emitted*	*kg CO2* *kg CO2/kWh*
$N_{peak} = \sum_{t} E_{feedin} \cup E_{backfeedin} > C_{max}$	$N_{peak} =$ *Peak moments transformer* C_{max} = *Criribig zone transformer*	*Number* *kWh*

Table 15: D equations CLD

Equations within the CLD

Active neighbourhood engagement

This formula calculates the proportion of people who are active within the neighbourhood. Households actively involved in the neighbourhood are those willing to participate in the energy community. This can include households that have already joined as well as those that have not yet joined. This factor is strengthened by community participation because the more people who join the community, the more they can share information and encourage others to participate. The recovery factor ensures a fair output and accurate representation of the real world.

Participation community

This formula calculates the proportion of people who have joined the community. This factor is strengthened by active neighbourhood engagement because the more people are active within the neighbourhood, the more likely others will join the community. The recovery factor ensures a fair output and accurate representation of the real world.

Participation in EMS challenges

This represents the number of households participating in challenges sent out by the EMS system, thereby adjusting their electricity usage. It is calculated by multiplying the community participation by the number of actively involved community members, and then by the average number of people who are at home during the time the challenge is sent out.

Active community participation

This formula calculates the proportion of people who are active within the community. Active households are those willing to participate in a challenge when they receive a notification. Households that have joined the community are those that have installed the smart meter and the application.

Electricity bill

The electricity bill represents the total cost of electricity for the neighbourhood. It is calculated by multiplying the amount of electricity supplied by energy providers to customers by the average electricity price. Prosumers can reduce their electricity bill by subtracting the overproduction from solar panels after their own consumption and the amount of shared electricity from the total costs. The average money earned from sharing includes both the price benefits for production and consumption. Additionally, any money earned from participating in challenges is subtracted.

Feed in electricity transformer

This represents the total electricity that flows through the transformer station. It is calculated by taking the total electricity demand and subtracting the electricity that is shared, and the electricity reduced through challenges. The average electricity reduced per challenge is the amount a household no longer uses because of its participation in the challenge, making this electricity unnecessary. The electricity consumed from solar panels is not subtracted because it is already included in the average household electricity demand.

Electricity demand neighbourhood

This represents the total electricity demand from the neighbourhood. It is calculated by taking the average electricity demand of a household and multiplying it by the electrification factor and the electricity price factor. As people pursue sustainability goals, they increasingly purchase electric devices like cars, heat pumps, and batteries, which impacts electricity demand. Additionally, electricity prices influence demand; higher prices tend to lower demand as people become more efficient with their electricity usage.

Energy sharing households
This is the total amount of energy shared by households over time. It assumes that overproduction is consumed by households when they have demand during overproduction. The demand for electricity will be lower when the “salderingsregeling” (net metering regulation) remains part of the law. This is because under net metering, consumers have a reduced incentive to use electricity simultaneously with its production. The amount of shared electricity cannot exceed the amount overproduced by these panels. To accommodate this, the formula uses the minimum function.

Overproduction solar
This is calculated by subtracting the electricity consumed by households with solar panels from the solar power they produce

Consumed solar panels households
The electricity produced by prosumers, which they consume themselves, is described by a time-dependent formula. This calculation operates under the assumption that when electricity is generated and there is simultaneous demand within the household, the produced electricity directly meets the household’s demand. The amount of electricity consumed from solar panels cannot exceed the amount overproduced by these panels. To accommodate this, the formula uses the minimum function.

Produced solar power households
The total solar production for all households is calculated by summing up the individual solar outputs from each household.

Produced solar power household
Each household’s solar production is determined by multiplying the number of sunlight hours by the surface area covered by solar panels and then by the efficiency factor of those panels.

Back feed-in electricity transformer
This process involves electricity that is fed back into the transformer, where it is transformed to the medium voltage network and subsequently distributed to other consumers in the network. The number of sunlight hours lead to an overproduction of solar energy. Consequently, this excess production increases the electricity back feed-in.

Dependency on energy supplier
This factor indicates how dependent households are on energy suppliers. It is calculated by adding the amount of electricity they consume from their own solar panels to the amount of electricity that is shared, and then dividing this sum by the total electricity demand.

CO2 emissions
This represents the CO2 emissions resulting from electricity feed-in. It operates under the assumption that the CO2 emission factor represents the average emissions produced by generating one kWh of electricity. This factor considers the composition of the electricity mix, which includes both fossil fuel and non-fossil fuel sources.

Peak moments transformer
This represents the number of times the electricity feed-in exceeded the critical zone of the peak load from the transformer. When production surpasses consumption, the electricity back feed-in can reach the critical zone as well. Therefore, the formula uses an OR sign.

