Beyond Grid Pressure

Exploring Public-Private Partnerships for Multi-Commodity Energy Hubs in The Netherlands: Insights from the Harselaar Case

Radboud University

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Preface

Dear reader,

The past five months have been an intriguing process leading to this master's thesis for my Master of Environment and Society Studies at the Radboud University in Nijmegen. The experiences during the research process have allowed me to specialise and integrate myself within the Dutch, very debated energy landscape. Being able to perform my internship at Oost NL has provided access to this complex world, and it has been an eye-opening experience.

Writing this preface, a déjá vu occurred of my first master's thesis, in which I entered a sector in a comparable fashion of having little to fundamental knowledge. The energy landscape has proven to be a highly technological and context-specific sector. During the internship and interviews, this quickly became obvious with the number of applied abbreviations in its jargon. Beforehand, I had never expected something so essential as energy to be so complex and become even more complex as a result of decentralisation transitions. In hopes of clarifying this complexified, essential basic human need, I hope to contribute to academic knowledge gaps and practical guidance to the Smart Energy Hub program. In doing so, guiding energy initiative takers, the involved case-study parties and the remainder who will contribute to a future-proof Dutch energy system.

I would like to thank my mentor, Mark Wiering, who has assisted me from the start to the very end of my research process. Foremost in sharing his enthusiasm for the topic, as well as his interest and faith in my skills as a researcher. Additionally, my thanks go out to all my internship connections, specifically, my mentor Robert-Niels van den Droffelaar, who has guided me and set up the required connections during my research. Without Robert-Niels, this research would not have been possible.

Harm Stevering

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Abstract

Energy is one of humanity's most fundamental needs, with electricity delivering power to nearly all aspects of modern life, our homes, schools, businesses and public spaces. Yet, the Dutch energy system faces significant challenges. Growing demand for electricity, complex prosumer behaviour, and lacking grid expansion by transmission and distribution operators result in expanded congestion. By 2030, over 350.000 energy users are projected to face grid-related constraints. In light of this situation, short-term solutions are required, both organisationally and technically. Nevertheless, implementing such niche-innovation solutions presents several challenges. This thesis explores the feasibility of implementing a Multi-Commodity Energy Hub (MCEH) via public-private partnerships (PPPs), within the Harselaar project in Barneveld. A case study was conducted using a mixed-methods data strategy, incorporating interviews, observations, and focus groups, to examine internal and external factors influencing PPP formation. The findings indicate that voluntary agreements structured towards a formal partnership, established in the cooperative format, are most suitable to facilitate local decentralised energy projects. Additionally, both internal and external influences, exacerbated by the energy landscape and PPP elements, define critical success factors (CSFs) that determine operational success in partnerships. Although this thesis provides general insights, PPPs remain highly context-dependent, hence requiring tailored partnerships for success.

Keywords: Critical Success Factors (CSFs), energy transition, Multi-commodity Energy Hubs (MCEH), grid congestion, Public-Private Partnerships (PPPs),

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1. Introduction

1.1 Problem statement

Energy has become one of the most essential basic needs throughout humanity's lifecycle. Whereas early civilisations relied on fire for the luxuries of light, cooking and heating, modern societies have advanced to heavily depend on electricity. Consequently, early humanity struggled to find and utilise energy sources compared to modern innovations that have made these luxuries integral to daily life (Solomon & Krishna, 2011). Electricity plays an enormous role in our current society, whether it is at home, school, shopping centres, or workplaces, the daily routines of humanity are centred around electricity availability (Zohuri & McDaniel, 2019).

Although some see electricity as a basic commodity and right, others experience living in energy poverty. A 2022 IEA report estimates a global increase in lack of energy access of 20 million, totalling nearly 775 million people, primarily in sub-Saharan Africa and South Asia (IEA, 2022). This is the result of the energy sector facing a series of shock events, creating barriers which hinder energy management and energy access. Including widespread inequality, political instability, violence, climate change, cost of living issues and export dependability (Pye & Dobbins, 2015).

Moreover, the impact of limited energy access, up to 5,000 kWh per capita annually, is noted to have a strongly correlated effect on lower life expectancies according to Zohuri & McDaniel (2019). The higher consumption contributing to increased life expectancy underscores the paradox of electricity necessity and market volatility, urging the need for energy reforms and secure, reliable access (Kez et al., 2024).

Nationally, the Netherlands have been struggling with their energy availability and management, with 396.000 households living in energy poverty in 2023 (TNO, 2023a). A key concern for further deterioration of the Dutch energy sector is the widespread grid congestion caused by rising electricity demand and consumption outpacing grid expansion (Rijksoverheid, 2025). These congestion challenges cause limited capacities for new businesses, buildings, residential and energy projects to connect to the energy grid (RVO, 2024). As consumers and businesses increase their electricity production, and grid expansion by transmission system operators (TSOs) and distribution system operators (DSOs) remains lacking, the grid pressure is expected to increase. Addressing these challenges requires short-term behavioural shifts, smart energy management (SEM) and flexible solutions (Netbeheerder Nederland, 2023).

As a response to energy challenges, the past decade has seen increasing attention towards explaining and configuring the energy transition and landscape. Academics have contributed by researching smart energy systems (SESs), renewable energy sources (RES), multi-energy systems (MES), decentralised energy systems (DES) and smart energy hubs (SEH) to address energy management (Mohammadi et al., 2018; Pascali et al., 2018; Tuballa & Abundo, 2016; Xu et al., 2020).

Koirala et al. (2016) have combined these findings into the development of integrated community energy systems (ICESs). ICESs are a framework for decentralised (multi-commodity) energy hubs (MCEHs), which allow for engagement with multiple actors and energy sources as efficiently as possible (Orehounig et al., 2015). In doing so, one reorganises an energy system to integrate distributed energy resources and engage in local community initiatives. Altering these underlying energy discourses has been argued to have the potential for reducing energy consumption and improving energy efficiency (IPC, 2022), therefore offering promising solutions to address the Netherlands' grid and energy challenges.

Despite a growing theoretical basis, the practical implementation and understanding of decentralised energy systems in the Netherlands remain limited. Specifically, key questions persist about decentralised smart energy systems regarding spatial implications, governing structures, public-private partnerships (PPPs), agency, legal restrictions, energy sharing, conversion and connections, costs and benefits and so forth (Koirala et al., 2016; Royal HaskoningDHV, 2022).

Overall, implementing local decentralised energy systems may have a crucial role in addressing energy grid challenges in the Netherlands (SmartEnergyHubs, 2025). Nevertheless, these incentives are still in their maturing stages, hence requiring practical pilots initiated by knowledge pioneers and change agents to refine these concepts. This research aims to contribute to this lack of knowledge base by assessing and providing recommendations for PPS in future MCEH projects by assessing the Harselaar case study.

1.2 Research Aim and Research Questions

This research investigates the role of public-private partnerships in implementing multi-commodity energy hubs in the Netherlands. It examines their impact on mitigating grid congestion and supporting the energy transition by studying a case study of an energy pilot project in Barneveld, aiming to create a locally integrated energy system. In doing so, the study combines literature with case research findings to draw general conclusions about the Dutch energy landscape. To conduct this, the study aims to answer the following research question:

To what extent can public-private partnerships assist the implementation of multi-commodity energy hubs in order to mitigate grid congestion and support the energy transition within the Netherlands?

To answer the above-mentioned main question, this thesis will attempt to answer the following sub-questions:

1. How can multi-commodity energy hubs mitigate grid congestion and support the energy transition in the Netherlands?
2. What is the utilised share of public-private partnership constructs in sustainable energy projects, and what elements are determents for the suitability of these projects within the energy transition?
3. Which stakeholders are involved in the development of multi-commodity energy hubs, both generally and for the Harselaar, and how do these stakeholders align, conflict, or influence the project's progress?
4. How does the socio-technic regime influence the realisation of public-private partnership arrangements in multi-commodity energy hubs, and how can possible barriers be addressed?
5. What critical success factors determine the operational success of implementing public-private partnerships within multi-commodity energy hubs?

1.3.1 Scientific relevance

Innovative sustainable developments, particularly in energy, are characterised by their complexity due to their long-term nature and the involvement of multiple stakeholders (Geels, 2011). Despite growing concepts and solutions in this field, questions remain on effectively implementing these in the Dutch energy landscape to improve resilience and flexibility (TNO, 2023b). Notably, the implementation of multi-commodity energy systems in the Netherlands has been underexplored. Investigating a pilot case study for an MCEH and refining the project using the ICES, MLP, and PPP frameworks may advance knowledge of the Dutch energy landscape (Koirala et al., 2016).

The adaptation of ICESs offers a modern approach to sustainable energy management, particularly in clarifying decentralised energy governance, which remains vague for national regulators (de Graaf, 2018). Although research on local energy initiatives in the Netherlands, Germany, and Scandinavia has grown (Oteman, 2014), energy systems remain dominantly centralised. In scaling these energy initiatives, public-private agreements are determined as crucial (Carbonara & Pellegrino, 2018). Hence, further intensifies the debate on how modern decentralised energy projects are to be governed. Research by Pinz et al. (2018) identifies various success factors indicating the potential of PPPs in sustainable development projects. However, their literature analysis noted that empirical management research within PPP projects rarely integrates sustainability concepts. As such, the knowledge base on PPPs in the context of sustainable development remains limited, particularly within the energy sector in the Netherlands. Consequently, it is essential to identify the most appropriate format of PPPs for this specific context. This study contributes to existing research by applying Cruz et al.'s (2022) work on PPPs and emerging hybrid schemes in the energy transition.

Furthermore, prior research has shown the potential for PPPs in sustainable energy projects; however, an overarching holistic overview is lacking (Pinz et al., 2018). Specifically, its implementation in the Dutch energy sector is lacking. This study addresses this scientific gap by reviewing relevant literature and applying it to a case study of an MCEH in Barneveld. The research explores the prevalence of comparable PPPs in the Dutch energy domain, identifies the key stakeholders (characteristics) and investigates underlying discourses within sustainable development using a stakeholder mapping (Bosman et al., 2014; Fassing, 2008). Additionally, it analyses external socio-technical influences, inducing challenges with implementing PPPs in MCEHs. In combination with the fundamental PPP elements, critical success factors are explored which determine the operational success for implementation (Cruz et al., 2022; Geels, 2011; Cheng, 2020). Through this approach, the study integrates theory with practical insights to assess the potential of PPPs in mitigating grid congestion and supporting the broader energy transition.

