MSc Thesis

Community Energy Storage:
A Case Study of Zwolle, the Netherlands

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August 2023

Acknowledgments

This thesis marks the end of my MEEM journey. I would like to take this opportunity to express my deepest gratitude to my supervisors, Dr. Gül Özerol, for her exceptional mentorship, patience, invaluable support, and encouragement, and to Dr. Ewert Aukes for his support, availability, valuable feedback, and expert advice. It was truly an honor to learn from them. I also extend my sincere appreciation to Gerard van der Schaar, Dr. Anne Dijkstra, Rober-Paul van Campen, and Emma Gerritsen for their generosity in sharing their time and insights with me, and their role in the realization of this thesis. And a special thanks to my MEEM peer, Richt Fokkens for her unwavering support, invaluable friendship, and all the things that I have learned from her. Finally, I would like to specially thank my amazing family for always being there for me, supporting me, empowering me, and warming my heart with their life.

Abstract

As societies are facing challenges of the energy transition, community energy storage (CES) has emerged as a promising solution. This qualitative study explores the transformative potential of CES in Zwolle, the Netherlands, along with key elements of the transformative capacity framework, factors promoting the adoption of CES and the enablers for its successful implementation. Engaging with diverse stakeholders, including energy experts, researchers, and energy community members, this study reveals a multifaceted perspective on the complexities and opportunities within the energy transition landscape.

In this study, CES is highlighted as a dynamic bridge between the current energy systems and sustainable community-oriented systems. Evidence from the literature suggest that co-production of knowledge through collaborations, stakeholder engagement, and supportive regulatory frameworks shape the transformative potential of CES. Additionally, collective vision and institutional support foster its further adoption. Factors that influence CES adoption include experimentations, resource accessibility, and reflexive regulations. Successful cases of CES experimentations indicate an amplifier effect, which is enabled through the availability of resources and supportive regulations. Surprisingly, stakeholder priorities were divergent, that necessitate tailored strategies for specific communities. The study creates theoretical insights into CES as an enabling solution towards the transition of energy systems in cities. Empirical findings enhance the understanding of the potential of CES, which can support policy makers, and practitioners, in advancing energy transition through integrated approaches that prioritize community engagement, regulatory adaptability, and collaborative knowledge production. Direction for further research include exploring stakeholder collaboration, regulatory frameworks, and the long-term economic and environmental impacts of CES.

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List of Abbreviations and Acronyms

Community Energy Storage	CES
Demonstration of Energy and Climate Innovation	DEI+
Greenhouse Gas Emissions	GHG
Multi-Level Perspective	MLP
Regional Energy Strategy	RES
Renewable Energy Source	RES
Transformative Capacity Framework	TCF
Urban Energy System	UES

1. Introduction

1.1 Empirical Background

The global energy landscape is facing radical changes, transforming from a centralized system to a decentralized system. This change is stimulated by the pandemic, war, and energy transition (Zakeri et al., 2022). Sustainable energy transition has been a pivotal part of public and private agendas, especially after the 1973 global oil crisis and the drastic increase in climate change impacts (Solomon & Krishna, 2011). It encompasses fundamental changes in energy systems entailing the emergence of innovative and complementary technologies in the energy sector (Markard, 2018). The energy sector is accountable for around 75% of the global greenhouse gas emissions (GHGs). Decarbonizing and transforming energy systems play a key role to achieve the target of net-zero emissions by 2050 in alignment with Paris Agreement objectives (Energy Agency, 2021; European Commission, 2019). However, energy transition is not solely limited to decarbonization through renewable energy technologies, it also requires changes in societal discourses, social engagement, and policies (Hainsch et al., 2022).

The population of urban settlements is expected to increase by around 70% by 2050 (*World Energy Outlook 2022*, n.d.), Urban settlements are also accountable for over 60% of global primary energy demand (Grubler et al., 2012). Urban Energy System (UES) is defined as "a formal system that represents the combined processes of acquiring and using energy to satisfy the energy service demands of a given urban area" (Keirstead et al., 2012). Hence, UESs play a significant role the in transition of energy systems towards sustainability as a response to climate change (Nik et al., 2021). During this transition process, communities generating energy from renewable sources, also known as energy communities, are considered a key component of transforming the existing centralized energy system into a decentralized, and cleaner system (Leonhardt et al., 2022).

The energy communities are considered new actors in the energy system. Energy community has been named in the literature in various forms, such as clean energy communities (Gui & MacGill, 2018), sustainable energy communities (Romero-Rubio & de Andrés Díaz, 2015), renewable energy communities (Dóci et al., 2015), smart energy communities (Savelli & Morstyn, 2021), civic energy communities (Verkade & Höffken, 2019), and low-carbon energy communities (Heiskanen et al., 2010). The common feature of these typologies is that they all rely on renewable energy sources (RES). Beyond many benefits of generating energy from RESs, a major drawback is fluctuation in the availability of RESs which causes volatility in generating energy (Maradin, 2021). Hence, for the further diffusion of RES, an intervention in the existing system is needed to mitigate the fluctuations of energy generation from RES.

Energy storage technologies are key components in energy communities that enable coping with fluctuations of generated energy from RES (Tarekegne et al., 2021). As a result, energy storage enables the decoupling of supply and demand which is an indispensable condition for mitigating the fluctuations of energy generated from RES and storing them for later use. Energy can be stored in various forms, namely, electrical, thermal, mechanical, and chemical storage (Mclarnon & Cairns, 1989). The focus of this research is on storing energy in the form of electricity. Energy storage can be used in a vast range from residential- to grid-scale also in various applications like "peak demand shaving, renewable energy utilization, enhanced building energy systems, and advanced transportation" (Koohi-Fayegh & Rosen, 2020). Energy storage is still in development. Two of the major hurdles to its development are economic feasibility and scalability (Kousksou et al., 2014). To overcome these challenges, there has been a shift from large-scale central energy storage systems to distributed, small-scale systems that are close to the consumers, known as community energy storage (CES) (Nourai et al., 2010). CES is an innovative energy storage system that is considered a key component of electricity grids (Sardi & Mithulananthan, 2015). CES is a promising solution for further deployment of RESs (Ambrosio-Albala et al., 2020), reducing the peak demand and improving grid stability (Koirala et al., 2018), improving self-sufficiency and energy security of energy communities (Koirala et al., 2020), and reducing total cost of ownership of the energy storage systems for the households (Dong et al., 2020).

In the Netherlands, the transition of the energy system to a low-carbon system and ensuring security through the reduction of dependency on fossil fuels, and the generation of electricity from RES are key parts of the Dutch policymakers' agenda (Homan et al., 2019). As shown in Figure.1, electricity generation from RESs has an upward trend. However, RESs still do not play a significant role in the energy mix of the Netherlands.

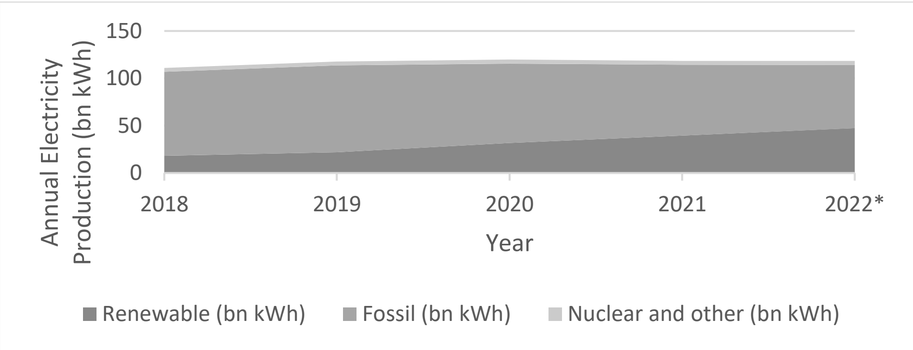

Figure 1- Annual electricity production per source in the Netherlands. As it is evident RESs indicate an upward trend. Data is collected from the Dutch Bureau of Statistics (CBS, 2022)

The "prosumer" portmanteau has been widely used in the literature for consumers of energy that also produce energy, from an increasing number of prosumers in the Netherlands resulting in the creation of Dutch energy communities, which are seen as opportunities to facilitate sustainable transition of the energy system. However, there are still shortcomings in regulatory frameworks for energy communities and the amount of energy generated in the energy communities (Inês et al., 2020). As it was mentioned, an opportunity to overcome the barriers to diffuse generating electricity from RESs in Dutch cities seems to be the CES. Hence, understanding the capacities required for the diffusion of the CES in UES yields an unobstructed vision of the required action plans and strategies that need to be present to enable diffusion of CES.

This research has been carried out in collaboration with Delta Futures Lab (DFL)(DFL, 2023), which is a multi-disciplinary network of MSc students, researchers, and professionals addressing the delta societies and Zwolle as a delta city in the Netherlands is the target of this research.