CLD without energy sharing

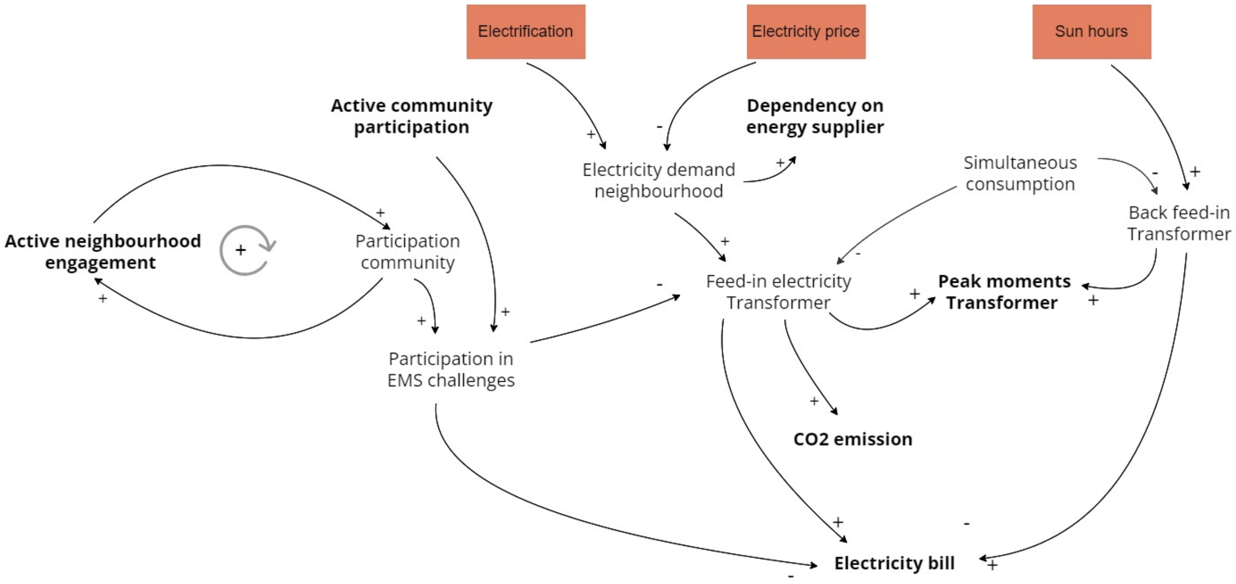

Figure 20: D CLD without energy sharing

E future situation

This section assesses the future state of the transformer under various scenarios by analysing key factors such as the capacity of solar panels, the electricity demands of electric vehicles, and household electricity needs. It also evaluates the number of daily electric vehicle charging sessions and their distribution, enabling simultaneous charging. The analysis begins by exploring five different scenarios. Then, it calculates and forecasts the current solar power capacity, followed by an assessment of the electricity demands of electric vehicles. The section concludes with an explanation of the transformer’s maximum capacity. This appendix corresponds with section 3.4 of the document.

Scenario’s

The sustainability goals in Amsterdam are quite ambitious regarding the adoption of solar panels and EVs. Consequently, four different scenarios for 2030 are proposed. The Municipality of Amsterdam aims for all cars operating in the city to be emission-free by 2030; therefore, one scenario assumes a 100% EV adoption rate. According to ElaadNL (2024), it is projected that 50% of people in the Netherlands will own an EV by 2035. In Amsterdam, however, it is assumed this milestone is expected to be reached by 2030, leading to a scenario where the city achieves a 50% EV adoption rate. For solar panels, it is projected that there will be a 30% annual growth rate compared to 2030 (Netbeheer Nederland, 2030), and Amsterdam aims to have 50% of all its available space covered with solar panels. One scenario considers the 30% growth, while another scenario considers a 15% growth.

Scenario		**Variable**	**2023**	**Unit**
0		Solar capacity	394.000	kWh
		Electricity demand EV	106.091	kWh
		Variable	**2030**	**Unit**
1	100% EV & 100% solar	Solar capacity	1.360.850	kWh
		Electricity demand EV	680.610	kWh
2	50% EV & 100% solar	Solar capacity	1.360.850	kWh
		Electricity demand EV	340.305	kWh
3	100% EV & 50% solar	Solar capacity	680.000	kWh
		Electricity demand EV	680.610	kWh
4	50% EV & 50% solar	Solar capacity	680.000	kWh
		Electricity demand EV	340.305	kWh