1.3.2 Societal relevance

As previously noted, the Netherlands is encountering significant challenges in capacity concerning its energy infrastructure, causing delays for new energy projects (Netbeheerder Nederland, 2023a). Such grid pressure exacerbates electricity availability in the Netherlands, resulting in more complex energy issues in a country that already accounts for over 396.000 households living in energy poverty (TNO, 2023a). Furthermore, TSOs and DSOs predict increasing pressure, with over 350,000 low-voltage grid users expected to face grid issues as of 2030 (Kiwatt, 2025). Directly addressing these challenges requires shorter-term solutions. Therefore, this study researches the implementation of multi-commodity hubs by assessing multiple frameworks, as viable structuring of decentralised energy structures in the Netherlands, to mitigate pressure on the energy grid and support the energy transition (Cruz et al., 2022; Geels, 2011; Koirala et al.,2016).

The application of the ICES framework to an MCEH may provide more efficient integrated operation of energy sources at the local level. However, it also proves to be beneficial for other aspects of the energy transition. ICESs regulate innovative solutions for local generation, load shifting, local balancing, collective purchasing and energy conservation methods (Koirala et al., 2016). In doing so, ICESs structure the planning, design, implementation and governance of modern energy systems at a community level (Harcourt et al., 2012). This collaborative approach between energy communities and business actors is expected to play a significant role in current and future Dutch energy management (Zomer, 2024). Researching and applying this underlying paradigm of energy systems clarifies theoretical knowledge and enhances practical energy management of the Dutch energy landscape.

Specifically, this research is structured via conducting a case study of a developing MCEH, located in the Harselaar. While previous studies have addressed improvements to the macro-level Dutch energy landscape, this research additionally aims to provide guidance for the case study and similar projects. In doing so, consolidating with Oost NL to research the possible role of PPP structures in collaboration formats for decentralised multi-commodity energy projects, while aligning with their vision of promoting regional economic and energy dependency (SmartEnergyHubs, 2024). Complementary to this, the research aims to assist the development process of the MCEH to depressurise the current grid and future-proof energy accessibility at the Harselaar area for possible residential and commercial zoning. Research contributions will be documented in a knowledge document and assessment framework (Appendix G) that guides PPPs in energy projects. This will be created for knowledge dissemination on the Smart Energy Hubs program, as well as overarching energy parties.

2. Theoretical Framework

2.1 The Dutch Energy Landscape: A Multi-level Perspective View

To successfully understand exogenous and internal determinants affecting sustainable development projects, it is crucial to delineate these in different macro, meso and micro levels. Hence, this first section will describe the Dutch energy landscape using the multi-level perspective (MLP) from Geels (2011). This model allows for analysis of societal transitions within sustainable development, while composing the context of multi-commodity energy hubs, as a niche innovation, and meso-scale energy grid influences using the MLP model. Geels (2011) uses the multi-level perspective model to analyse the interplay of transitions at three analytical levels: (1) Socio-technical regimes (established practices and associated rules), (2) Niches (radical innovations) and (3) an exogenous Socio-technical landscape. This research sees the development of decentralised MCEHs as complex transitional developments in the overarching Dutch energy environment. As such, the MLP model is seen as most suitable for understanding these complex developments. The three analytical transitional levels and further delineation of the sub-regimes are described in Appendix A. The final MLP model, as proposed by van Geels (2011), is visualised in Figure 1.

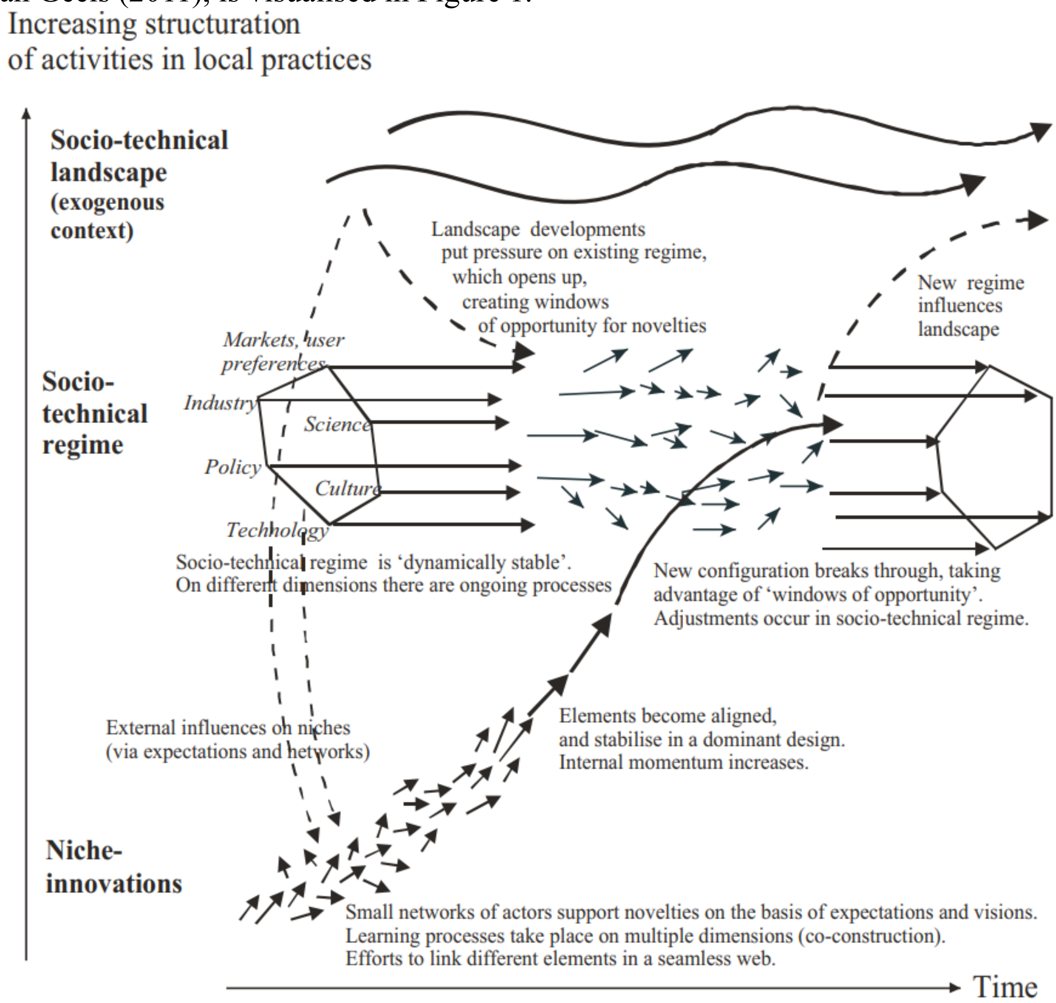

Figure 1. Multi-Level Perspective Model (Geels, 2011)

Challenges of grid congestion and sustainable development in the Dutch energy landscape

The preceding section outlined the different analytical levels and their research application. As such, this section adds to the analytical model by clarifying the Dutch context by examining the underlying causes and challenges of grid congestion and energy development within the Dutch energy sector.

The Netherlands has encountered significant obstacles in transitioning its energy grid to renewable sources, ranking 20th out of 25 European countries in a GLOBALSEC (2024) report. The findings indicate that the nation is unprepared to achieve its 2030 energy goals due to persistent grid system challenges. A primary issue is the difficulty faced by Dutch network operators in connecting new energy loads to various regions, whereas grid capacity is already overburdened (Rijksoverheid, 2025). This situation arises from increasing grid pressure and a lack of capacity and resources among network operators. In response, operators have significantly increased their planned grid investments, which have doubled since 2021, rising from €30 billion to €60 billion (Netbeheerder Nederland, 2023b).

Additionally, the emergence of prosumers, actors that both consume and produce energy, has intensified grid volatility. Prosumers contribute to fluctuations in grid demand by consuming, locally producing, storing, and in some cases converting energy (Doumen et al., 2022). These fluctuations make load forecasting more complex, a challenge in which the Netherlands has performed poorly, ranking last in the European Union according to GLOBALSEC (2024). Both the energy behaviour of prosumers as well as exogenous political incentives to abolish the “salderingsregeling” contribute to peaks in energy supply that reinforce negative spot prices. Resulting in insecurities for consumers to locally invest in the Dutch grid (Molenaar, 2024)

Finally, in line with the prior mentioned challenges, there has been a high growth of intermittent RESs, including wind, biomass and solar energy. By 2023, 48% of Dutch energy was generated from renewables, compared to just 12.38% in 2015 (CBS, 2024). This growth has outpaced the capacity of grid operators, showcasing the government’s high levels of ambition for achieving 85% renewable energy production by 2030. Despite acknowledging these challenges, there is an urgent need for a more flexible energy grid in the Netherlands that can effectively forecast and manage energy consumption and production.

2.2 Multi-Commodity Energy Hubs: An Integrated Community Energy System Lens

Multi-Commodity Energy Hubs

The concept of the future energy hub is evolving into a configuration commonly referred to as multi-commodity (smart) energy systems (MCES). These integrated networks manage diverse power sources like photovoltaics, wind, thermal energy, and hydrogen while supporting variable loads from electric vehicles and heat pumps (Shi, 2016). The number of energy producers and consumers allows MCES to leverage flexibility, which optimises energy operations (Alizadeh et al., 2012; Palensky & Dietricht, 2011). The collective use of these smart systems functions in an energy hub where the sharing, production, conversion, storage, and consumption of different energy carriers take place (Mohamaddi et al., 2017). This study refers to the multi-commodity energy hub (MCEH) as the integration of MCES principles with energy hub functionality.

Integrated Community Energy Systems

To explore the practical implications of the MCEH concept, the ICES model of Koirala et al. (2016) is applied. However, first, an explanation and specification are required to fully incorporate the concept into the case of the Harselaar. Koirala et al (2016) created an extensive framework which can be adapted to multiple contexts; hence, the framework needs to be adapted to the Harselaar case. In this research, ICESs are defined using the conceptualisation of Mendes et al. (2011, p.4841):

"A *multi-faceted approach for supplying a local community with its energy requirements from high-efficiency co-generation or tri-generation as well as from renewable energy technologies coupled with innovative energy storage and conversion solutions, as well as electric vehicles and demand-side management measures*".