1.2 Research Problem

Many studies focused on the socio-economic issues of CES, such as community engagement, economic incentives, energy poverty, and energy autonomy, whereas the socio-technical issues like ownership and control, financing, technical expertise of the community, equity, and access, and integration with the grid are understudied (Koirala et al., 2016, 2021). Additionally, the existing UES is a combination of lock-ins and unsustainable practices, which makes it crucial to research the transformation ability of this system, also known as 'transformative capacity,' to adopt new and sustainable configurations (Walker et al., 2004). Surprisingly, the capacities for the adoption of CES are not studied so far. Hence, there is little knowledge of the capacities that enable diffusing community energy storage in urban energy systems. The research will cover this knowledge gap by applying the Transformative Capacity Framework (TCF) that enables identifying the factors that lead to the adoption of CES in the UES.

1.3 Research Objective

The objective of this research is to identify the potential of UES to incorporate CES in the existing urban energy system in Dutch cities, focusing on the city of Zwolle by developing and applying the TCF. The municipality of Zwolle is actively pursuing the targets of 2030 and 2050 and multiple energy corporations are actively looking into engaging in energy storage initiatives. Having the perspective of TCF points out the enablers of diffusing CES in UES.

1.4 Research Questions

To achieve the research objective, I will answer the following main research question:

> *What is the transformative potential of community energy storage in Zwolle, the Netherlands?*

To comprehensively explore the transformative potential of CES in Zwolle, the Netherlands, I formulate two sub-questions on the elements of transformation capacity for CES adoption, and the factors and enablers that affect the adoption of CES in Zwolle, respectively:

> *1: What are the elements of transformative capacity that need to be present to facilitate the adoption of community energy storage in Zwolle, the Netherlands?*

> *2: Which factors promote the adoption of Community Energy Storage, and what are the enablers for adopting Community Energy Storage in Zwolle, the Netherlands?*

The main research question is an exploratory question that aims to investigate the transformative potential of CES using the TCF. The first sub-question is a descriptive question that seeks to identify the key elements of transformative capacity that are necessary for the adoption of CES in Zwolle. The second sub-question is an explanatory question that aims enablers for adopting CES. This could have benefits for policymakers, researchers, and practitioners in the field of energy transition and electricity grid, as it could inform the development of effective strategies for promoting the adoption of CES in Zwolle and other communities. Additionally, it could contribute to the broader understanding of how TCF can be used to facilitate socio-technical innovations in the field of transforming UES.

2. Literature Review

This chapter provides an overview of the existing body of knowledge on CES and present the theoretical framework of the thesis. The first section explains the concept of energy communities, and their relevance to the topic. Then, section 2.2 focuses on CES, providing a comprehensive definition. The scope of this section expands to the existing technologies of energy storage that can be deployed. Furthermore, the existing configuration of CES, that are suitable for shared energy storage, and applications of CES highlighting its energy-related uses. Section 2.3 presents the transformative capacity framework and the relevant factors for this research. Finally, section 2.4 provides the theoretical framework.

2.1 Energy Communities

Energy communities focusing on renewables have been developing in the Netherlands since the 1970s (Moroni et al., 2019). The term “energy community” has been interpreted in diverse ways in the literature. For instance, some research focused on geographical location, production and consumption similarities, and cultural similarities (de São José et al., 2021). Hence, a concise definition of an energy community can be, a self-sustaining, self-sufficient social enterprise that produces energy, while meeting its demands, sells the excess energy to the grid.

The concept of energy communities is still evolving, and various configurations and typologies are being introduced in academia. However, the building block of all these communities is generating energy from renewable energy resources. Hence, considering the unprogrammable nature of renewable resources, especially wind, and sun, a storage system is needed to mitigate the fluctuations in generation and solve the generation and demand mismatch. As a result, energy communities are relevant environments for the adoption of CES.

2.2 Community Energy Storage

2.2.1 Definitions of CES

Community energy storage is becoming a favorable option for further diffusion of generating energy from RESs, managing grid load to avoid congestion, enabling further economic viability of energy storage, and decarbonizing the residential sector (Parra, Norman, et al., 2016). CES is defined in multiple ways. According to Roberts and Sandberg, CES is an in-between solution for residential- and grid-scale storage of energy that contributes to storing volatile energy generated from RES and dynamic residential loads like heat pumps and electric vehicles (Roberts & Sandberg, 2011). Figure 2 demonstrates the scale of the CES and its position in the UES.

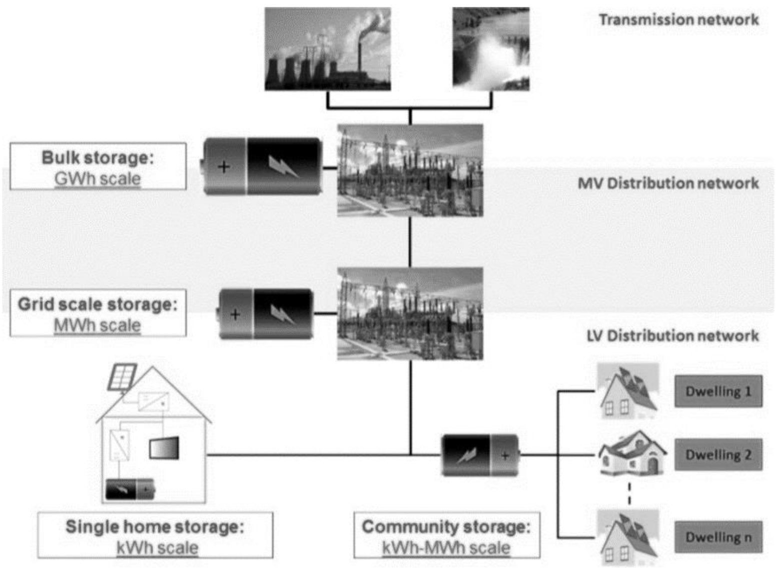

Figure 2- Scale of the community energy storage in comparison with the residential scale and utility scale (Parra, Swierczynski, et al., 2017, p.732).

CES is also referred to as a proper option to balance supply and demand in generating energy from RESs, with positive impacts on distribution networks, and benefiting from economies of scale (van der Stelt et al., 2018). A more comprehensive definition of CES is "an energy storage system with community ownership and governance for generating collective socio-economic benefits such as higher penetration and self-consumption of renewables, reduced dependence on fossil fuels, reduced energy bills, revenue generation through multiple energy services as well as higher social cohesion and local economy" (Koirala et al., 2018, p.573). The significance of this definition is taking the social, economic, and governance perspectives of the CES into account, providing a clearer image of the CES.

2.2.2 Energy Storage Technologies

Energy storage refers to converting energy into another storable form and reconverting it when it is needed (Guney & Tepe, 2017). Energy can be stored in various forms; however, the focus of this research is on storing energy in the electricity form. Since the highest share of energy generated from renewable sources is in the electricity form.

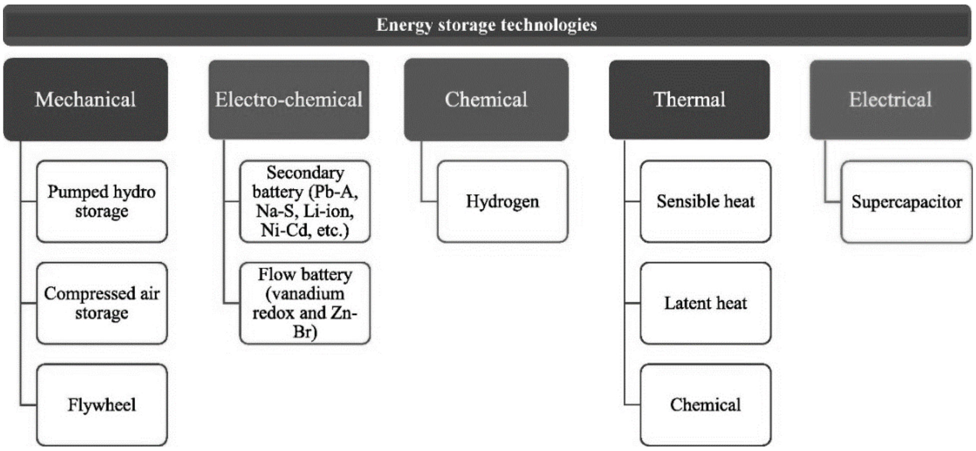

Figure 3- Classification of various forms of storing electrical energy (Zhao et al., 2015, p.546).

According to Figure 3, secondary batteries, and flow batteries are suitable to store electricity in electro-chemical form. CES applications can have limitations in terms of the economic viability and the space required for the storage system. The most common electro-chemical technologies are the battery energy storage systems using Lithium-Ion or Lead-Acid batteries (Hesse et al., 2017; Parra et al., 2017), whereas Vanadium redox flow batteries are proper technologies for CES (Zhang et al., 2016). In addition to these technologies, DrTen® is an emerging sea salt storage technology that is being developed in the Netherlands. It is an innovative technology with a comparatively low environmental footprint (Koirala et al., 2020). However, DrTen® has not shown significant practical outcomes. In addition to these technologies, hydrogen is also gaining momentum in CES systems (Parra, Gillott, et al., 2016).