Table 16: E Scenario’s

Solar power

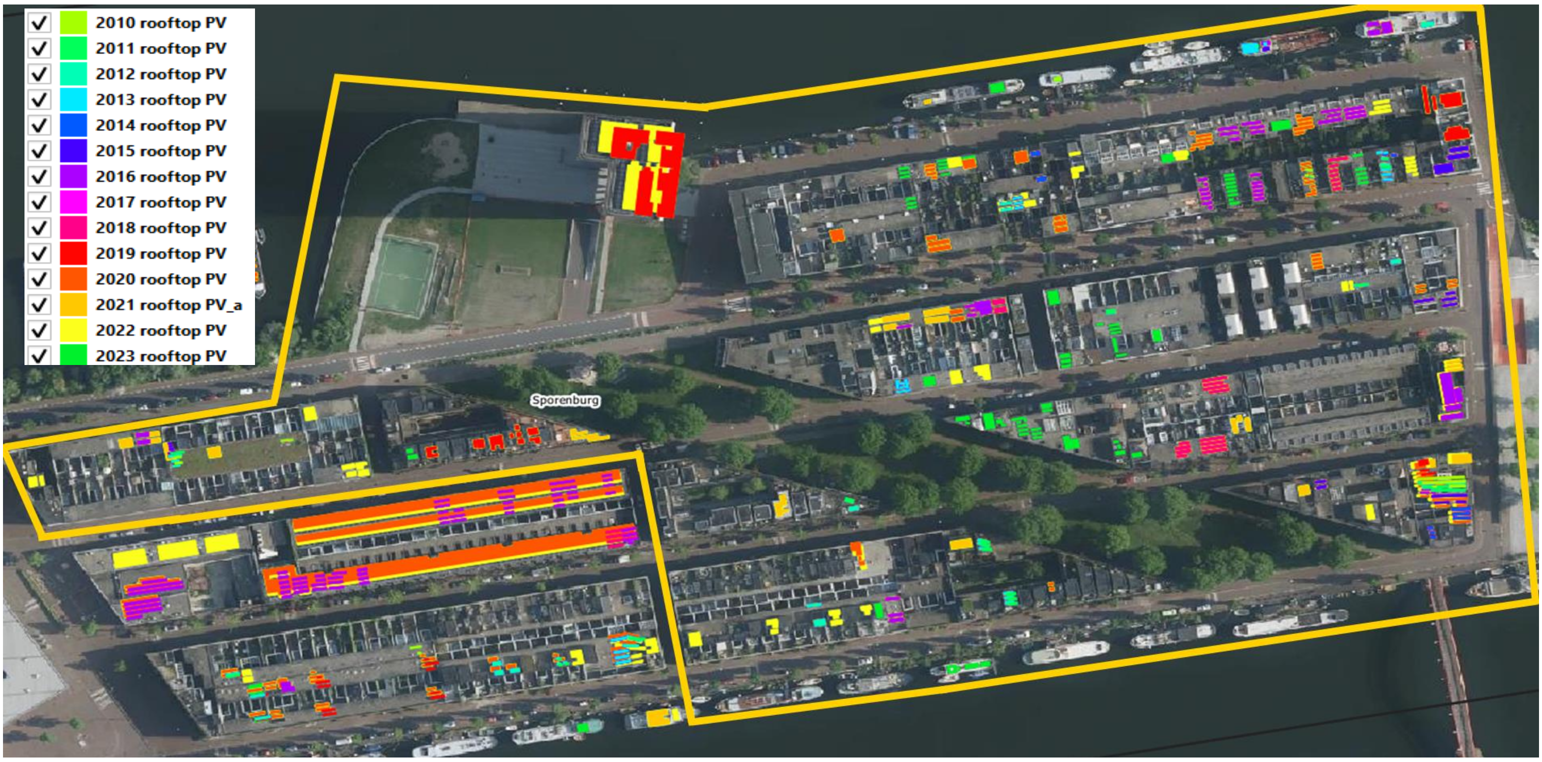

Figure 21: E QGIS solar panels

QGIS is a free, open-source Geographic Information System (GIS) software that enables users to edit, visualize, and analyse geospatial information (Qgis, 2024). It is useful for calculating the area of solar panels in the residential neighbourhood Sporenburg, which is visualized in Figure 21.

Since the solar panel areas are not pre-defined, they must be manually digitized using QGIS's editing tools. This process involves drawing polygons over the areas covered by solar panels on imported imagery or maps. Once the solar panels are mapped, QGIS's field calculator is used to compute the area of each polygon, representing the solar panels. Currently, a total area of 2,265 square meters is covered with solar panels. Looking ahead to 2030, there is anticipated a growth of 30% more solar panels each year compared to 2023. This growth rate is considered reasonable as it aligns with the approximately 30% growth experienced last year and is necessary to meet climate targets (Netbeheer Nederland, 2024) (Ministry of Economic Affairs, 2023). Consequently, it is expected that by 2030, there will be 7,021 square meters of solar panels in the Sporenburg neighbourhood.

For projections in 2023, a yield of 205 Wp (Watt peak) per square meter is used for the solar panels, slightly below the current average of 228 Wp per square meter (Voltasolar, 2024). This accounts for the age of the solar panels in this neighbourhood.

EV electricity demand

From the FlexPower project (ElaadNL, 2019) and other charging sessions, data have been gathered, providing insights into typical charging behaviours, which have informed the creation of charging profiles. This is done by Resourcefully and utilized in the dashboard (model from resourcefully), which now enables the simulation of charging behaviour for 2023. It is assumed that the charging behaviour will remain stable. By 2030, the charging sessions are expected to mirror those in 2023 in duration but will increase in frequency. The total number of EV charging sessions for 2023 and 2030 has been forecasted based on the annual energy demand for EVs.

To calculate the annual energy demand for EVs, the average distance driven by a car and the efficiency of EVs are used. Additionally, the number of cars per household in the area is considered. The final calculation is performed using the formula below:

$$annual\ E_{demand}\ MSR = \ km\ driven * \frac{efficiency}{100} * Number\ of\ EV$$

The average kilometres driven per vehicle is assumed to be 11,750 km per year. This average is calculated based on data from CBS, which showed that during a year influenced by COVID-19, the average was 10,600 km (2022 data), whereas in 2019, a non-pandemic year, it was 12,900 km. The selected average considers the possibility of continued remote working post-pandemic, but not to the extent observed during the peak of COVID-19 restrictions.

Efficiency in EVs is typically measured by their energy consumption over distance, expressed in kWh per 100 kilometres. The top three best-selling EV models—Tesla Model 3, Hyundai Kona, and Kia Niro—have an average efficiency of 15.83 kWh/100km (Netherlands Enterprise Agency, 2022) (Gitlin, 2023) & (Misoyannis, 2024). These models are recent, so the efficiency rate of 15.83 kWh/100km may not yet represent the average for all vehicles, which can vary between 15 and 30 kWh/100km. Consequently, a more conservative estimate of 20 kWh/100km is chosen for 2023 calculations. For projections in 2030, the rate of 15.83 kWh/100km is used.

The number of EVs in an area can be determined by using the EV adoption rate in conjunction with the number of cars per household. In the context of transformer Sporenburg, with its 556 households and an average of 0.66 vehicles per household, the projected maximum number of EVs in Sporenburg would be 366.

The annual energy demand prediction from EVs in the transformer cannot be directly used in the dashboard because the dashboard relies on charging profiles and power ratios to forecast the charging conditions in each area, using the number of daily sessions as input. Consequently, the energy prediction must be converted into a weekly session count.

Charging sessions

The number of weekly charging sessions, categorized by Friday, Saturday, Sunday, and the remaining weekdays, determines the total energy charged throughout the year for each iteration. The dashboard creates a profile for each EV based on their specific charging profiles, power ratios, and the frequency of charging sessions. It’s not possible to know precisely how many sessions will be needed to match the energy amount predicted for each scenario. To ensure accuracy, the dashboard simulates the scenario until the energy demand from the simulation aligns with the predicted demand from the static method. Once the average number of weekly sessions is known, it can be allocated across the different days of the week.