Figure 2 sketches the three spatial functional levels within the ICES framework. For the research case, the development of the Harselaar business zoning is classified as the community level and individual businesses within this business zoning area are classified as the household level. The regional/national level is the connection to the wider energy grid and energy markets.

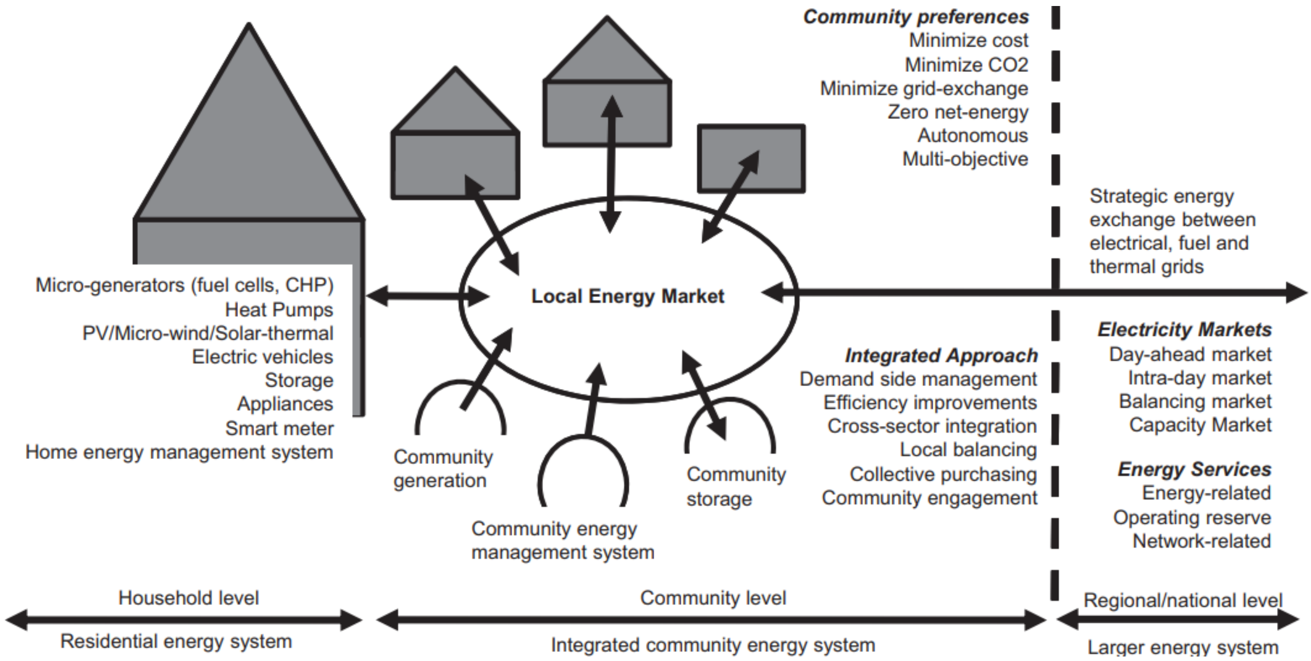

Figure 2 Functions of an ICES at multiple levels (Koirala et al., 2016)

Due to its large conceptualisation, Koirala et al. (2016) note the importance of categorising the ICESs in its context to assess strengths and weaknesses, as is sketched in A1 (Appendix A). Furthermore, the authors differentiate ICESs based on technological aspects and the interests of actors in ICESs, as noted in Tables A2 and A3 (Appendix A). To assess these actors, a stakeholder mapping and analysis will be conducted as discussed in Chapter 2.4.

Multi-Commodity Energy Hubs as a mitigator of grid congestion and supporter of the energy transition

Although MCEHs are noted to be a relatively new concept, modelling their fundamentals using the ICES framework poses possible short(er)-term enhancements to the mitigation of grid congestions and the energy transition. For instance, the Dutch energy landscape faces high urgency issues of overburdened grid capacity and a lack of resources for centralised network operators to address these issues (Netbeheerder, 2023; Rijksoverheid, 2025; Tennet, 2025). The implementation of MCEHs allows for the depressurising of the grid by locally producing, converting and storing integrated energy on a decentralised grid infrastructure (Koirala et al., 2016). Therefore, requiring no further large-scale connection or improvements to the overburdened grid as a result of community-level energy realisation.

Besides resolving excess energy disadvantages, the number of participants, energy sources, and technologies being implemented via smart energy systems creates a flexible energy system which is capable of better addressing irregular energy grid levels (Alizadeh et al., 2012; Palensky & Dietricht, 2011). This proves to be specifically useful in recent energy landscape trends, as a result of the increasing share of renewable energy sources in our grids (CBS, 2024). Although these RES, such as solar and wind, have become intermittent, the ICESs model emphasises the need for multi-source and multi-fuel to address their production irregularities and "keep the lights on" (Koirala et al., 2016; Sovacool, 2009).

While these opportunities allow improvements of issues prevailing in the grid and energy landscape context of the Netherlands, they must be acted upon. The ICES framework highlights the importance of addressing community engagement and passive consumer mobilisation. Specifically, communities with self-imposed and targeted energy strategies are suggested to benefit prosumer sentiment and engagement in their role of the energy transition (Kelly & Pollit, 2011). This may prove to be especially impactful for the opted local integrated community energy system as the Harselaar.

Another impactful development for community participants is seen within the beneficiaries of energy agreements and internal contracts. Rather than abolishing energy beneficiaries like the salderingsregeling, MCEHs enable the efficient integration of energy agreements for all community participants (Mendes et al., 2011). In doing so, facilitating the trading of energy volumes on the local energy exchange via agreed-upon prices, facilitated by a smart supply and demand matcher (SDM) management system (Kok et al., 2005).

However, realising such agreements requires pre-defined structures, such as PPP legal constructions, to align and balance stakeholder interests as all actors are interdependent in achieving the MCEH's energy goals (Koirala et al., 2016)

2.3 Public-Private Partnerships in Sustainable Development

Public-private partnerships (PPPs) have seen rapid growth and development in the literature, resulting in multiple varying definitions. Specifically, what PPPs are and how they are to be utilised (Song et al., 2016). Generally, PPP constructions are characterised by their temporal timeframes and contextual sectors. Energy PPPs originated from the 1970s when contracting models were the first and most utilised form of PPP. Recent developments differ from these traditional PPP forms, as the last decades have seen an increase in new PPP-related constructs for energy management (Sovacool, 2013).

Likewise, a new trend is seen in PPP constructions within sustainable development, differentiating itself from other sectors. Although defining PPP constructions using a single definition remains difficult, this paper defines them as:

"Forms of cooperation between public authorities and the world of business(private) which aim to ensure the funding, construction, renovation, management or maintenance of an infrastructure or the provision of service while also sharing its risks, costs and benefits" (European Commission, 2004, p.327; Klijn & Teisman, 2003. p1).

To facilitate the practical implementation of PPPs in energy sector projects, Cruz et al. (2022) analysed traditional and hybrid PPP forms supporting sustainable development. They found six elements that characterise PPP and hybrid PPP constructions: (1) Purpose, (2) Form, (3) Time frame, (4) Stakeholders, (5) Risk, reward, resource and responsibility sharing, and (6) Critical success factors described in Figure 3.

The authors do not express a preference for PPP forms in sustainable development; rather, they compare and note the advantages and disadvantages. Specifically, emphasising the high contextual dependence each PPP construction possesses (Cruz et al.,2022).

Generally, the use of PPPs in the energy transition field has seen an increasing amount of attention; however, the practical implementation for an MCEH remains vague, hence applying such frameworks is of great importance. Cruz et al. (2021) categorised different hybrid PPP forms, each supporting one of the four phases of the energy transition. The scope of an MCEH is diversified over four phases (EIGEN, 2023a); however, academia suggests Voluntary Agreements (VAs) to be a suitable fit, as it:

"*Aims to achieve energy efficiency flexibly and cost-effectively. VAs are typically bottom-up approaches mobilizing potential energy savings that would be difficult to achieve with traditional command-and-control approaches*" (Zhang et al., 2018, p.281).

Although VAs and public-private energy projects have been fairly represented in literature, this thesis will validate and combine this literature to apply it to the case and context of the Dutch energy landscape.