2.2.3 Configurations of CES

There are three configurations for CES, namely shared residential energy storage, shared local energy storage, and shared virtual energy storage (Koirala et al., 2018). Shared residential energy storage refers to a setup wherein multiple households have individual energy storage units installed in their households or within their premises. Depending on the requirements of the households, these units have a capacity range of 1.5 to 4.5 kWh (Dong et al., 2020). The advantage of this system is that it is positioned behind the power meter, allowing the stored energy to be shared among members residing in a close distance to the units and through the local physical grid. An Example of such a project is the CES initiative in Heeten, the Netherlands. This project involved the participation of 27 households, with each house having a storage capacity of 5 kWh (Koirala et al., 2018a).

Shared local energy storage refers to an energy storage system (module) with a capacity ranging from tens to hundreds of kWh. This system is stored in front of the power meter and behind the transformer, allowing for convenient access and consumption by the community. The ownership and governance of these energy storage systems are collectively managed by the community members, ensuring shared benefits and responsibilities. Additionally, the stored energy can be accessed and shared through the local physical distribution grid, promoting efficient utilization and distribution. An example of such projects can be Etten-Leur, where a 230-kWh capacity electricity storage system meets the electricity needs of the approximately 200 households (Koirala et al., 2018).

Shared virtual energy storage refers to a network of decentralized energy storage systems, installed at various locations. What sets these systems apart is their independent ownership and governance, allowing for flexibility in their management. The available capacity of these energy storage systems can be aggregated and virtually shared at a national and even international level through transmission grid. This sharing is made possible by market design and regulatory frameworks that enable efficient utilization and distribution. The shared virtual energy storage has a potential to facilitate collaborative energy management on a broader scale.

2.2.4 Applications of CES

Two major applications of CES in UES are renewable energy time shift and demand load shifting are significant applications of CES, since they allow optimal use of RES and allow demand side management for the grid, these two applications are considered complimentary (Parra, Norman, et al., 2017). Renewable energy time shift refers to shifting grid injection from times that have low financial value (i.e., off-peak) to high financial value time, which requires short-term storage (Akhil et al., 2013). However, this research focuses on seasonal renewable energy time shift, which refers to creating a buffer capacity to deal with seasonal and time-dependent fluctuations of energy generated from renewables, enhancing energy security and integration of renewables into the grid (Guerra et al., 2020). Demand load shifting is shifting demand from high peak to low peak times that contribute to grid balance (Parra, Norman, et al., 2017). These applications allow for resolving the supply-demand mismatch and increase energy security. They also lead to peak shaving or load leveling that minimizes energy loss in the grid, which shifts the load from high peak to how peak times, i.e., fills the load valley (Kalkhambkar et al., 2016).

An important incentive to employ CES is economic incentives, for instance, the communities can benefit from energy arbitrage revenues, and net revenues from energy price fluctuations, which can increase the profitability of CES (Salles et al., 2017). Another important incentive is an environmental incentive, CES contributes to the reduction of GHG (van der Stelt et al., 2018). Finally, CES can be used as an emergency power backup to ensure electricity service reliability (Onar et al., 2012).

2.2.5 CES as a Socio-Technical System

Building upon the MLP as a framework to analyze socio-technical transformation, and considering the concepts of CES, it can diffuse in three distinct layers in UES. These layers are the External Environment, Actor Network, and Physical system, as shown in Figure 4, (Koirala et al., 2018, p.578). The interactions between the layers are dynamic, non-linear, and complex. Also, they are dependent on configurations, technologies, geography, and social preferences. Hence, CES can be considered a complex socio-technical system.

Figure 4- Layers of community energy storage to align with urban energy systems (Koirala et al., 2018, p.578).

The physical system consists of energy generation and storage technologies and control and management devices. Actor network consists of societal actors, such as households, communities, municipalities, and national governments, and energy system actors, such as energy suppliers, system operators, technology providers, regulators, and market operators. Both the physical system and actors network rely heavily on the configuration of the CES (i.e., residential, local, and virtual). The external environment has to do with the dominant technologies and market configurations. As it is evident, to analyze CES as a system it is necessary to focus on Actors network and physical system. Having all these defined, it is necessary to identify the potential of the CES as a socio-technical system to transform UES.

2.3 Transformative Capacity

The concept of capacity is new and emerging in studying the urban energy system transitions, compared to urban sustainability discourse (Cheung et al., 2023). This research aims to explore key elements of transformative capacity that energy community actors should possess to enable the diffusion of CES in the UES. Transformative capacity is a property of the system (Wolfram, 2016), and it is the potential to make a fundamental change in the existing system when the existing practices are not sustainable anymore (Walker et al., 2004). In the transformation of socio-technical systems, the preliminary stages are also called pre-development stages. Typical activities of this stage are network formation, experimentation, and learning (Rijke et al., 2013).

The TCF consists of ten key components that are categorized into three major categories, 1) Agency and interaction forms, 2) Core development processes, and 3) Relational dimensions (Wolfram, 2016). Although these categories and their related components are interdependent, each category targets specific outcomes and independent outcomes. Agency and interaction form the target to reach, 1) Collective stewardship through aligning diverse actions, and 2) Social Justice. Core development processes aim to, 1) Foster innovation through creating, nurturing, and anchoring novelties, and 2) Enable exnovation through exposing and dismantling path-dependencies and lock-ins, Figure 5, (Wolfram et al., 2019, p.439).

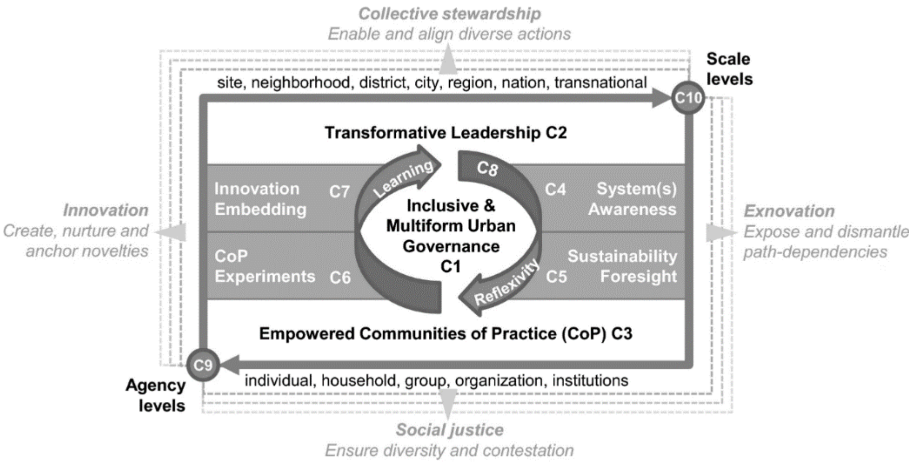

Figure 5- Components of the urban transformative capacity and targeted outcomes (Wolfram et al., 2019, p.439)

Taking into consideration that CES is a complex socio-technical system in the pre-development stage it is crucial to identify capacities that foster innovation and exnovation. Hence, this research focuses on capacities related to core development processes. Core development processes have four components: 1) Systems(s) awareness, 2) CES foresight 3) Experimentations, and 4) Innovation embedding (Wolfram, 2016) as presented in Table 1 and explained below.

Components	Sub-components	References
System Awareness and Memory	Baseline analysis and system awareness	Burch & Robinson (2007), Ferguson et al. (2013)
	Recognition of path dependencies	Wolfram (2016)
CES Foresight	Diversity and transdisciplinary co-production of knowledge	Mader (2013), Rauschmayer et al. (2015)
	A collective vision for radical sustainability changes	Hodson & Marvin (2010)
Experimentation	None	Dolata (2009)
Innovation Embedding	Access to resources for capacity development.	Moulaert et al. (2005)
	Planning and mainstreaming transformative action.	Romero-Rubio & de Andrés Díaz (2015)
	Reflexive and supportive regulatory frameworks.	Gottschick (2018)

Table 1- Components and subcomponents of core capacity development processes

2.3.1 System Awareness and Memory

The first condition for transformative capacity is the awareness of the stakeholders about system dynamics, and path dependencies (Burch & Robinson, 2007). This component consists of two sub-components (Wolfram, 2016): 1) Baseline analysis and system awareness. System awareness means it continuous monitoring the existing conditions of the system in terms of institutional and governance structures, and existing resources to plan any required action to promote utilization of CES in residential communities. 2) Recognition of path dependencies. This sub-component has to do with the extent that the system recognizes physical, regulatory, and financial barriers that threaten the feasibility of CES. It also considers the strategies that exist to tackle the lock-ins and path dependencies.