It makes sense that the number of charging sessions differs between weekdays and weekends. Additionally, the frequency of daily charging sessions varies, which is why data of the number of charging sessions from the Sporenburg area is utilized to estimate the potential number of sessions. This involves determining a logical maximum number of daily charging sessions based on current trends. To achieve this, current data on the number of public charging sessions in Sporenburg is used to project a reasonable estimate for the year 2030. Unfortunately, there is no available data on private charging sessions. Various simulations are conducted to identify a realistic scenario that considers both public and private charging stations, along with the total electricity demand from EVs. This analysis resulted in a scenario that projects the maximum demand for electricity from EVs in 2030. The characteristics of this scenario are detailed and in Table 17.

Electricity demand households

Another input variable is the electricity demand from households. Using data from Liander (2023) on average electricity usage, along with postal code data from PDOK (2024), the average electricity usage within the neighbourhood Sporenburg can be calculated. For 2023, this figure is 3,165 kWh. It is assumed that electricity usage will remain the same by 2030, as the increase in electrification, which typically raises electricity consumption, is offset by improvements in the efficiency of electrical products.

Variable	2023	Scenario 4,5	Scenario 2,3	Unit
Max charging sessions on a day	22	120	240	Number of charging sessions
Max charging points occupancy	15	68	132	Number of charging points occupied
Charging peak	100	382	709	kW
Average charging demand per vehicle at charging peak	6.66	5.6	5.4	kW
Max household demand peak	535	535	535	kW
Max peak to grid (solar)	204	1044/450	989/395	kW

Table 17: E Characteristics scenario's

MAX transformer load

In a transformer substation with a specified capacity of 1000 kVA, the actual power (P) that can be effectively utilized is determined by multiplying the apparent power (S) by the power factor (PF). In this case, the power factor is 0.85, which represents the efficiency with which electrical power is converted into usable work. The power factor is a measure of the cosine of the phase angle between the current and voltage in an AC system, reflecting the ratio of actual power to apparent power. A power factor of 0.85 indicates that 85% of the apparent power is converted into actual power.

Given the transformer substation's capacity of 1000 kVA, the actual power is calculated as follows: $P = S * PF = 1000kVA * 0.85 = 850kW$. This calculation shows that, despite the nominal capacity of 1000 kVA, only 850 kW of power is effectively available for the neighbourhood.

F Power interest grid

In the figure below the power interest grid before the interviews is visualised. This analysis corresponds with section 4.2 of the document.

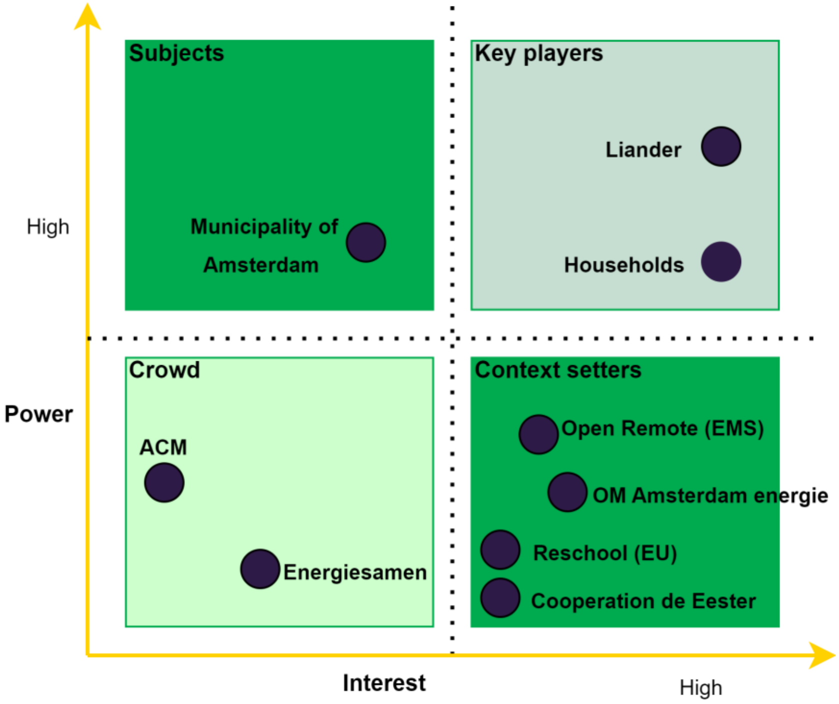

Figure 22: F Initial power interest grid

G Interview questions

In this section, the interview questions designed for the semi-structured interviews are visualized. These questions, which are utilized in section 4.3.2 for stakeholder interviews, are presented to give a clear overview of the topics and themes explored during the discussions.

Theme	Research question
Intro	Intro about myself Intro about the project Question about their background and role in the organization
Interest	What are your interests within the community?
Actions	What specific actions can you take within this community?
Barriers	What are the things you absolutely do not want to happen within this community? Where do you see challenges or difficulties within this community? What are your expectations from other stakeholders in this community? Who, in your opinion, should take the lead or make drastic changes?
Succes	What factors do you consider to be critical for the success of this community?
Stakeholder specific question	~

Table 18: G semi structured interview questions

H Stakeholder analysis

In this section, the results from the initial analysis of the stakeholders, along with the outcomes from the interviews, are visualized. The initial tables, labelled as ‘General,’ are based on assumptions and serve as a preliminary overview. The subsequent tables incorporate additional information from the interviews to ensure that no interests or actions that might have been initially overlooked are captured. This appendix corresponds with section 4.3.2 of the document.