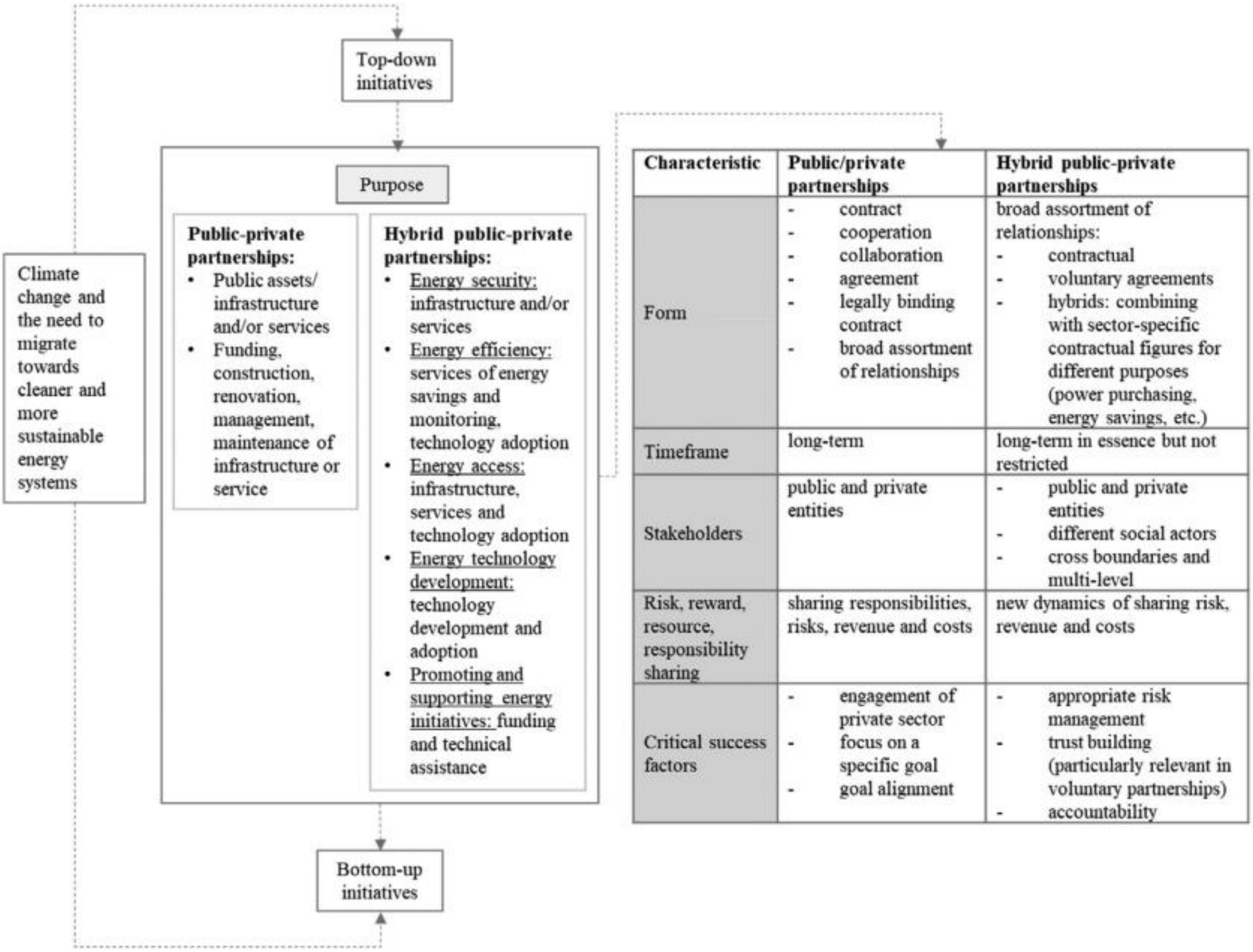

Figure 3 Framework analysing PPP and hybrid PPP in sustainable development (Cruz et al., 2022)

2.4 Stakeholder analysis and mapping

Finally, to analyse the Harselaar case and substantiate informed choices for the implementation of PPP constructions, it is essential to provide a holistic overview of the stakeholders. Stakeholder models have become a vital topic in management literature (Fassin, 2010), due to their powerful visual representation and interconnections of interests. Whereas stakeholders' interests may vary, in this paper they are categorised in "economics, social change, work, security and safety, environmental issues, education and awareness" (Florea, 2013). In which a divide is centred between private and systematic interests as noted by Koirala et al. (2016).

To model these interconnections, the stakeholder model of Fassin et al. (2008) is utilised. This solar stakeholder model illustrated in Figures 4.1 and 4.2 includes three categories of stakeholders: (1) Stakeholder (firm), (2) stakewatcher and (3) Stakekeeper. In which Fassin et al. (2008) elaborate on their roles and functions as:

(1) *Traditional stakeholders*: These are the real stakeholders, essentially the classic stakeholders who have a concrete stake. These are the stakeholders directly involved and related to the PPP construction with a real positive (or at least expected) loyal interest in the project.

(2) *Stakewatchers:* The stakeholders, who do not have a stake themselves but who protect the interests of real stakeholders, often as proxies or intermediaries. Examples are unions guarding the interests of employees and workers, or climate change agents and NGOs.

(3) *Stakekeepers*: The independent regulators, who have no stake in the firm but have influence and control, the firm has little reciprocal direct impact on them. The government in the case of the energy transition, the Ministry of Climate and Green Growth tends to be the main generic stakekeeper in the Dutch energy sector.

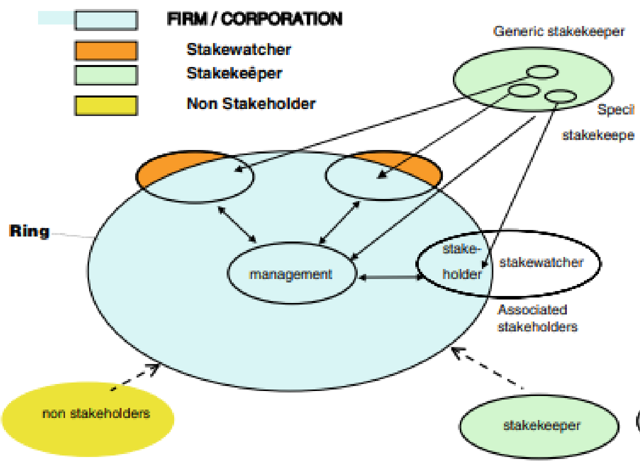

Figure 4.1 Solar stakeholder model (Fassin, 2008).

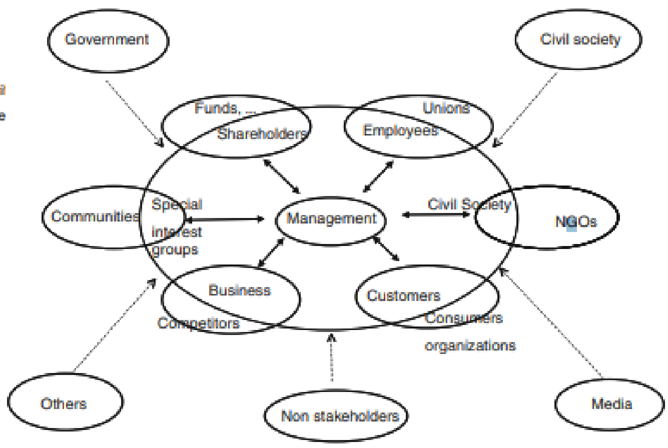

Figure 4.2 The stake model of the firm (Fassin, 2008).

After mapping the stakeholder relations of the PPP construct, the interests, positions, alliances and importance to the project will be evaluated using Schmeer's (2000) stepwise stakeholder analysis guidelines presented in Appendix A. In addition to this analysis, the underlying discourses will be investigated as discourses influence institutional salience, stakeholder consensus, and decision-making criteria (Hugé et al., 2012).

2.5 Conceptual model

The preceding paragraphs provided a theoretical foundation for this research. The elaborated frameworks and contexts will be applied in the case study to address the research aim and questions. These concepts are integrated into the conceptual model shown in Figure 5. First, central to the model is the use of energy-focused public-private partnerships to implement the niche innovation of a multi-commodity energy hub. This process is being influenced by three sets of variables, including external and internal influences as well as critical success factors. First, the socio-technical (sub)regime(s) control the implementation of a niche innovation through established practices and associated rules (Geels, 2011), which represent the external control relation. Secondly, the internal PPP elements by Cruz et al. (2022) structure the preconditions for a PPP to be successfully implemented. In combining their respective influences, these factors formulate additional contextual CSFs that influence the operationality of a PPP once implemented. These three variables determine the overall success of a PPP to facilitate the implementation of the MCEH, as such controlling the impact the MCEH, as a niche innovation, has on the energy landscape and mitigation of grid congestion. In other words, the (sub)regime(s) define the parameters, the PPP elements structure the quality of the PPP, while both determine additional operational CSFs. These intertwined variables are continuously affected by the dynamic, evolving nature of the Dutch energy landscape. Resulting in initiating reinforcing loops that reshape (sub)regime(s), elements and CSFs via the niche-innovation. A detailed description of the variables, their definitions, indicators, and measurements are provided in the operationalisation table in Appendix B.

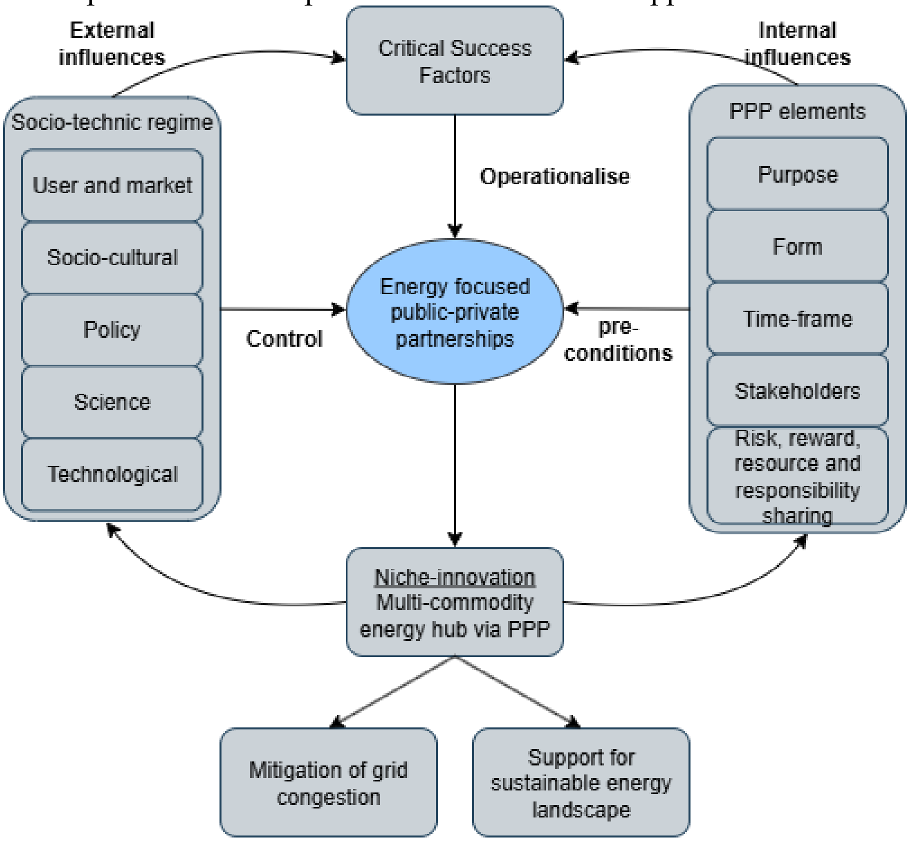

Figure 5 The conceptual model

3. Methods

3.1 Research philosophy

In research, particularly sustainable development, researchers are confronted with epistemological, ontological and other methodological questions. Recent trends and literature highlight significant differences between these fundamental questions, indicating varying epistemological views on knowledge (Escobar, 2016). Although there is no way to elevate one over another based on ultimate, foundational criteria, it is important to reevaluate and argue one's research considerations (Guba & Lincoln, 1994).