2.3.2 CES Foresight

The transformation of the cities towards sustainability poses practical concerns for the future. These concerns should be addressed and resolved through communication and collaboration among all stakeholders involved in CES. This will allow for the development of effective and practical policies targeting achieving sustainability goals. This component consists of two sub-components (Wolfram et al., 2019): 1) Diversity and transdisciplinary co-production of knowledge. This sub-component measures the degree of involvement of various stakeholders from diverse societal sectors and scientific disciplines in the process of producing knowledge related to CES. 2) Collective vision for radical sustainability changes. This sub-component has to do with a definite and well-defined future vision that aims for a radical change of the UES by widely adopting CES.

2.3.3 Experimentation

Practical experimentations in the urban context are vital tools for developing transformative knowledge and capacities. The impact of these experiments can be magnified by achieving a collective vision, as described in the previous part. Additionally, experimentations are the first phase of development of every niche innovation. Experiments test the viability of the innovations and create an environment challenging the existing regime. In the case of CES experiments from a technological perspective are the development of novel storage technologies and testing their capabilities. From a socio-technical perspective experiments are the pilot projects that are either planned or commissioned. Experimentations allow us to identify how the innovative system differs from the existing systems.

2.3.4 Innovation Embedding

This framework assumes that all the actors have access to basic resources, including, financial and material resources (Wolfram, 2016). The process of embedding resources begins with involving people and evolves into embedding practices or technologies into communities, organizations, plans, and legal frameworks. A key success factor for this process is the extent that the barriers are removed, and the innovation embedded into the existing system.

Additionally, innovation embedding is the process of disseminating and transferring the insights, outcomes, and impacts of innovation like CES to other individuals, organizations, or contexts. It can involve sharing knowledge and expertise through various channels, providing resources, and funding for training and collaboration, replicating or adapting CES in different settings and locations, and influencing institutional changes that ensure and sustain the diffusion of CES.

This component consists of three sub-components: 1) Access to resources for capacity development. Stakeholders of the CES share resources to develop capacities for further development of CES. Also, this allows for the dissemination of the outcomes of CES and improves the results. 2) Planning and mainstreaming transformative action. The plans and actions to take the CES to another level and mainstream the innovation to enable transformative action. 3) Reflexive and supportive regulatory frameworks. The emerging regulatory framework in response to the CES systems and supportive mechanisms like financial incentives play a key role in developing transformative capacities.

2.4 Theoretical Framework

The TCF emphasizes the importance of building capacities in fostering sustainable urban transformations. Taking into consideration that CES is a socio-technical system, I aim to identify the transformative capacities of this innovative socio-technical system. Hence, I study the innovation and exnovation components of the core capacity development processes in the actor network and physical system of the CES. By identifying the factors that denable adoption of CES, it is possible to develop effective strategies for promoting the adoption of CES in the UES.

3. Research Design

This chapter describes the applied research methodology and will explain the research methods used and the reasons for using these methods. The process of the research is summarized in the research flow diagram in Figure 6.

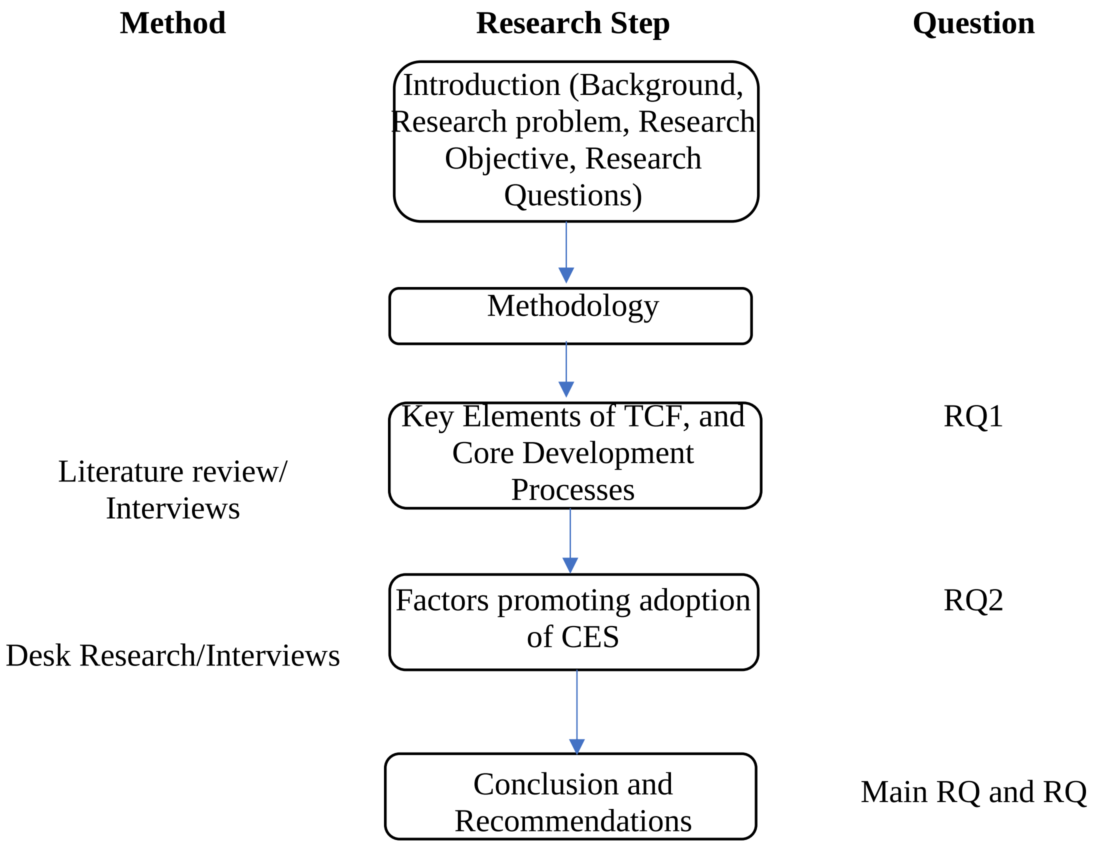

Figure 6- Research flow diagram

3.1 Qualitative Research Approach

To have a better understanding of the research topic, a qualitative approach was employed. This method was selected to gain an in-depth understanding of transformative capacities with a focus on core development processes. To achieve this objective, exploratory design was used to obtain a broad set of insights from the key stakeholders. The geographical scope of the research is the City of Zwolle in the Netherlands, which is the capital of Overijssel province. Since this project is a part of the DFL, and Zwolle is a part of that justifies the selection of this city. Another reason for selecting Zwolle was the access factor to energy transition authorities in Zwolle.

3.2 Document Review

In this research, scientific and gray literature was used to support and gain knowledge about various aspects of CES and TCF. The identification of the nature of CES and Core development processes that lead to innovation and exnovation, involved an extensive literature review. Also, in some parts of the research as it is indicated in RFD literature and desk research was used to complement primary data. For the literature review, a semi-structured literature review methodology was used. The main databases for the literature review were Google Scholar and Scopus. To search comprehensively and effectively different Boolean searches were used. Also, for searching grey literature related to CES, like news articles, policy documents, governmental reports, and company reports, Boolean searches were used. Since most of the grey literature was in Dutch, Google Translate was used to translate them into English. The documents issued by governmental authorities were prioritized.

3.3 Stakeholder Interviews

To clarify the key stakeholders that are involved in developing core developing processes, a stakeholder analysis was conducted. A clear understanding of the key stakeholders provides invaluable strategic information for decision makers. For this analysis, the power-interest matrix was employed. The key stakeholders identified were Communities, Grid operators, Technology providers, Researchers, and municipalities. The complete stakeholder analysis is in Appendix 1, in which the roles of each stakeholder are defined.

The primary data for the qualitative analysis was gathered through semi-structured interviews with key stakeholders. This section explains the method used for interviews. The guiding pre-defined questions of the interviews were tailored according to each stakeholder and each TCP component. The interviews were semi-structured with open-ended questions to obtain in-depth descriptive data. The interview procedure consisted of three main stages: Organization, Implementation, and Analysis. Figure 7 demonstrates the interview procedure and steps of each stage.