 General	All households are connected to a heating network and use electricity for cooking, resulting in eight different household stakeholders: those with and without solar panels, those with and without an EV, those who join or do not join the community and install a smart meter and download the Open Remote EMS application, and those with and without a private EV charging point. In theory, there could be many more combinations.
Interests	Low and stabilized energy costs Minimization of carbon footprint Energy security with continuous availability of electricity Secure handling of private data
Actions	Modify energy consumption patterns for cooking, EV charging and heating by: • Respond to prompts and challenges from EMS app by lowering their energy consumption • Adjust usage in response to excess production from renewables by charging the EV or using other high consumption systems like washing machine and dishwasher Invest in energy efficiency projects: • Solar panels or batteries on own property • Collaborate with others in a solar park project • Smart grid technologies such as IoT devices • Insulation and appliances with high-efficiency ratings Choose different types of energy contracts that offer advantages like variable rates versus fixed rates or that facilitate energy sharing Utilize personal professional expertise and knowledge to educate and encourage neighbours to participate in the energy community Distribute flyers, share info in neighbourhood app or organize event Buy an EV

	Household 1: Hybrid car, EV charging point, solar panels, 2 person household, fixed energy contract
Interests	Fostering of a neighbourhood feeling within the energy community Enjoyment of the process of experimentation
Actions	

	Household 2: No car, solar panels, dynamic energy contract and 2 person household
Interests	-
Actions	-

	Household 3: Fossil fuel car, solar panels, 3 person household.
Interests	Financial support for households with limited financial resources Fostering of a sense of collaboration within the neighbourhood
Actions	

	Household 4: Fossil fuel car, solar panels, dynamic energy contract, 2 person household
Interests	Reduction of district heating costs
Actions	Discuss and negotiate with the district heating company to make heat generation more sustainable Invest in a collective heat pump with the neighbourhood

The Amsterdam city municipality can significantly influence the energy community through the implementation of policies, the enhancement of infrastructure, and educational campaigns. Their focus is on sustainability, economic growth, and ensuring equitable access to energy. Achieving the 2030 climate goals, which include ambitions for zero-emission mobility necessitating 65.000 charging points, a sharp increase from the 10.000 available in 2020, illustrates just one of Amsterdam's ambitious plans for sustainability. Moreover, power capacity is crucial not only for supporting economic vitality within high-demand sectors, where currently 350 companies are on the waiting list for an electricity network connection (Liander, 2023), but also for guaranteeing fair energy distribution. Amsterdam leverages financial incentives, legislative measures, and public assets, demonstrating its capacity to guide and adjust the use of these assets and remain flexible in power consumption, especially during periods of high demand, as evidenced by projects like FlexPower.

Gemeente Amsterdam	General
Interests	Achievement of sustainable neighbourhoods: • Electric cooking • Heat pump • Solar panels • EV charging stations Promotion of economic growth Guarantee of equitable energy access for stakeholders Assurance of continued construction and development in residential areas
Actions	Organizing an event to inform households about the value of the energy community Provide subsidies and advice in energy efficiency projects, such as solar panel installations or home insulation for households within VVE Manage and install public assets such as street lighting and public buildings

Gemeente Amsterdam	Private/semi-public EV charging infrastructure
Interests	Transition from fossil fuel to EVs and charging points Reduced use of personal cars Car sharing Energy sharing for households who have less financial means
Actions	Develop a tool that allows homeowner associations to understand the benefits they can derive from their connection to the electricity grid Provide subsidies for charging points for EV’s

Gemeente Amsterdam	Department for households
Interests	Enhancement of trust and the relationship between citizens and the municipality
Actions	Engage in discussions with communities to share knowledge and establish connections with key stakeholders such as CPOs, energy experts, or funding organizations

Liander operates as the exclusive electricity network operator in Amsterdam, overseeing the maintenance and development of the electrical grid. This organization holds the responsibility for granting permissions and making room for new connections, whether for businesses or renewable energy sources, while also managing data on the electricity network to facilitate the implementation of smart grid technologies. Their foremost objective is ensuring grid stability and reliability, a commitment contractually guaranteed to their customers. Additionally, Liander aims to expand the grid to guarantee equitable access to grid resources for all users, ranging from residential neighbourhoods to businesses and charging stations. With technical expertise and a focus on expanding infrastructure, Liander is equipped to invest in and adopt innovative or smart technologies that further enhance the grid’s stability and reliability. Among their initiatives are monitoring the electrical grid and encouraging customers to modify their usage patterns, helping to reduce peak load demand.

liander	General
Interests	Grid stability and reliability Equitable access to grid resources for neighbourhoods, businesses, and charging stations Efficient use of the electricity network
Actions	Upgrade the transformer station to a greater capacity Process and approve applications for new connections for households and EV charging points Collect and share grid data Control the voltage on the electricity network (inverters of solar panels will be switched of when voltage is too high)

liander	Sustainable mobility
Interests	Electricity supply matched with demand
Actions	Conduct research into a demand response program that incentivizes households to adjust their energy usage during peak times through variable rate pricing.

liander	Data analysis low voltage network
Interests	Optimization of the electricity network use Minimization of disruption in the electricity grid
Actions	Calculate where additional capacity for electricity connections is possible Conduct research into stakeholder management and determine the role Liander should play in initiatives like energy communities Calculate and predict where and when issues such as grid congestion will occur on the electricity grid on cable and transformer level

EQUANS EMPOWERING TRANSITIONS	
Interests	Power supply for EVs Expansion of charging stations
Actions	Control the capacity of charging at charging stations Install new charging stations within residential areas

OM Amsterdam Energie is a non-profit energy provider operating as an energy collective, were customers receive their energy directly from local energy cooperatives. Committed to a non-profit model, the organization reinvests profits into developing new sustainable energy production systems and consistently lowering rates for its members. It acts as an energy provider for households, and in this specific context, OM Amsterdam Energie is actively developing ways to facilitate households in sharing their generated energy. This initiative rewards households with higher financial compensation for their surplus energy than the usual rates for feeding it back into the grid.