Conducting a case study reality is seen as partly shaped by its actors, hence aligning with a subjective epistemological and constructivist paradigm (Guba & Lincoln, 1994), where multiple realities coexist, constructed by "*the interaction of what they already believe and the ideas, events, and activities with which they come into contact*" (Ciot, 2009 p.195). In contrast, a more positivistic stance pertains towards climate change and the necessity for sustainable energy transitions, as these knowledge events are noted as factual and not collectively constructed (Calder, 2012)

3.2 Research approach

The choice for one's research approach is primarily based upon its mode of reasoning using (known) knowledge. Common approaches are based on deductive, inductive or abductive reasoning (Thagard & Shelley, 2005). This research adopts an abductive approach, utilising theoretical concepts of sustainable development, PPPs, integrated energy systems, and transition analysis to conduct the most suitable and applicable analysis for a practical case. In this approach, theory guides empirical research, allowing for observations and the selection of the most plausible explanations (Thiel, 2014).

Moreover, as noted previously, this research balances between the positivistic and constructionistic divide, in which the Dutch energy transition and its struggle are noted to be a given objective. However, this research examines complex intra-stakeholder contexts where multiple realities are prominent. This subjectivist and constructivist philosophy approach suits a qualitative research design, which is ideal for gaining a deeper understanding of social constructs. This approach allows a thorough view of the involved actors in the PPP construction and identifies the best fit (Tenny et al., 2022). Additionally, the implementation of PPPs in the Dutch energy sector, specifically for MCEHs, remains rather unknown. Qualitative research is crucial for such unexplored fields to uncover new insights (Scheepers et al., 2016). To assess the current energy landscape and energy transition in the Netherlands, this study provides a balanced qualitative and quantitative, directed methodology using literature and document analysis.

3.3 Research Strategy

Once the philosophy and approach are specified, a suitable research strategy needs to be selected. To generate usable results, it is essential to have an applicable research strategy (Van Thiel, 2014, pp. 86-87). This research will examine the MCEH project of the Harselaar, located in the municipality of Barneveld, through conducting a single case study in collaboration with Oost NL, the hub director, and associated stakeholders.

To answer the main research question, five sub-questions are formulated. The first three originate from a descriptive design to explore phenomena, interrelations, and comparisons between theory and practice. The last two use an exploratory design, which is suitable for investigating underexplored knowledge for PPP arrangements in the Dutch energy sector (George & Markus, 2023; Sheppard, 2020). Overall, both research designs prove well-suited for a case-study design (Van Thiel, 2014, pp. 58-59).

Furthermore, case study methodology enables a versatile, comprehensive, holistic, and in-depth investigation of a complex issue. The Dutch energy transition has seen rapid changes creating complex challenges for the TSOs, DSO's and prosumers (TNO, 2023b). This complexity is further emphasised by the contrast of sustainable transitions as goal-driven compared to emerging historic transitions (Smith et al., 2005). Furthermore, sustainable transitions are prone to free-rider risks due to limited incentives (Elzen et al., 2011). The Harselaar project illustrates this complexity, as multi-actors collaborate from the bottom up to engage in a transition for the niche innovation of an MCEH. This complexity will be unravelled by delineating data using specific codes and embedded data sets. (Harrison et al., 2017).

To successfully perform the case study, it is crucial to create clear boundaries for the research design. Harrison et al. (2017) emphasise the importance of being selective and specific in structuring parameters, including the participants, location(s) and processes when researching. Additionally, a timeframe is recommended to assess the scope and applicability to other possible case study designs for future research. After configuring the just characteristics, the Harselaar case proves to be a unique case for researching PPP constructs within the Dutch energy sector. In which all internal parties are motivated to partake in the project, although lacking experience in creating an MCEH.

Lastly, the Harselaar initiative envisions becoming the first Dutch MCEH to consume, converse, transport and share locally produced sustainable energy sources on a large scale, extending to over 600 local businesses in the future (SmarEnergyHubs, 2024) Finally, its timeframe to realize on-site innovations in less than two years is in line with this thesis's scope. This combination of the timeframe, the undiscovered field and scale allows generating meaningful findings.

3.4 Research methods, data collection and data analysis

To successfully execute the research design, a suitable methodology, data collection and analysis are required. This research combines primary and secondary research to collect and analyse data. In doing so, this research starts with desk research, followed by observations, semi-structured interviews and focus groups. The use of multiple methods allows the creation of triangulated data, supporting more comprehensive and synergistic overviews of one's case (Yin, 2014).

3.4.1 Desk Research

First, desk research is conducted in which existing data from academia is analysed to form the foundation of knowledge to formulate research and sub-questions (Van Thiel, 2014, p.106). This is further elaborated by performing a document and literature analysis on roles and suitability of PPP models. These analyses substantiate the knowledge required for deductively categorising coding structures for the semi-structured interviews as discussed below.

3.4.2 Semi-Structured interviews

Following desk research, this research uses semi-structured interviews to structure questions to gather data for its case study. This allows for providing deeper insights into the stakeholders' perspectives of the Harselaar project while facilitating access to gather sensitive information, which is key for identifying CSFs for PPP constructions (Cruz et al., 2022; Scheepers et al., 2016). Furthermore, given the limited amount of secondary data, semi-structured interviews are ideal for generating new knowledge.

To ensure validity, interview protocols will be tailored to different stakeholder roles. This study has aimed to conduct at least 10 interviews, depending on stakeholders' availability. Interviews, coding, and documentation will be conducted in Dutch or English, eliminating the need for translation. Table 2 outlines the conducted interviews and the referred abbreviations of each respondent for this research.

Compared to other formats, semi-structured interviews have a structured set of open-ended questions. This allows for following the desired line of action for gathering information (Dicicco-Bloom & Crabtree, 2006). The interview guidelines are structured to align with the research (sub)questions and may vary per stakeholder. First, an introductory section will address the research aim, ethical and confidentiality responsibilities of the interview. Subsequently, the interview starts with the first section of the interview presenting the first sub-question, continuing sequentially. The guidelines are provided in the RIS database and on request, given the varied quantity of guidelines.

Table 2. Interviewees for the case study

Date	Interviewee	In-text reference
27-02	Official Municipality Barneveld	Municipal official
13-03	Owner, Private party one	PP 1
17-03	Land issuer of a business park in Gelderland province	Land issuer
20-03	Real Estate Manager Private party two	PP 2
24-03	Oost NL Business Developer	BD 1
27-03	Energy Hub Director Harselaar	Hub director 1
31-03	Oost NL Senior Business Developer	BD 2
01-04	Energy Hub Director Zwolle	Hub director 2
03-04	Energy Hub Director Deventer	Hub director 3
08-04	Province of Gelderland official	Province official
06-06	Advisor for energy transition, Liander	Advisor Liander

3.4.3 Observations

In addition to the interview, the researcher will have access to conduct on-site observations at the Harselaar project. Direct observations are complemented by academia as the gold standard among qualitative data collection techniques (Murphy & Dingwall, 2007). The use of observations allows for revealing new insights into processes, structures and behaviours which other collection methods may not have access to (Furlong, 2010). Access to the case is provided through collaboration with the hub director and Oost NL. Observations will continuously be conducted over four months to identify patterns and support findings.

3.4.3 Focus groups

Finally, focus groups combine both observations and interviews, which is key for researching dynamics among participant groups, responses to group questions, and body language, which can explain important and controversial topics. Focus groups are especially interesting in social science and user research disciplines as they can provide more nuanced and neutral feedback than individual interviews and are easier to organise than larger-scale experiments or surveys (George, 2023).

To successfully conduct a focus group, the research scope and hypotheses must be formulated. Likewise, to regular structured interviews, it is important to have structured guidelines guiding the sessions and participants, who must be carefully selected to achieve fair representation. Finally, a moderator or co-moderator is required to facilitate the session by leading or assisting by taking notes (George, 2023). This session will collectively be led by associates from Oost NL and the energy hub director. Table 3 indicates the group meetings and participants for this research.

Table 3. Focus group sessions

Number	Date	Participants	Topic
1)	10-03	Dirkzwager, Oost NL, Hub Director Harselaar, researcher	Legal form of PPP constructs
2)	21-05	Liander, Oost NL, Hub Director Harselaar, researcher	Role of Liander within MCEH and collaboration of Harselaar
3)	24-06	Municipality Barneveld, PP1, PP2, Hub Director Harselaar, Oost NL, researcher	Internal focus group to align goals and processes towards initial collaboration.

3.4.4 Data analysis

Semi-structured interviews

After conducting semi-structured interviews, all data will be transcribed and coded to categorise similar data chunks and pull out cluster parts of the data relevant to the research question(s). This organising and displaying of data chunks allows for concluding and further analysis (Miles & Huberman, 2013). Coding is especially important given the complexity of the large chunks of data gathered via the case study.

The coding process consists of two phases. First, a deductive approach allows the establishment of theoretical concepts derived from the theoretical framework to develop initial coding schemes (Miles & Huberman, 2013). The second phase uses an inductive approach to generate new codes from interview and observation data using open, axial, and selective coding (ATLAS.TI, 2024; Miles et al., 1998). Insight from these primary data may especially prove to be useful for clarifying PPP critical success factors and socio-technic regime influences on PPP constructs, where current literature remains limited.

Together, the phases produce five coding tables, each representing a sub-question (Appendix B). The predefined coding tables will continuously be refined during the coding process. This research uses ATLAS.TI to analyse the transcribed data sets, creating an overview, identifying patterns and trends to categorise codes into dimensions and indicators. These transcribed data sets will be submitted to Radboud's database along with the research.

Observations

Observations can significantly contribute to a case study when analysed effectively. Morgan et al. (2017) present a framework that integrates single-case observations with other qualitative data collection methods to identify case-specific themes and relationships. The model sketches a detailed explanation of the data collection and analysis for observations (Appendix C).

Focus group lab

Analysing focus groups is like analysing semi-structured interviews, particularly the need for documentation and transcription. However, focus groups consist of between six and twelve participants, enhancing the reliability of the results (George, 2023). Transcribing this data is more complex than one-on-one interviews, hence requiring each participant to be assigned a number or a pseudonym. The following steps are to clean and code your data to achieve transcribed data sets. Additionally, focus groups allow for observations in which documenting initial notes and impressions of the moderator(s) is essential (George, 2023). These observations are further analysed and implemented using the framework of Morgen et al. (2017).