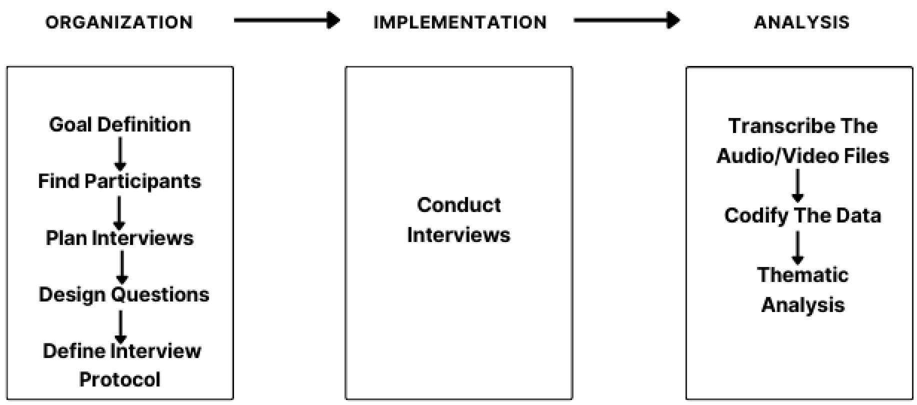

Figure 7- Stages of the interview procedure

The first step was to define the goal of the interviews. The goal of the interviews was to gain insights into the components of the core development processes that are a part of the TCF. Hence every component was matched with the related stakeholder (Appendix 2). Afterwards, the quest for finding participants began. It was an incredibly challenging process, after contacting 31 stakeholders, only nine participated in the interviews. Table 2 presents the anonymized list of interviewees, their stakeholder group, and their role.

Code	Stakeholder group	Role
Interview 1	Municipality	Energy Transition Expert
Interview 2	Municipality	Energy Transition Expert
Interview 3	Researcher	CES and Energy Innovation Researcher
Interview 4	Researcher	CES and Energy Innovation Researcher
Interview 5	Grid Operator	Middle Management
Interview 6	Technology Provider	CEO and Co-founder
Interview 7	Technology Provider	R&D Engineer
Interview 8	Communities	Energy Community Member
Interview 9	Communities	Energy Community Member

Table 2- List of interviewees and their roles

After planning the interviews, the open-ended questions for each key stakeholder category were designed (Appendix 2). The last step of this stage was defining a structure and protocols for the interview. A general protocol was followed to ensure the consistency of the interviews (Appendix 3).

The second stage was conducting the interviews. After interviews, the audio or video files were stored in a safe cloud. The last stage was Analysis. The audio or video files were transcribed in two ways.

For the online interviews, using the Record and Transcribe feature of Microsoft Teams, the transcriptions were ready immediately after the interview. However, the video was watched again, and the missing parts were added to the transcriptions.

For the interviews that were in person, the audio files were transcribed using the Dictate feature of Microsoft Word. However, the transcription is not precise and listened to the files again and corrected the missing parts and mistakes in the transcription.

After receiving the approval of the transcripts from interviewees, the next step was data analysis.

3.5 Data Analysis

The qualitative data analysis involved two main sources of data: primary data gathered through semi-structured interviews, and secondary data obtained from governmental and policy documents, as well as documents from companies engaged in energy storage technologies or projects. This analysis followed a systematic process that entailed identifying required data based on the identified components and sub-components. Additionally, themes and patterns were extracted from the interview transcripts. As described in the previous section, the first step was transcription of the interviews and ensuring accurate representation of the participant responses. Then, the analysis began by assigning a specific color to each sub-component introduced in Table 1. The data was examined line-by-line to identify ideas, concepts or topics referring to each sub-component. The color-coded data then were grouped together to provide a framework for the analysis.

For the analysis of the secondary data, a similar color-coding process was employed. I manually read through the documents, identifying and coding relevant information based the research questions and objectives. The color codes used for document analysis were developed iteratively, as new themes and concepts emerged from data. The coding process allowed for a systematic exploration of the documents, extracting valuable insights and information. It is worthy to note that the selection of the documents used as secondary data source were based on availability and relevance of the documents to the thesis subject.

Finally, taking into consideration that this study involves a single researcher, steps were taken to ensure data triangulation. First, I maintained a reflexive approach (Brown, 2019), to ensure a quasi-objective outcome, and avoid biases. This involved seeking out diverse and even contradicting viewpoints of participants in the research process. Hence, the involvement of different viewpoints helped to counteract the individual biases. Second, I looked for external validation by engaging in peer debriefing. I looked for external evaluation from the people familiar with CES, for the findings of this study. This provided an opportunity to present and discuss the findings to find out about alternative perspectives and interpretations. This process enhanced the objectivity and credibility of the data analysis.

3.6 Ethical Considerations

To ensure an ethically responsible research according to the regulations of Behavioral, Management, and Social Sciences faculty, also considering that I involved human participants in my research, in a direct manner (interviews), I applied beforehand for the approval of the ethics committee. As the first step to address ethical considerations, interviewees were informed that free to ask questions at any time, were not forced to respond to any of the questions and had complete freedom to depart at any time. I made sure that the interviewees understood the reason for the interview and how long the session would take. I also informed the interviewees when the recording was going to begin and finish. These safety measures were put in place to guarantee that respondents experience respect and comfort while taking part in the interviews. Lastly, the oral consent of the interviewees was taken to ensure their voluntary participation in the research.

4. Results

This chapter presents the results of the analysis of interviews and documents according to the observed components of the core development processes and through the application of the TCF.

4.1 System Awareness and Memory

This component is about the strategic agendas and action plans for tackling existing barriers or lock-ins.

4.1.1 Baseline Analysis and System Awareness

Baseline analysis and system awareness are subcomponents of system awareness and memory that is vital to identify the lock-ins and facilitate CES adoption. According to an energy transition expert, “As of the awareness of the systems, there are some small agendas under development for residential areas in the municipality, however currently the system currently focuses on the high-voltage network in the industrial communities” (Interview 1). Another energy transition expert also mentions that “the pilot projects in residential communities are very limited and the communities are not aware of the potential of CES and its cost-effectiveness” (Interview 2). From the perspective of the municipality, the focus is on high-voltage industrial energy storage rather than low-voltage residential storage.

Also, according to an energy community member “The role of the community is to get involved in such initiatives, increasing knowledge, and just diving right into it. Not everyone is that enthusiastic about energy and batteries, but I think it is essential for the future, and at some point, we just must get used to it.” (Interview 8). The system should be aware of the potentials and benefits of the CES.

According to a report by Royal Haskoning, there is potential for nine projects to establish for smart energy communities in Overijssel and Flevoland provinces. And an inevitable component of these communities is energy storage systems. These communities are crucial for avoiding grid congestion, and they are called “emergency departments” for the UES (Royal Haskoning DHV, 2022). This is in contrast with the awareness of the authorities at the municipality about the low-voltage energy storage.

Additionally, according to National Energy Plan, the potential of energy storage is still underused in the Netherlands, and it is lagging compared to other European countries (NEP, 2023). One of the innovative solutions that might enhance the utilization of energy storage systems is neighborhood energy storage or CES (Energy Storage NL, 2016).

4.1.2 Recognition of Path Dependencies

Another subcomponent of system awareness and memory is recognition of path dependencies. According to the two energy transition experts at the municipality, there is a shared recognition of the barriers posed by regulations and grid connectivity challenges for integrating storage systems. While acknowledging those obstacles, their strategic focus lies in high-voltage applications, aligned with the municipality`s industrial energy transition projects. Additionally, one of the experts emphasizes that retaining the existing barriers is influenced by a business and financial perspective. The business viability of industrial projects outweighs that of residential ones, making it easier to overcome the cost-effectiveness barrier for storage systems at the industrial scale. Furthermore, community knowledge is identified as a limiting factor, as it contributes to the inertia toward change and the preference to maintain the current situation. Accordingly, it can be concluded that the municipality fully acknowledges the existing path dependencies, and barriers. However, their current priority is on high-voltage network for industrial communities. Also, the community`s knowledge acts as a barrier, due their tendency to maintain the existing state and refuse change.

From the grid operator perspective, there is a need to build substations, but institutional and financial barriers deter acting in this field (Interview 5). Interviewee 5 adds this is even though "expansion requires a huge amount of investment and also, we want to have the battery storage systems, but the availability of storage assets is a barrier… many companies are asking for batteries, not only because they can receive financial incentives from the government in terms of incentives, but they can also lower their peak load".

According to the National Energy Storage Action Plan, in the Netherlands electricity storage systems are seen as consumers of energy, which leads to paying high transport costs for them (NEP, 2023). The increase in transmission rates by grid operators threatens the financial viability of these systems. Hence, energy storage systems require a legal status that exempts them from high transmission tariffs. Their exemptions should be aligned with EU Regulation (2019/943) and EU Directive (2019/944) (NEP, 2023). EU Regulation (2019/943) prohibits double charging of electricity storage facilities for the electricity injected and withdrawn from the grid, also re-dispatching of electricity storage facilities should be market-based and non-discriminatory (R-EU2019/943, 2019). EU Directive (2019/944) also emphasizes the market and competition-based energy storage without double charging (D-EU2019/944, 2019). In addition to these regulations, it is crucial to prioritize grid connection permission for storage systems. Also, Incentives and multi-layer funding are required to facilitate the adoption of energy storage systems.

4.2 CES Foresight

This component is about the involvement of diverse stakeholders in generating the required knowledge related to CES, their visions for fostering the adoption of CES.