Their objectives are centred around ensuring customer satisfaction and retention, expanding their portfolio of renewable energy sources, and fostering efficient energy usage. Furthermore, they aim for the optimal utilization of local production and consumption to eliminate feed-in tariffs charged by the grid operator, Liander, costs that would otherwise be passed down to customers. With their comprehensive market knowledge and expertise, OM Amsterdam Energie could play a crucial role in the energy community by promoting the efficient use of energy. Additionally, as a significant entity within the system, they possess the capacity to influence the development and appearance of the energy community. The strategy from OM Amsterdam Energie in facilitating energy sharing and expanding its renewable portfolio reflects a careful consideration of market growth ambitions and a commitment to sustainable energy practices.

om nieuwe energie	General
Interests	Enhancement of customer expansion Expansion of renewable energy projects
Actions	Offer different types of green energy contracts: variable and fixed Future: implement an option for households with the same energy provider to share energy within the community

om nieuwe energie	CEO
Interests	Transparent pricing for green electricity Enablement of energy sharing within communities
Actions	Acquire energy cooperatives to connect Link members with experience in energy cooperatives Perform analyses for customer to determine the feasibility energy projects and identify any unmet needs

The Authority for Consumers and Markets (ACM) holds regulatory oversight of the energy market, with the capability to provide policy advice and develop guidelines to direct policymakers. Its objectives are to promote market transparency and ensure fairness. In this endeavour, it prioritizes consumer empowerment and protection. As a regulatory body, the ACM boasts considerable expertise in both the energy market and consumer rights, making it a pivotal entity in fostering an equitable and transparent energy environment.

Autoriteit Consument & Markt	General
Interests	Assurance of market transparency and fairness Enhancement of customer empowerment and protection
Actions	

Open Remote is at the forefront of developing the EMS for the energy community. They ensure a seamless EMS experience through dedicated customer support and comprehensive training. Their commitment is in developing a system that can significantly reduce peak loads on the grid by enhancing energy efficiency. Possessing deep technical expertise and access to critical data, Open Remote is adept at creating and managing this sophisticated technological platform. As adoption of the system broadens, they gain valuable insights, enabling continuous improvement and optimization of the EMS. Open Remote’s dedication to developing the EMS and enhancing grid efficiency is guided by the potential of technological innovation to revolutionize energy management

openremote Creating Meaningful Connections	General
Interests	Improvement of energy efficiency Reduction of peak loads through their EMS system Growth of their user base
Actions	Develop and maintain the EMS system that monitors and sends challenges to the households within the energy community Support in the instalment of the application and smart meter at households Conduct data analytics on the energy data from the households to assess the impact

Energie Samen operates as an academy with the motto, “The more energy shared, the less energy required to produce.” It plays a pivotal role in supporting energy communities by offering educational programs, providing access to its network for collaborative efforts, and advocating for policies and engagements that enable the formation and success of energy communities. With a wealth of experience in the energy sector, Energie Samen has accumulated a significant amount of knowledge and expertise over recent years, positioning itself as a key resource and ally in the promotion of sustainable energy practices. Their rationality is rooted in the belief that education and collaboration are key to advancing sustainable energy practices within communities. Decisions are made with the aim of maximizing the impact of educational programs and advocacy efforts to support the energy transition.

energie samen	General
Interests	More energy cooperations/communities focused on renewables and energy efficiency
Actions/resources	Offer educational programs on their website for cooperations about the initiation, development, construction, and operation of a solar park, covering the following aspects: • Legal • Financial • Technical

energie samen	Interests of energy cooperatives department
Interests	Favourable legislation and regulations for energy cooperatives
Actions/resources	Organize weekly events featuring speakers who provide legal and financial support for cooperatives Facilitate financial resources through a fund in collaboration with Triodos and ASN for the purchase of solar panels for cooperatives

Energy Commission	General
Interests	Promotion and support of sustainable neighbourhood initiatives Enablement of home disconnections from natural gas in the neighbourhood
Actions	Use their website, events, and newsletter (350 members) to stimulate the FlexCity project within the Sporenburg area By showing advantages and results of the project

Energy Commission	CEO
Interests	Transition of households from gas to full electricity connection Affordable energy access for low-income individuals within the neighbourhoods
Actions	Spread awareness to neighbouring communities outside the Eastern Docklands about the solutions being developed within their area

Reschool is an EU-based organization that finances projects within energy communities, including initiatives like the FlexCity project. Its main objective is to foster the development of energy communities to enable their broad adoption in the future. With access to substantial funding resources and a network of experts, Reschool actively supports a variety of energy community initiatives throughout Europe. Reschool operates with the rationality of using financial and expert resources to catalyse the development and adoption of sustainable energy practices within communities. The organization's decisions are informed by the potential for projects to inspire broader change and contribute to the energy transition on a larger scale.

reschool	General
Interests	Development of energy communities for widespread adoption in the future
Actions	Providing financial resources to support the FlexCity project Development of the FlexCity program Instalment of the smart meters Rewarding system for the households Development of the EMS system

Resourcefully	General
Interests	More energy communities and guidance as a consultant for these projects Acquisition of knowledge and expertise within the realm of energy communities Development of a business model based on the deployment and expansion of energy to communities
Actions	Utilize their model to predict the load on the transformer station Contact various stakeholders from network to establish the energy community Organize meetings with stakeholders to discuss and develop the energy community

Kantelingen	General
Interests	Scale up energy communities and serve as a guiding consultant for these projects Acquire knowledge and expertise within the realm of energy communities Develop a business model based on the deployment and expansion of energy communities
Actions	Calculate the business case for the energy community, analysing potential economic benefits Leverage knowledge and expertise during meetings with stakeholders

I Free riders

Here the concept free riders is further explained and this section corresponds with section 4.6 of the document.