3.5 Validity, reliability and ethics

3.5.1 Validity

Sound validity is essential for assessing the trustworthiness, quality, and acceptability of research findings. Validity testing is evaluating what is supposed to be researched (Burns, 1999). Golafshani (2003) argues for using a mixed-methods approach with triangulation to boost internal validity. Hence, this research applies three qualitative empirical instruments to collect data: (1) Semi-structured interviews, (2) observations, and (3) focus group labs. Triangulating these collection methods on the same subject strengthens the validity and evaluation of the data found (Merriam, 1998).

Given the partly constructivist multi-actor perspective, this research requires a focus on the findings' trustworthiness as outlined by Lincoln & Guba (1985), who mention four elements of trustworthiness: credibility, transferability, dependability and confirmability. To ensure credibility, member checks will be conducted where preliminary results are shared with participants to validate results and experiences (Lincoln & Guba, 1985). Subsequently, the transferability and confirmability in constructivism conflict with positivistic external validity concerns (Van Thiel, 2014). In doing so, this research acknowledges the influence of contextual dependency on its transferability and confirmability. Nevertheless, these reasonings are supported by the abductive research design, minimising generalizability concerns (Bhandari, 2023a)

3.5.2 Reliability

Reliability is closely related to the consistency, dependability and replicability of data (Nunan, 1999). The first step towards reliability is to apply mixed methods using triangulation to collect diverse information that complements each other. This research conducts three methods and secondary desk research to diversify data sources.

Each data collection method has advantages and limitations, potentially leading to biases or reliability challenges. Semi-structured interviews and focus groups exhibit lower reliability due to their in-depth research, yielding subjective data. To improve reliability, interviews will involve multiple participants from comparable organisation or institutions. Additionally, the role of the researcher as both observer and analyst may introduce bias (Bhandari, 2023b). Recognising these biases is crucial to not skew one's data (Zohrabi, 2013). To mitigate this, multiple methods will confirm observational data using triangulation (Bhandari, 2023b).

3.5.3 Ethics

Finally, in social science research, protecting integrity and ethical considerations is essential. This study conducts qualitative research through a case study involving multiple participants. To obtain honest and reliable data this research ensures a safe space for participants. Hence, ensuring their confidentiality and anonymity. The generated data will only be distributed to the thesis supervisor(s), the intern organisation and partly to participants on request. Additionally, participation in the interviews is entirely voluntary, allowing interviewees to withdraw or decline answering specific questions at any time. Before data collection, both interviewees and questionnaire participants will be informed of ethical considerations using American Psychological Association standards (American Psychological Association, 2017).

4. Results and analysis

The following chapter of this master thesis provides a customised stepwise analysis guide, functioning as both a theoretical lens and practical implementation for initiative takers, intermediaries, hub directors and other stakeholders considering implementing a PPP for an MCEH. The analysis consists of five total steps as visualised in Figure 6.

Initially, to effectively design a PPP framework and provide appropriate guidance for one's case, it is essential to understand the specific role, share and suitability of PPP constructs in its respective sector. Accordingly, step 1 addresses these as delineated by Cruz et al. (2022) by performing a document and literature analysis.

Step 2 involves analysing the project and the involved stakeholders to determine the appropriateness of a PPP as a potential collaboration model. This step is conducted by sketching the project's case and using Fassin's (2008) and Koirala's (2016) stakeholder identification and mapping, as well as Schmeer's (2000) stakeholder analysis.

Once sectoral PPP knowledge, project case and stakeholder characteristics are clear, step three is divided into two steps, assessing the internal and external influences determining PPP implementational success. Step 3A analyses external socio-technical regime influences on the Harselaar case based upon Geels' (2011) MLP framework. Whereas step 3B delineates the preconditions required to implement a PPP based upon the five elements provided by Cruz et al. (2022).

Next, the prior steps are based upon generalised frameworks. Given the complex context-specific cases MCEHs operate in, step 4 addresses case-specific critical success factors (CSFs) that determine operational success for the PPP. These CSFs are formulated on the framework of Cruz et al. (2022), however refined for the case by combining the most important influences of steps 3A and 3B.

Finally, once all previous steps have been completed, the researcher is able to conclude if the project and stakeholder context, preconditions, external influences and CSFs allow for a suitable ground to implement a PPP. Step 5 assesses the possible organisational and legal structures for a PPP incentive, aiming to implement MCEH.

Although the stepwise analysis may be applied in a general sense, the above-mentioned steps will be elaborated upon in the following chapter using the Harselaar case as the sample case. In doing so, seeking explorative results aimed to generalise to comparable cases. The results and limitations will be further discussed in the reflection.

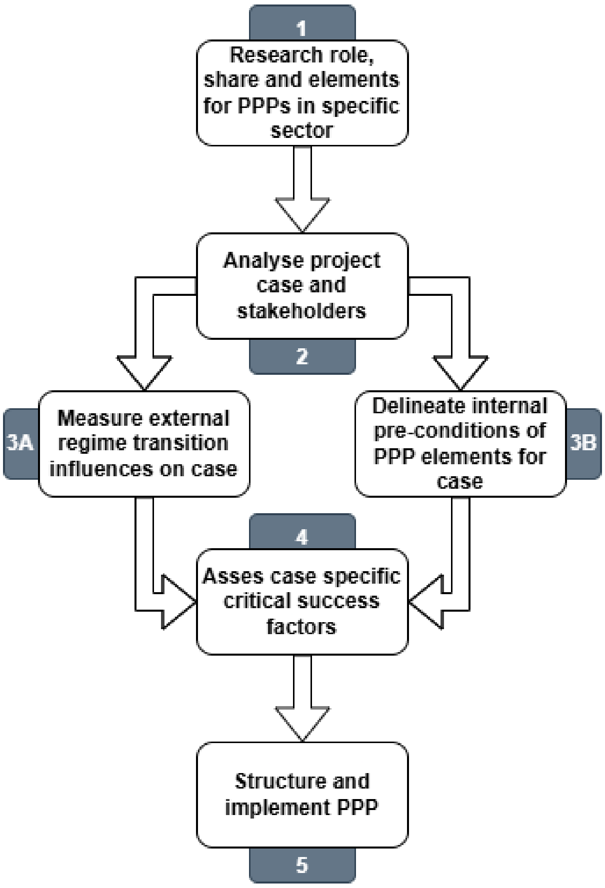

Figure 6 Stepwise PPP analysis guide

4.1 Step 1: Public-Private Partnerships for Sustainable Energy Development in the Dutch Energy Landscape

A distinct trend can be observed in the formation of Public-Private Partnerships (PPPs) within sustainable development projects, setting them apart from those in other sectors (Sovacool, 2013). Hence, step one researches PPPs for sustainable energy developments in the Dutch energy landscape.

4.1.1 Role of Public-Private Partnerships in enhancing energy sector projects

PPPs in the energy sector have been noted to be used by several governments as a method for developing energy efficiency projects (Grimsey and Lewis, 2002; European Commission, 2003; Canadian Council for PPPs, 2004). Specifically, the Ministry of National Affairs and King's relations emphasise the complexity of spatial projects with large societal interest, such as sustainable energy projects. These are to be cautious for choosing a collaboration model like PPPs, which facilitates, protects and supports the societal interest (MBKR, 2019). In doing so, relying on the strengths of both public and private sectors to mobilize resources, mitigate risks, accelerate the deployment of energy technologies while assuring a shared compatible objective and balanced interest of both parties (Pätari & Sinkonen, 2014; Roshchanka & Evans, 2016; Taghizadeh-Hesary, and Yoshino, 2020).

Specifically, the popularity of adopting PPPs is attributed to its robustness and usefulness on three adaptation pathways:

(1) Improving efficiency regarding cost saving and enhanced service delivery by leveraging the private-sector expertise, resources and capital (Casady, 2020; Zhang and Xu, 2022).

(2) Optimising outcomes generated by life-cycle incentives within a long-term arrangement and project phase bundling (Lenferink et al., 2013)

(3) Adding value through a risk-sharing mechanism between the public and private parties, transparency of governance, and business-oriented thinking (Villani et al., 2017; Casady, 2020).

Additionally, this research suggests a fourth role characterising the necessity and robustness of PPP constructions within sustainable development projects. This is directed towards the rationales that sustainable development requires community engagement and support to achieve specific outcomes and overall outcomes in transition theory (Stirling, 2005). Hence, the fourth adaptation for the use of PPPs is seen in:

4) Actively procuring societal and community engagement through support should be systematically integrated into development activities to lower project risks, avoid disputes and grievances, as well as avoid cost and time overruns during implementation (Davis & Franks, 2014; Watkins, 2017; Power Africa, 2020).

These four adaptation enhancements enable PPPs to be a successful mode in achieving sustainable development and energy projects (Pinz et al., 2018; Wang and Ma, 2020)

4.1.2 Evaluating the share of Public-Private partnerships in Dutch sustainable development and energy projects

The following section conducts a document analysis and literature review on PPPs in Dutch sustainable development and energy transition projects. In doing so, it analysed 24 governmental, consultant, private documentation in the forms of reports, meetings and government documents which are noted in Appendix D. The analysis is conducted by filtering the varying forms of PPP constructions, mentioned by Cruz et al., (2022) and the varying legal entities available within energy hubs mentioned by Dirkzwager (2024) & Firan (2024) in documentation of Dutch sustainable projects. The aim is to analyse the current presence of PPP constructions and collaboration forms in these projects to validate which formats are most used. The findings are shown in Tables 4.1 and 4.2.