4.2.1 Diversity and Transdisciplinary Co-Production of Knowledge

The co-production of regulatory frameworks, business models, governance models, and technology facilitate the adoption of CES (Interview 3). Distribution system operators, municipalities, renewable energy communities, and researchers should co-produce the models and technologies (Interview 3). In the case of Zwolle, research institutes and municipalities haven't implemented collaborative projects so far due to collaboration and governance complexities, as seen in the Gridflex project. The researcher adds, "Institutions (both formal and informal rules) are the key to the successful formation of any CESs, including the ones based on energy storage systems. For this specific type of system, the institutional designs would play an even more crucial role, as the access and use of the energy storage system also need to be regulated or governed." (Interview 4). Energy transition expert at the municipality also emphasizes that there were some weak collaborative projects in

Zwolle (Interview 1). According to the existing documents, there are no cases of co-production of knowledge in Zwolle.

4.2.2 Collective Vision for Radical Sustainability Changes

Energy transition expert mentions that currently, energy storage is not the main goal for the municipality due to the cost-ineffectiveness and lack of awareness (Interview 1). Interviewee 3 mentions that currently there is a weak vision for the CES, and due to limited awareness of the stakeholders and actors of UES about this innovation. Interviewee 4 also confirms this view, however, to build a collective vision they suggest increasing knowledge (providing information on CESs and energy storage), providing enough targeted subsidies, organizing sessions for neighborhoods to share their opinion on such topics, and other supportive schemes (such as free hours) (Interviews 3 & 4). According to Energy Storage Roadmap, which is recently published, the Minister for Climate and Energy has promised to conduct a study into the desirability of home and neighborhood batteries and possible policies to solve bottlenecks and publish them in the third quarter of 2023 (Routekaart Energieopslag, 2023).

4.3 Experimentations

According to an interviewed researcher, to guarantee the success of the CES experimentation in residential communities, besides the financial benefits of the projects, there should be complementary projects that use the obtained profit of the CES to improve the well-being of the community (Interview 3). For instance, these profits can be used to build a local playground, improve a local park, or organize local community events. All these actions have a multiplier effect in ensuring the success of the experiments. The researcher adds “Collective action is the most essential characteristic of CESs, so any actions that can stimulate are highly recommended to ensure the success of the experimentation. I think when people understand the impact of their role, and be able to implement and measure it, they will form their CESs.” (Interview 4).

The community member indicates that their community participates in CES through the local energy cooperative, which is an ambitious group of people. The community member also adds “My community learned a lot from this project” (Interview 8). Additionally, another community member, mentions that it was hard to draw the attention of the community members, but after joining the meetings fortunately everybody was willing to participate (Interview 9). This indicates that experimentations are crucial for creating capacities in communities to transform the energy system.

Energy transition expert at the municipality emphasizes the experimentation and the positive impacts of learning by doing. Also adds the current experiment that the municipality of Zwolle is also following eagerly is related to a 10MW storage system in a location close to the central station (Interview 2). However, the same expert emphasizes that the municipality is prone to industrial pilot projects due to their perceived higher impacts and fewer social complications.

According to Energy Storage Roadmap, the Netherlands will need 10 GW of batteries in 2030 to guarantee the reliability of a high-voltage grid (Routekaart Energieopslag, 2023). However, due to the current cost-ineffectiveness of the battery storage systems and despite high requests of connecting to the grid, it is expected no more than 2 GW of this capacity realize by 2030 (Routekaart Energieopslag, 2023). An operating large-scale project in Zwolle is Bomhofsplas. The German company initially developed this project, BayWa re, and then was sold to a consortium of Energiefonds Overijssel (provincial fund), Blauwvinger Energie (local cooperative), and an unnamed private investor (Veselina Petrova, 2020). Bomhofsplas can generate and store energy for 72,000 households, and members can buy certificates to join the community. This project can be proper experimentation for a business model, governance model, and social acceptability of CES. As of under development processes, the project of Ijssel Powerplant plans to create an 'Energy Garden' by generating electricity from solar panels and having CES on the site. This project is still in its preliminary stages (*Ijssel Centrale*, 2023).

4.4 Innovation Embedding

This component is about having equitable access to the essential resources to facilitate the process of embedding innovations into communities, organizations, plans, and legal frameworks, thereby fostering the successful integration of an innovation like CES into the existing systems.

4.4.1 Access to Resources for Capacity Development

Regarding the access to resources for capacity development, the grid operator mentions that their company shares resources to develop a CES project, but it is not focused on electricity batteries and focused on gas storage systems in terms of hydrogen (Interview 5). Also, mentions that their company built a neighborhood of 20 houses. The stakeholders have access to resources and the test is being finalized, and the storage system will be in form of battery. According to Interviewee 6, who works for a technology provider, "We have various definitions for the community in our company. For us, a community can be a group of residential buildings, but also, we consider a super yacht as a community. We are a manufacturer and we try to build the best batteries we train our dealers system installers and customers sometimes on how to use these products of ours and I always try to have a dealer or a system installed, in between because they can advise best and they have the practical knowledge of how to do things but we also see the partnerships like what we have with different parts of our value chain. We also constantly communicate with communities about the needs and outcomes of their projects." Interviewee 7, also from the technology provider company, adds that to be able to find solutions they established a collaboration network so that they can create the proper solutions for the benefit of all the stakeholders. Their network grants access to their resources to empower the collaboration and make it more efficient. Energy transition expert also adds, for the industrial 10 MW project they are collaborating with energy providers and grid operators and other actors to find a proper space and setting for the shared energy storage (Interview 1).

Zwolle is a part of the development of Regional Energy Strategy 1.0 (RES 1.0), which is a plan to produce more electricity from renewable sources in the regions defined by the strategy document. They plan to involve the people and businesses who live and work here in the process. They need to decide where to put the wind turbines and solar parks that will generate the electricity and how to connect them to the power grid. They need to do this by early 2025 so they can meet their goal by 2030. They report on their progress in the RES 2.0, which they should send to the national government by 1 July 2023. After that, they start working on RES 3.0, which is the next phase of the plan. The partners of RES 1.0 are municipalities of the Overijssel province, province, water boards, and grid managers (RES 1.0, 2023). However, there is no emphasis on the CES in the documents.

4.4.2 Planning and Mainstreaming Transformative Action

For the sub-component of planning and mainstreaming transformative action, grid operator (Interview 5) mentions that despite being personally interested in CES, there are no major examples of large communities in Zwolle. Also adds that there are some cases for further mainstreaming the CES, but the available space is a major limitation. Interview 6 mentions that, the electricity consumption is increasing, and the expansion is inevitable. For this expansion, there is a need to also expand the infrastructure. So, it should be a priority for the actors of the energy system to look for solutions and speed up experimentations in pilot projects. Energy transition expert mentions "There are some projects at their preliminary stages and some projects started noticeably big but did not yield any remarkable results or just went silent. I think some more time is needed to see the actual outcomes of the projects." (Interview 2). Furthermore, the plans for CES are at national level and the government released an energy storage roadmap in 2023 (Routekaart Energieopslag, 2023).

4.4.3 Reflexive and Supportive Regulatory Frameworks

Reflexive and supportive regulatory frameworks are important to facilitate the adoption of CES. Technology provider for energy storage technologies (Interview 7) mentions, the existing incentives are now too small for battery storage systems, and some additional funding is required to make them scalable and with a justifiable return on investment. Interviewee 7 adds "Besides financial incentives, there is a need to revise the safety regulations and ensure that the existing systems are error and disaster-proof." According to Interviewee 8 two main challenges their community faced in the process of adopting CES were lack of funding and high implementation costs of the storage system. Community member (Interview 8) adds "Even though we live in quite a wealthy neighborhood, we did have some problems with funding this project. That's why we searched for subsidies from the government and found out that it was possible to receive a starting budget for that. That gave the project a kick start and lead to more people being willing to invest." Interview 5 also brought the risk perspective of investing in CES, due to extremely high upfront costs that need to be mitigated through some financial mechanisms.

In the Netherlands, the only supportive fund that indirectly supports investment in CES is RVO (DEI+). Demonstration Energy and Climate Innovation (DEI+) is a budget dedicated to entrepreneurs who have an innovative solution or technique to reduce CO2 emissions. DEI scheme for 2023 covers the projects that lead to the flexibility of the energy system, including storage systems for renewable energies. This Scheme only supports pilot projects in this field (Rijksdienst voor Ondernemend Nederland, 2023).

5. Discussion

In this chapter the findings presented in the previous chapter are analyzed focusing on the main research question and sub-questions. The discussion is focused on transformative potential of CES in Zwolle, the Netherlands. Additionally, the key elements of TCF, factors that promote the adoption of CES, and the enablers for adopting CES in the context of Zwolle, are analyzed.