In energy communities that focus on managing shared resources such as the transformer station, the problem of free riders can become challenging. In the neighbourhood there is a limited capacity at the transformer stations, so it is crucial to manage energy use wisely. During peak hours, people must use energy thoughtfully to ensure everyone can do essential tasks like cooking, while avoiding energy-intensive activities like charging EVs. This careful use helps make sure there's enough energy for everyone's needs. However, the presence of free riders, who take advantage of the community's efforts without contributing themselves, threatens the core values of mutual support and shared benefits in these communities. For example, when the community works together to adjust their energy use and invests in technology to help manage it, free riders enjoy the benefits of more available electricity without helping to cover the costs. This unfair situation places a heavier load on those who do contribute and might make them less likely to support future sustainability initiatives.

Furthermore, free riding can significantly reduce the success of energy-efficiency measures across the community. These initiatives depend on widespread participation. However, when free riders enjoy the savings from others' efforts without adjusting-and even increasing- their own energy use, it undermines the shared goal and reduces impact on these initiatives. Significant free rider influence can lead to the overuse of the transformer station, rendering the community's conservation efforts fruitless. Free riding not only jeopardizes the sustainability and operational viability of the transformer station but also threatens the cohesion and trust within the community, which are vital for the long-term success of such initiatives. Addressing this issue requires thoughtful governance, incentive structures, and community participation strategies to ensure that contributions and benefits are equitably shared among all members. This fosters a culture of mutual responsibility and support, crucial for the community's sustainable future.

Some examples of potential free riders in the energy community:

- Energy providers can assume the role of free riders by offering cheap energy during peak times. This behaviour encourages an increase in energy consumption exactly when demand is already high. This situation might occur, for instance, when there is a surplus of energy generated from wind or solar power, making it advantageous for the providers to sell this electricity at such times.
- Residents in the neighbourhood may also act as free riders by disregarding the community's collective efforts and either maintaining or increasing their energy use during peak periods. This individual behaviour runs counter to the energy community's efforts to evenly distribute energy usage and prevent the transformer from being overloaded.

J Survey questions

In this section, the survey questions are further explained and categorized. These questions correspond to section 5.2, facilitating a better understanding of their relevance and application.

Label	Element	Question	Scale
Consent/intro	-	Consent statement	-
Socio-demographic characteristics	Age	What is your age?	Ordinal
	Household	With how many persons do you live?	Interval
	Solar panels	Do you have solar panels?	Binary
	Type of housing tenure	In what type of household do you live?	Nominal
	Car	What type of car does your household have?	Nominal
Filter	Awareness	I am aware that the FlexCity project is currently active in my neighbourhood	Binary
	Involved	I have installed the smart meter or the FlexCity app	Nominal
Awareness	Awareness of technical aspect	I am aware that there is a limit to the amount of electricity that can be used simultaneously by everyone in the area.	Binary
	Awareness of problem	I am aware that the growing use of electric heating, cooking equipment, cars, and other electrical appliances will lead to higher electricity peaks on the grid in the future.	Binary
	Awareness of Consequences (AC)	I am aware that larger electricity peaks in the future could potentially lead to issues such as restrictions on electricity usage, power outages, or halts to the connection of electric car charging stations.	Binary
Attitude	Ascription of Responsibility (AR):	I am aware that we, as residents and a community, can reduce these peaks by adjusting our electricity consumption throughout the year.	Binary
	Responsibility	As users of the electricity grid, we (households) have a responsibility to adapt our electricity use to help address the existing problems	Likert
	Responsibility	The issues with the electricity grid are a concern for the network manager (Liander), not for the users (households)	Likert
Motivation	Egoistic value	This reduces my energy bill	Ranking
	Egoistic value	I enjoy participating in experiments	Ranking
	Altruistic value	This provides my neighbour with an additional connection, for example, a car charging point	Ranking
	Altruistic value	This enhances the sense of community in the neighbourhood	Ranking
	Biospheric value	This allows me to save CO2	Ranking
Subjective norms		I have neighbours or friends in the neighbourhood who are involved in the FlexCity community	Binary
		I have neighbours or friends in the neighbourhood who participate in neighbourhood projects	Binary
Perceived behavioural control	Effort (egoistic)	I find it too much effort to adjust my electricity use one or two times a week	Likert
	Mistrust towards communities	I have too little confidence in the outcomes of a community (Dioba et al., 2024)	Likert
	Egoistic value	I’m not willing to make an effort for the neighbourhood if others don’t participate	Likert
Perceived behaviour control joined		It is clear to me how I can earn points with the app	Likert

	I understand the effects of my adjustments in electricity usage on CO2 emissions, cost reduction, and peak load impact	Likert
	I am currently financially motivated enough to participate in the challenges	Likert
Important factors joined	There must be a board that takes the lead	Ranking
	Clarity about the impact of my adjustments in electricity usage	Ranking
	The financial incentive must be high enough	Ranking
	There needs to be something innovative to keep me involved and willing to participate	Ranking
Intention	Indicate your willingness to participate in the energy community based on the information you currently have (move the slider)	Ranking

Table 19: J Survey questions

K Survey distribution

In this section, the distribution of the survey conducted in the Sporenburg neighbourhood is visualized. This section corresponds to section 5.4 of the document.