Table 4.1 Quantitative results document analysis share of PPP constructions

Code	Code Group	Frequency	Percentage
PPP construction	Organisation structure	**12**	**50,00%**
VA-Voluntary agreements	Energy efficiency	**9**	**37,50%**
PPA-power purchase agreements	Energy security	**8**	**33,33%**
Technology development partnerships	Energy technology development	**7**	**29,17%**
City-level partnerships	Energy efficiency	**6**	**25,00%**
Group transport agreement	Energy security	**6**	**25,00%**
Thermal energy services	Energy efficiency	**5**	**20,83%**
PP-independent power producer	Energy security	**5**	**20,83%**
Deliberative partnerships	Energy initiatives type II partnerships	**4**	**16,67%**
Private-private partnerships	Energy security	**3**	**12,50%**
ESCO-Energy Service Company	Energy efficiency	**2**	**8,33%**
Multi-stakeholders partnerships	Energy initiatives type II partnerships	**2**	**8,33%**
5Ps-pro-poor PPPs	Energy access	**1**	**4,17%**
Global partnerships	Energy initiatives type II partnerships	**1**	**4,17%**
Green renovations	Energy efficiency	**0**	**0,00%**
Environmental partnerships	Energy security	**0**	**0,00%**
Voluntary technology development	Energy technology development	**0**	**0,00%**

Table 4.2 Quantitative results document analysis share legal entity forms

Code	Code Group	Frequency	Percentage
Cooperative	Collaboration form	**17**	**70,83%**
Association	Collaboration form	**13**	**54,17%**
Private limited company	Collaboration form	**12**	**50,00%**
Foundation	Collaboration form	**9**	**37,50%**

Elaboration findings document analysis

Analysis of legal and collaboration documents revealed a representation of 50% of Dutch energy projects referenced traditional PPPs. Specifically, a direct mention of PPPs was found in reports of TKI urban energy (2020) and Next2Company (2023) related to district heating, as well as the National Plan Energy Systems (2023) of the Ministry of Economic Affairs (EZK). The remaining nine inquired findings mentioned closely related notions without mentioning the direct abbreviation or definition as mentioned by the European Commission (2004) and Klijn & Teisman (2003).

Within the 12 documents that mention PPP structures, PPAs and voluntary agreements were most often mentioned, followed by technology development projects. These forms of PPPs focus on enhancing energy efficiency, energy security and energy technology development (Cruz et al., 2022). Notably, green infrastructure reconstruction was lacking in its presence. A differentiation is noted between environmental PPPs, prioritising ecological quality and energy sector PPPs, which tend to focus on addressing grid capacity constraints and optimising energy efficiency.

Furthermore, this document analysis aimed to verify legal collaboration forms within the Dutch energy sector. The results indicate a strong presence of energy cooperatives within the Dutch energy sector, most being implemented in collaboration with local residents, businesses and energy communities (Local4Local, 2024; RVO, 2024; HIER, 2023).

The association and private limited company presented comparable quantitative results. However, the implementation of the private limited company was also seen to be implemented in more complex endeavours involving multiple legal entities parallel in a project (Freon, 2024; EIGEN, 2023b; EIGEN, 2023c). The association and foundation were often collectively mentioned within local, smaller-scale solar, thermal and wind residential projects (HIER, 2023; NPLW, 2024; Next2company, 2023). Altogether, a varied mix of legal formats is being implemented within the Dutch energy sector. Hence, the choice for a legal form largely depends on "*the local context, interests and goals of the involved business owners, and specific wishes of decision-makers and financers* "(Firan, 2024, p.4).

4.1.3 Suitable Public-Private Partnership Elements for Sustainable Energy Projects

The following section seeks to evaluate the most suitable PPPs for sustainable energy projects within the Dutch energy landscape. It applies deductive analysis and assesses written literature using the five PPP elements mentioned by Cruz et al (2022) to characterise PPP constructions. The literature analysis's scope focuses on PPP forms in the Dutch energy landscape, as indicated by the document analysis, and specified for sustainable energy projects. Previously used literature sources in the theoretical framework are also discussed and consulted for snowballing literature.

<u>Literature review</u>

To obtain the highest quality and relevance, literature was excluded by language, publication date, subject area, document type, and methodological quality (Fink, 2019). These exclusion criteria are listed in Table E1 (Appendix E). Searches were conducted via Web of Science and Scopus Elsevier, with duplicates removed. After scanning abstracts, reading full texts, and supplementing with snowballing methods, a final selection of 21 articles remained. The search process is elaborated in Table E2, and the selected articles are portrayed in Table E3 (Appendix E). The following sections elaborate the findings of the literature review, focusing on the five elements for successful PPPs (Cruz et al., 2022).

1) Purpose

The first element indicates the urgency of sustainability challenges and the complex energy sector as primary drivers for creating customised PPPs. The core of these partnerships requires aligning public and private interests to leverage strengths and distribute risk. Combining both allows for complementary strengths and pooling of resources to achieve long-term sustainability goals (Rossi et al., 2019). These synergies between public and private parties address the energy challenges by improving efficiency, security, as well as decarbonization and implementation of decentralised grid infrastructure, such as MCEHs. (Wang & Ma, 2020).

Specifically, research notes public purpose to focus on policy objectives including balanced energy access, environmental sustainability and regional business resilience (Martinez et al., 2023; Nel, 2018). These priorities are often overlooked by private parties, while private capital and expertise can support these objectives (Marcelo et al., 2019; Antonio et al., 2016). On the contrary, private parties are motivated by commercial opportunities, especially in evolving technological environments, due to their high complexity. Overall, private parties favour operating in stable regulatory frameworks (Taehri et al., 2025).

Academica states that clear and transparent articulation of purpose is essential within PPP agreements (Marcelo et al., 2019; Klijn & Koppenjan, 2016). Purpose is further enhanced by including contractual flexibility, governance structures, and performance wins. Including these in one's PPP helps reduce opportunism and foster adaptability during the project's lifecycle.

Purpose is always context-specific, influenced by sectoral focus, geographic scale, and stakeholder composition. Overall, literature highlights a dual purpose for PPPs in energy projects:

1. Process acceleration of public energy policy goals, ensuring technical, financial and operational efficiency by private engagement.
2. Sharing of risk, acquiring investments, practising innovation and accelerating project implementation (Yescombe & Farquharson, 2018).

(2) Form

The form of a PPP refers to its organisational, legal and statutory arrangements used to govern collaboration between the public and private parties. Likewise, as purpose, form is context specific, varying from traditional concession models to hybrid and voluntary agreements (Cruz et al., 2022; Martiniello et al., 2020; Veum, 2018). Although Dutch energy projects implement multiple PPP formats, a trend is seen towards adaptive formats that operate under complex, dynamic, multi-stakeholder environments. These environments require flexible structures that balance the varying public and private goals and interests (Klijn & Koppenjan, 2016). Here, three correlated forms are noted:

1. Performance-Based Contracts

Instruments such as Independent Power Producer (IPP) models and Power Purchase Agreements (PPAs) are frequently applied in energy PPPs (Martiniello et al., 2020; Salci & Jenkins, 2018). Such contracts allow parties to align party incentives, share risk and acquire investments. This is particularly important for large-scale renewable or energy efficiency projects.

2. Institutionalised structures

Legal structures such as joint ventures or special purpose vehicles (SPVs) are noted to formalize collaboration between parties. Such institutionalized structures benefit from operational flexibility which allow for adaptive governance. Literature indicates incorporating feedback and learning mechanism as essential in its contract and structural design (Klijn & Koppenjan, 2016).

3. Collaborative and hybrid agreements

Newly developed PPP energy projects favour hybrid collaboration forms to enable broader stakeholder engagement while maintaining social and project objectives (Cruz et al., 2022; Nel, 2018). Voluntary agreement (VA) frameworks, favouring co-regulation over formal contractual enforcement, are often mentioned. However, their effectiveness depends strongly on mutual trust and shared risk awareness (Veum, 2018; Ferrare & Lange, 2013).

A notable case is the Dutch LTA1–LTA3 agreements, where small-medium enterprises (SMEs) voluntarily improved energy efficiency and adopted renewables. In return, the participants received regulatory support and carbon tax incentives enabled by the Ministry of Economic Affairs (Veum, 2018).

<u>(3) Timeframe</u>

The timeframe of PPPs is indicated as a fundamental factor influencing the project design and project success. Literature indicates that successful energy PPPs are commonly long-term oriented. A longer timeframe reduces investment risk and improves financing, especially in high capital contexts (Weis & Sarro, 2013). Additionally, hybrid PPPs implement adaptive timeframe models that address entry challenges in technology, regulation, and finance. In doing so, phasing investments over multiple checkpoints throughout the project's lifecycle (Nel, 2018).

Klijn and Koppenjan (2016) further critique this by identifying rigidity as a barrier to PPP performance over time**.** Avoiding this requires renegotiation clauses and adaptable checkpoints of performance agreements to align with the purpose of one's project lifecycle.

Combining long-term commitments with phased implementation enables reflective "stop-and-go" moments within the lifecycle, allowing for critical reassess or renegotiate project process. These processes support risk-sharing in which public actors can share performance risk, while private partners are incentivised to optimise energy efficiency and project deliverables (Martiniello, 2020).

<u>(4) Stakeholders</u>

In the energy sector PPPs, stakeholders are broadly categorised into public and private entities, with further divides. Although consistent convergence is seen in literature, its application within the energy context varies at the institutional level and role.

Public entities, including government agencies and municipalities, are responsible for policy formulation, regulatory oversight, and ensuring alignment with national and local energy objectives. Their roles differ across governance scales. Local governments, in particular, often act as facilitators or initiators of energy transitions through integration with urban planning (Petersen & Heurkens, 2018). Martinez (2023) and Marskamp et al. (2024) identify three municipal roles in energy hub projects:

(1) *Pioneering* municipalities act as initiators and co-owners via state-owned or subsidised energy projects.
(2) *Scouting* municipalities facilitate and cooperate with privately initiated energy projects
(3) *Testing* municipalities conduct traditional regulatory responsibilities and test policy changes.

In contrast, DSOs and TSOs function privately but have the responsibility to regulate the high, medium-, and low-voltage grids while shaping policy. Similarly, innovation agencies, as Oost NL, collaborate closely with government bodies while enjoying greater operational autonomy (Oost NL, 2025).

The private section includes most remaining parties that are not categorised above, with stakeholder engagement and purpose being highly dependent on contractual structure, policy environment, and risk-sharing mechanisms (Iossa et al., 2007; Mazher, 2025). PPPs are therefore recommended to align parties' strengths and interests based on one's case. In doing so, ensuring accountability and long-term commitment (Wang & Ma, 2020).

Overall, the analysis confirms Koirala et al.'s (2016) overview of competitive and regulated parties. However, literature emphasises the importance of financial institutions for advancements within energy projects (Tahari et al., 2025; Weis & Sarro, 2013). Additionally, Nel (2018) and Salci and Jenkins (2018) mention a role change for IPPs and project developers, in which both partake in broader energy systems and sub-regimes. To further clarify the stakeholder field, this thesis performs a stakeholder mapping, as presented in chapter 4.2, by using the model of Fassin (2008).