Regarding transformative potential of CES, the awareness gap identified between energy transition experts and authorities pinpoints the necessity of aligning strategic agendas and action plans. The municipality`s focus on high-voltage industrial energy storage systems, rather than low- or medium-voltage residential storage, poses a potential barrier to transformative change. Nevertheless, energy community plans and national energy plans, emphasize the importance of CES as an effective solution for energy transition and grid stability. The recognition of path-dependencies is a critical factor influencing the transformative potential of CES. While acknowledging regulatory barriers and financial viability, stakeholder`s emphasis on and support of industrial projects raises questions about the inclusivity of transformative actions. The findings highlight the need for a balanced approach that addresses both industrial and residential scale projects, considering the financial feasibility and community knowledge.

Regarding the key elements of TCF, these findings highlight the role of diverse stakeholder involvement and transdisciplinary co-production of knowledge in facilitating the adoption of CES. The challenges faced in collaborative efforts suggest the need for collaboration mechanisms. The concept of institutions as key players in CES formation aligns with importance of regulatory frameworks in enabling transformative change. The lack of a strong collective vision for CES reveals a gap in transformative capacity. The weak stakeholder vision due to limited awareness and engagement calls for proactive strategies.

Considering the factors promoting the adoption of CES, the findings shed light on experimentations as a driving factor. The multiplier effect seen in successful experiments, such as reinvesting the profits of CES projects in communities, promotes the potential of localized actions and creating community awareness. However, challenges in attracting the interest of the communities and motivating their participation emphasize the need for awareness campaigns and targeted engagement strategies. Moreover, proper access to resources for capacity development is a significant factor promoting the adoption of CES. Diverse levels of stakeholder access to essential resources clearly indicate the potential disparities that can arise during the process of innovation embedding. This research reveals the vitality of supportive frameworks, financial incentives, and safety regulations in encouraging CES implementation.

The main enablers for the adoption of CES are planning, mainstreaming transformative action, reflexive, and supportive regulatory frameworks. While challenges in space availability and project outcomes exist, the findings emphasize the importance of continuous evaluation and scaling up successful small-scale experiments. Also, the alignment of attitudes of the stakeholders with the energy storage roadmap indicates the possibility for regulatory support in enabling transformative change. Financial incentives, safety regulations, and supportive regulations that facilitate the adoption of CES play a crucial role in mitigating barriers. The identification of regulatory gaps and the call for revised safety regulations point to opportunities for fostering the adoption of CES. The external validity of this research is related to the extent on how well the findings are aligned with the existing knowledge and whether any unexpected or surprising insights emerged.

The motivation behind this research was to delve into the transformative capacity of CES in Zwolle. However, while this research aimed to shed light on crucial aspects, it is important to acknowledge the limitations that posed challenges during the data collection process. One significant limitation was time. The nature of interviews and the search for suitable interviewees proved to be time-consuming, thus affecting the extent of data collection. The complexity of obtaining comprehensive insights within a limited time constrained the depth of the exploration. Additionally, due to a short time span after the projects, it was not possibly to fully observe and study the outcomes of the CES projects. Furthermore, language barriers emerged as another notable limitation. Given that many potential interviewees were more comfortable expressing their ideas and comments in their native language, the absence of Dutch language proficiency on my part hindered effective communication. Also, in analyzing the policy and governmental documents, lack of Dutch language proficiency, limited the richness of the data obtained. Finally, my perspective and potential biases introduced subjectivity into the study. The interpretation of data and framing the questions during the interviews could have unintentionally influenced the responses obtained. It is essential to recognize these limitations as they underscore the practical challenges that researchers encounter when striving for comprehensive investigations. While the research contributes valuable insights, these limitations should be considered when interpreting the findings and considering the applicability and generalizability of the findings.

This research makes meaningful contributions by providing a deeper understanding of the transformative potential of CES in Zwolle. While some of the findings align with what has been previously observed (Koirala et al., 2018), such as the underutilization of energy storage potential, this research also brings forward insights that are specific to the context of Zwolle. This adds depth and specificity to the adoption of CES. A surprising finding of this research was the diverse priorities of the stakeholders in CES. The experts and authorities prioritize the industrial-scale energy storage while the community is interested in residential-scale initiatives. These divergent priorities imply a need for aligning the perspectives of the stakeholders to create a more inclusive and effective strategy for adoption of CES. This finding highlights the importance of understanding the local dynamics and involve various stakeholders in energy transition discourse.

6. Conclusion

This thesis provided insights into the transformative potential of CES in Zwolle, the Netherlands. Through qualitative analysis, I investigated the key elements of transformative capacity, factors that affect CES adoption, and the enablers for adopting CES. By interviewing a diverse range of stakeholders, valuable insights into the complexities and opportunities which contribute to changes in the energy transition landscape, were gained. I investigated the transformative potential of CES in Zwolle within the context of the multifaceted nature of the energy system. CES emerged as a pivotal element in the energy transition process, and a potential to facilitate the existing energy system to a sustainable and community-oriented system. The transformative potential extends beyond technological innovation, encompassing collaborative production of knowledge, community engagement, and supportive regulatory frameworks. Hence, CES is a promising solution that can contribute to a resilient and sustainable energy system in Zwolle.

Exploring the key elements of transformative capacity required for adoption of CES in Zwolle revealed valuable insights. The involvement of diverse stakeholders emerged as an indispensable element, with emphasis on the comprehensive and inclusive approach to energy transition. Co-production of knowledge through collaboration was found out to be an effective way to bridge the gaps and create a shared understanding among stakeholders. The formation of a collective vision emerged as a powerful driver, converging the perspectives of different stakeholders towards the common goal of having a sustainable and secure energy system. Supportive regulatory frameworks also play a vital role, necessitating the adaptive policies that support the integration of community-based solution in UES. All these elements contribute to creating an environment for the adoption of CES.

Factors promoting the adoption of CES are varied and interdependent. Experimentations are effective facilitators, providing a platform for testing and learning from CES initiatives. The experimental approach enables stakeholders to refine strategies, address challenges, and optimize outcomes. Additionally, having a proper access to resources is a critical enabler, allowing stakeholders to leverage necessary inputs for CES implementation. Reflexive and supportive regulatory frameworks emerged as instrumental in navigating barriers and creating an enabling environment for adoption of CES. The surprising divergence between stakeholder priorities, regarding industrial and residential initiatives, emphasizes the importance of community-specific strategies. Tailored interventions acknowledging local dynamics can enhance the adoption of CES.

The insights generated from this study hold implications for both theoretical understanding and practical action in the context of energy transition. Recognizing the transformative potential of CES and understanding the key elements that facilitate its adoption enables stakeholders to develop strategies tailored to the local context of Zwolle and other cities. Further research can focus on three directions. First, a comprehensive exploration of stakeholder collaboration dynamics can provide insights into how different actors interact and contribute to the successful implementation of CES projects. Second, an in-depth analysis of the of regulatory framework`s effectiveness and adaptability is essential to guide policy makers and foster the integration of CES into broader energy transition strategies. And finally, investigating the long-term effects of CES adoption on achieving energy transition targets can shed light on the way these systems contribute to sustainable and resilient energy landscapes.

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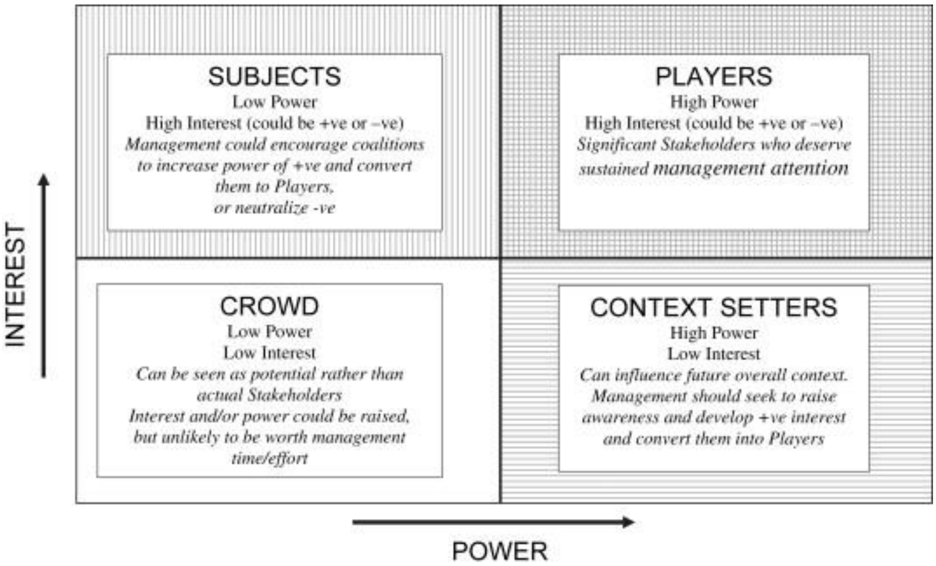
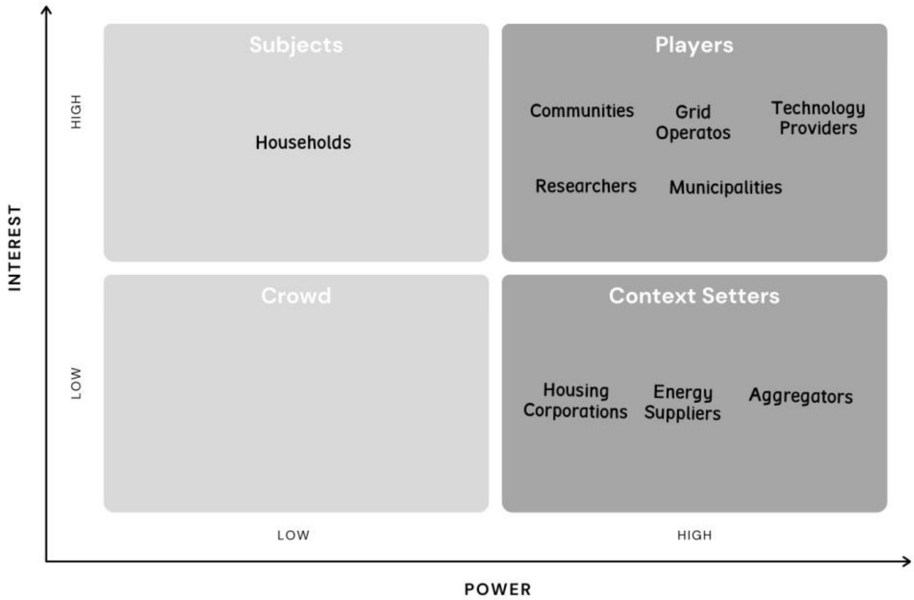
Appendix 1. Stakeholder Analysis