Figure 24: K Survey distribution

Hallo, we zijn bij u langs geweest, maar we hebben u jammer genoeg gemist. Ik ben student aan de TU Delft en ik ben bezig met mijn afstudeeronderzoek. Ons project gaat over de buurt Sporenburg en het opzetten van een lokale energiegemeenschap. Uw mening is hierin onmisbaar! Zou u zo vriendelijk willen zijn om deze QR-code te scannen met de camera van uw telefoon en vervolgens de enquête in te vullen. Uw deelname is zeer waardevol en helpt ons enorm met het onderzoek. Alvast hartelijk dank :)

Figure 23: K Flyer design

L Survey results

In this section, the various test results are visualized using data from the survey. These visual representations help to illustrate the outcomes and patterns identified in the survey data. The analysis begins with the results from the ranking questions. Subsequently, a correlation and linear regression test are conducted to determine whether households that ranked financial motivation as their first or second priority responded differently to the question, “I’m currently financially motivated enough to participate in challenges,” compared to those who ranked it lower. Finally, a t-test is performed to discern any differences between households that have joined the community and those that have not. This section corresponds to 5.5 of the document.

Ranking questions statistics

Question	Mean	Median	Std dev	
Rank-Enjoy experiments	3,32	2.5	1.398	N=92
Rank-Extra connection neighbour	3.2	2.5	1.513	
Rank-Enhance sense of community	3.03	3	1.162	
Rank-Reduce bill	2.74	4	1.366	
Rank-Reduce CO2	2.72	4	1.536	
Rank-Clarity impacts	2.86	1	1.302	N=29
Rank-Board taking the lead	2.52	3	1.153	
Rank-Something innovative keep me involved	2.34	2	1.01	
Rank-Financial incentive must be high enough	2.28	3	0.96	

Table 20: L Ranking stats

Correlation financial ranking

		Experience-financially motivated enough
Motivation-financially-rank1,2	Pearson correlation	-0.299
	Sig (2-tailed)	0.115
	N	29

Table 21: L correlation financial

Multilinear regression financial ranking

N=29

Parameter	Estimate effect	Std. Error	t-value	p-value
Constant	3.000	0.228	13.175	<0.001
Rank12	-0.667	0.409	-1.631	0.115

Table 22: L Multilinear regression financial

Independent t-test

N=92	*Levene's test for equality of variances*		*T-test for equality of means*		
Question	F	Sig	t	Two sided p	Mean difference
Rank-Enjoy experiments	0.002	0.965	-0.622	0.536	-0.198
Rank-Extra connection neighbour	0.370	0.545	-0.581	0.563	-0.205
Rank-Enhance sense of community	1.214	0.274	0.322	0.748	0.087
Rank-Reduce bill	1.692	0.197	0.270	0.788	0.087
Rank-Reduce CO2	0.021	0.884	0.654	0.515	0.230
Barrier-Too much effort	10.486	0.002	3.586	<0.001	0.784
Barrier-Confidence	3.606	0.061	1.423	0.159	0.304
Barrier-Effort others participate	4.167	0.044	4.749	<0.001	0.890
Responsibility-Users of the grid	0.2407	0.125	-2.240	0.028	-0.579
Responsibility-Liander	0.060	0.807	2.945	0.005	0.662

Table 23: L Independent t-test

Group 1 = Household don't participate
Group 2 = Household that participate and have installed smart meter + application

M Success factors

In this section, an overview of all the success factors is visualized, providing a clear summary that corresponds with the conclusions of the study in section 6.2. This visualization helps in understanding the key elements that contributed to the success of the project.

It is important to clarify that the scope of this study was intentionally focused on specific predetermined factors within the current technological and organizational environment of Sporenburg. External changes, such as shifts in economic conditions, regulatory frameworks, or advancements in technology, were not considered within the parameters of this research. These elements can significantly impact the needs and potential success of energy community but were deemed beyond the immediate scope of this study.

Therefore, while the identified factors are crucial and can indeed facilitate the creation of a successful energy community in Sporenburg, they are contingent upon a broader context where external changes could affect their effectiveness or relevance. The success of these factors assumes that Sporenburg's current situation remains stable. If these factors are maintained and the external environment does not change, the community in Sporenburg is well-positioned for success. However, any shifts in the broader context would require a re-evaluation of these factors and, an adjustment of strategies to ensure continued success.

Technical	Prioritization
Households have smart meters installed	Critical
Households have application installed	Critical
Liander has installed smart meter on the transformer	Critical
A sufficient amount of EVs in the neighbourhood	Critical
EMS system must be developed	Critical
Demand response program must be developed	Critical
A sufficient amount of EVs in the neighbourhood	Critical
Enough solar panels or other renewable energy sources in the neighbourhood	Critical
Cybersecurity measures	Non-critical
Households use heat pumps or other electric heating solutions	Non-critical
Households use electric cooking	Non-critical
Cybersecurity measures	Non-critical
Scalable system	Non-critical
More of the households are of the type owned	Non-critical
Automation on adjusting electricity usage	Non-critical
Organizational	
Active community participation	Critical
Active neighbourhood engagement	Critical
Key stakeholders Liander, Households and the Municipality must be involved	Critical
Varied motivational incentives	Critical
Clear business case for all key stakeholders	Critical
Possibility for energy sharing	Critical
Clarity on the impact of participation	Critical
Strong board that takes the lead	Critical
Operational leadership	Critical
Financial incentives must be high enough	Non-critical
Something innovative within the community to keep households involved	Non-critical
Free riders who are high consumers must be limited	Non-critical
Educational and training programs	Non-critical
Energy sharing is possible	Non-critical

Table 24: M Succes factors