In this section the stakeholders are analyzed, and the key stakeholders are identified. Conducting a stakeholder analysis is necessary since it provides information about the stakeholders who play a key role in enabling diffusion of CES. To select the stakeholders, the actor network (explained in 2.3.1) were selected. Using the power-interest matrix (Ackermann & Eden, 2011), a tool that uses two dimensions of power and interest of stakeholders, the key stakeholders are identified. The key stakeholders are the ones that have high interest and high power also known as "players," as shown in Figure A1.



A1- Power-Interest matrix, adopted from (Ackermann & Eden, 2011, P.183).

The actor network of CES consists of households, communities, housing coroportations, energy suppliers, aggregators, grid operators, technology providers, reaserchers and municipalities.



A2- Power-Interest matrix for CES actor network

The key stakeholders for this study are identified based on their high power and high interest as shown in Figure A2, who are communities, grid operators, technology providers, researchers, and municipalities. Their roles are described in Table 3.

Key Stakeholder	Role
Communities	Organize and initiate CES projects.
Grid operators	To operate and maintain the electricity transmission and distribution networks.
Technology providers	To develop cutting-edge and cost-effective technologies for energy storage systems.
Researchers	The role of researchers who are specialized in CES and Energy Innovation is to research novel business models, configurations, and innovative socio-technical systems that facilitate the diffusion of CES.
Municipalities	To develop and implement local energy strategies and proper incentive mechanisms to enable the diffusion of CES in energy communities.

Table 3- Key stakeholders and their roles

Appendix 2. Interview Questions

The interview questions addressing each stakeholder are presented below, however, these questions were only to guide the interview.

1. Representatives of the Zwolle Municipality

Question	**The core capacity development component**	**The core capacity development subcomponent**
How would you describe the current state of community energy storage systems in the municipality of Zwolle?	System Awareness and Memory	Baseline analysis and system awareness
What is the level of community awareness about the benefits and potential of energy storage systems in Zwolle?	System Awareness and Memory	Baseline analysis and system awareness
How do past decisions and investments affect the current state of energy storage in the municipality of Zwolle? For instance, can you provide examples of specific projects or initiatives that were implemented in the past and how they have impacted the current storage infrastructure? Are there any instances where mistakes or successes from the past have influenced the current strategies and priorities for energy storage within the municipality?	System Awareness and Memory	Recognition of path dependencies
What steps are being taken by the municipality of Zwolle to ensure that the energy storage systems are being utilized to their full potential?	System Awareness and Memory	Recognition of path dependencies
What steps are being taken by the municipality of Zwolle to ensure that the community is aware of the benefits of Community Energy Storage?	System Awareness and Memory	Recognition of path dependencies

2. Researchers

Question	**The core capacity development component**	**The core capacity development subcomponent**
How would you describe the role of community energy storage systems in the larger context of sustainable energy transition in the Netherlands?	CES Foresight	Diversity and co-production of knowledge
In the context of Community Energy Storage initiatives in the Zwolle, what are the key factors that contribute to a successful outcome(s)? Specifically, the factors that enable these initiatives to effectively contribute to the local energy transition goals, engage the community, and ensure long-term sustainability.	CES Foresight	Diversity and co-production of knowledge
How can we assess the impact of community energy storage systems on the community and the environment?	CES Foresight	Collective Vision for Radical Sustainability Changes
What specific strategies or approaches can be implemented to empower communities and enable them to actively participate in transformative actions towards sustainability, such as the transition towards renewable energy, energy efficiency improvements, and other key sustainability measures, through the adoption and utilization of energy storage systems?	Experimentation	Experimentation

3. Grid Operators (DSO/TSO)

Question	**The core capacity development component**	**The core capacity development subcomponent**
What are the activities of your company regarding the development and implementation of community energy storage systems?	Innovation Embedding	Planning and mainstreaming transformative action
What types of challenges have you encountered while implementing energy storage systems in communities? For instance, specific obstacles, complexities, or issues that your company has faced during the implementation of these systems. Can you provide examples of the challenges and share how your company has addressed or overcome them?	System Awareness and Memory	Recognition of path dependencies
How do you see energy storage systems contributing to the overall sustainability goals of the company and the community?	Innovation Embedding	Planning and mainstreaming transformative action
What innovative approaches have you seen being used to increase the capacity and effectiveness of community energy storage systems? Specifically, the strategies, technologies, or practices that have been successfully employed to enhance the storage capacity and improve the overall effectiveness of these systems. Please provide examples of how these innovative approaches have been implemented and their demonstrated effectiveness in community energy storage projects.	Innovation Embedding	Access to resources for capacity development

4. Technology Providers

Question	The core capacity development component	The core capacity development subcomponent
How do you ensure that your energy storage systems are designed to meet the needs of diverse communities? In specific, the needs of communities for ensuring energy security, affordability of energy storage, environmental impacts of energy storage systems, and infrastructural integration of energy storage systems.	Innovation Embedding	Access to resources for capacity development
What types of partnerships or collaborations have you developed to ensure that communities are effectively utilizing your systems?	Innovation Embedding	Access to resources for capacity development
How do you see your products contributing to the broader transition toward renewable energy?	Innovation Embedding	Planning and mainstreaming transformative action
What types of innovative features or technologies are you incorporating into your energy storage systems to increase their transformative capacity?	Innovation Embedding	Reflexive and supportive regulatory frameworks

5. Representatives of Energy communities in Zwolle

Question	The core capacity development component	The core capacity development subcomponent
How did your community become involved in community energy storage initiatives?	Experimentation	Experimentation
What types of benefits have you seen from the implementation of these systems in your community?	Experimentation	Experimentation

Also, in your opinion, what are the potential benefits that have not been achieved yet?		
How do you see the community's role evolving in the development and implementation of energy storage systems?	System Awareness and Memory	Baseline analysis and system awareness
What challenges have you encountered in implementing energy storage systems, and what solutions have you found to be effective in addressing these challenges?	Innovation Embedding	Reflexive and supportive regulatory frameworks

Appendix 3. Interview Protocol

Section	Content	Estimated Time (Minutes)
Appreciation	Good morning/Afternoon, thank you wholeheartedly for your generosity in devoting your time to participate in my thesis research. My name is Aidin, and I am conducting this interview for my thesis on Community Energy Storage. Your contribution will undoubtedly enrich the study and contribute to its meaningful outcomes.	1
Introduction	The objective of my research is to identify transformative capacities of the urban energy systems to incorporate community energy storage in the existing urban energy system in Dutch cities, focusing on the city of Zwolle.	1
Consent	To maintain the accuracy of the information, may I have your consent to record our conversation? This way, I can ensure that I capture all the crucial details you share. Rest assured that the recording will be used solely for research purposes and will be kept confidential and the ethical guidelines of the University of Twente for interviews will be followed.	1
Ask questions	Depending on the stakeholder (Appendix 2)	30-45
Wrap up	I want to express my sincere gratitude once again for your participation in this interview. Your expertise and insights have been incredibly valuable, and I am grateful for the time you have dedicated to helping	1

	me with my thesis. Your input will undoubtedly enhance the quality of my research. Thank you once again for your generosity and support.	