(5) Risk, reward, resource and responsibility sharing

The final analysed element of Cruz et al.'s (2022) PPP framework includes risk, rewards, resource and responsibility sharing, which is often mentioned in literature. The following section outlines each principle by addressing its potential and challenges that influence PPPs.

(i) Allocating risk: Enhancing Resilience and Managing Asymmetries

Effective risk allocation is essential for PPP viability and lifecycle success. Particularly for high-upfront capital-intensive and long-term energy projects (Marcelo, 2019). Nevertheless, overly complex, in-depth and rigid contracts can reduce process performance and cause delays. Therefore, implementing flexibility constructions such as renegotiation clauses, (intentional) contractual incompleteness, performance-based indicators and dispute resolution mechanisms are crucial (Klijn en Koppenjan, 2016). These measures sustain trust, which allows adaptation to changing sub-regimes and fosters project resilience and responsiveness (Geels, 2011).

(ii) Structuring rewards to align incentives and ensuring performance

Overall, specific context-based agreements are seen in structuring rewards between public and private parties in energy projects. Three subdivisions stand out:

(1) Performance incentives such as EPCs and PPAs focus upon longer-term contracts and dealmaking to enhance energy security, efficiency and optimisation on a cost basis. Often leading to reliable revenue, accessibility and stability for energy producers, ensuring public value is maximised (Martinello et al., 2020)
(2) Market mechanism refers to the effect of market-oriented PPP deals. Exemplary, the reduction of emissions can be assessed as a reward and traded on the carbon credit market (Khan et al., 2020).
(3) Policy and knowledge dissemination represent a broad spectrum of rewards where partnerships support target and policy goals set for public bodies. In return, parties receive policy incentives or long-term pricing. In contrast, knowledge institutions benefit from non-monetary rewards via knowledge dissemination (Brogaard, 2019).

(iii) Pooling Resources: Operationalise Complementary Strengths

Furthermore, a new trend is noted where public parties act as co-developers of energy development projects (Cruz et al., 2022; Petersen & Heurkens, 2018). These cases focus on pooling resources and leveraging complementary strengths. Such collaborative strategies allow for additional value creation. Public parties contribute zoning permits, subsidies and regulatory power to PPPs, creating legitimacy. Controversially, private parties such as independent power producers (IPPs) contribute to large project investments by bringing capital, expertise and swift process power. Private parties also possess higher risk tolerance and financial flexibility compared to public parties (Nel, 2018).

(iv) Responsibility Allocation: Ensuring Clarity and Accountability

Finally, clearly defining responsibilities remains crucial to avoid conflicts and validate stakeholder accountability. As such, a balanced role division in the designing, financing, and operationalising of a project should align with stakeholder strengths (Thompson et al., 2018). However, early-stage agreements often suffer from vague role definitions, which weaken commitment and reduce effectiveness (Cornelis, 2019). To prevent this, lasting engagement and clear arrangements are essential. The literature identifies four divisions for responsibility and accountability allocation:

1. *Public accountability* is linked to the responsibility of securing an affordable supply of energy for the public. (Martinez, 2023).
2. *Private accountability* refers to private parties' allocation of the design and operations of a project due to high levels of expertise.
3. *Collaborative accountability* focuses on the flexibility of role tailoring and adjustment to fit the project needs, typically seen in hybrid PPPs (Cruz et al., 2022).
4. *Institutional learning* specifies the importance of ongoing reflection of roles and responsibility allocation. Literature emphasises public actors to benefit from maturing over the project's lifecycle. Furthermore, immature public actors may misallocate roles, undermining performance (Marcelo, 2019).

Concluding remarks on the suitability of PPPs

In conclusion, to successfully facilitate the implementation of a PPP in energy projects, literature emphasises tailoring and implementing the five elements of Cruz et al. (2022). Purpose in energy PPPs is rooted in aligning public policy objectives with private-sector business cases, innovation and investment capabilities. Form indicates the institutional and organisational structure of PPPs, ranging from traditional concession contracts to voluntary hybrid models. Frequent forms include performance contracts, institutionalised vehicles (Joint ventures, SPVs) and modern collaborative frameworks (Vas, Dutch LTAs). The time frame indicates that long-term contracts provide investment certainty but may hinder adaptability. Modular timelines and renegotiation clauses using go/no-go checkpoints assist in lowering risk entrance level and balancing flexibility. Resulting in higher commitment, improving resilience and performance. Stakeholders include public authorities, semi-public actors (e.g., TSOs/DSOs), and a diverse range of private actors, including IPPs, developers, and financial institutions. Role division requires a tailored division to align incentives and complement strengths. Risk, reward, resource, and responsibility sharing are seen as interdependent pillars. Suitable PPPs (1) allocate risk to high-risk tolerance capable parties, (2) align rewards to performance, (3) pool complementary resources, and (4) clarify responsibilities to ensure transparency and accountability.

4.2 Step 2: Stakeholder Involvement and Project Dynamics in the Harselaar Multi-Commodity Energy Hub

4.2.1 Project the Harselaar: A Case Description

This case study explores the potential for the Harselaar Business Park to implement an MCEH. The current park, located in the municipality of Barneveld, consists of over 600 companies, of which a desired additional 60 companies are to be implemented via the MCEH. Furthermore, the park is strategically positioned to maximise the local generation and distribution of renewable energy. The site hosts key industrial clusters, including wind energy, hydrogen, metal and concrete industries, transport and logistics, and recycling, which are poised to benefit from integrated energy solutions (Smart Energy Hubs, 2025b). The business park meets a high demand and attractiveness for new businesses to settle, in addition to its current businesses. Nevertheless, this favourable business climate is deteriorating as a result of grid development capacity issues.

Harselaar's location along the internationally significant TEN-T Corridor (North Sea–Baltic States) ensures robust connectivity to Central and Northern Europe, creating opportunities to decarbonise the transport sector through the deployment of fast-charging plazas, battery-swapping systems, and hydrogen refuelling infrastructure for heavy transport (Smart Energy Hubs, 2025b). Moreover, opportunities exist to leverage renewable energy production from the RES Foodvalley initiative and local energy cooperatives (RES, 2023). Figure 7 represents the location of the MCEH in the municipality of Barneveld.

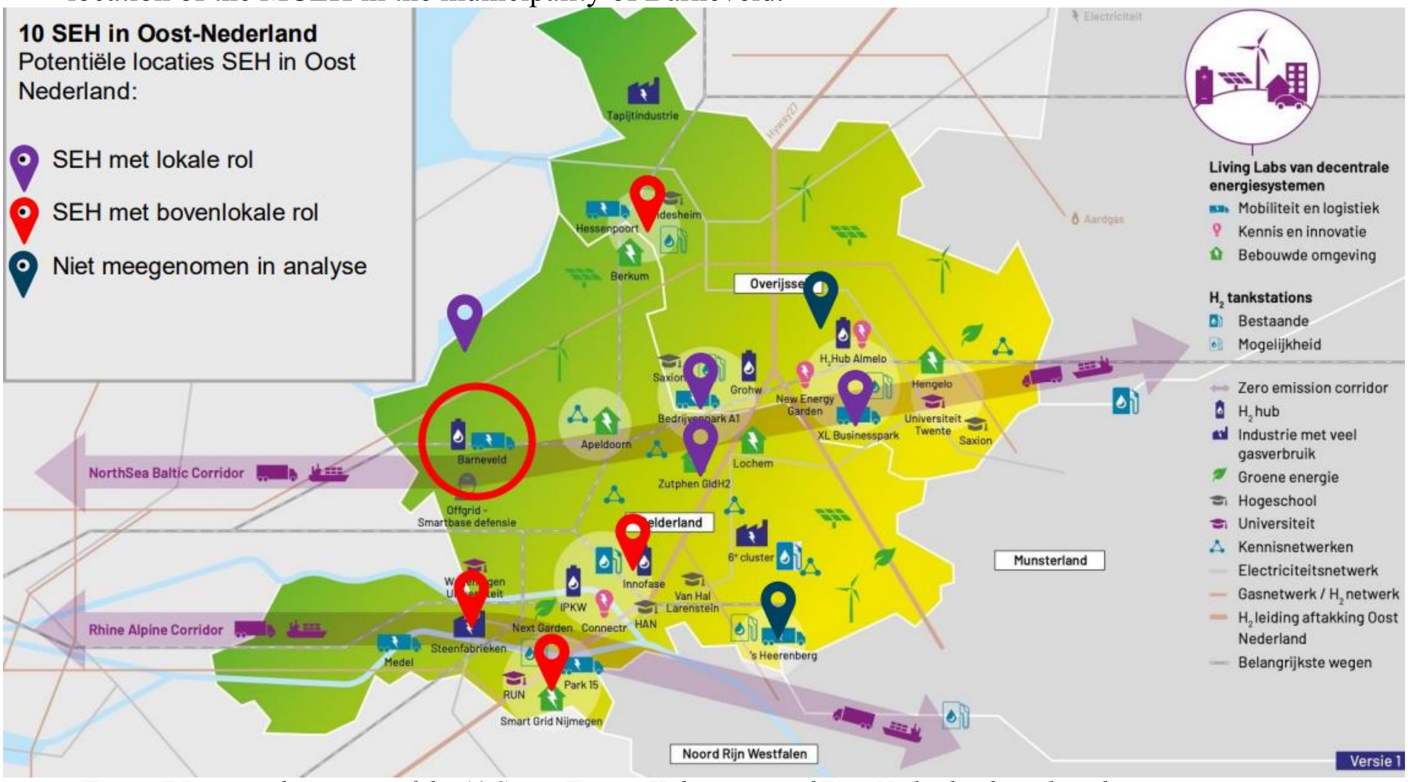

Figure 7 Logistical mapping of the 10 Smart Energy Hub projects of East-Netherlands, red circle representing the case (Smart Energy Hubs, 2022)

The business park also plays a critical role in addressing the broader challenges and opportunities associated with the energy transition facing Barneveld and the Netherlands as a whole (Hub Director Harselaar, 2025). By adopting a decentralised energy system that prioritises local renewable energy generation, hydrogen conversion, large-scale battery storage, and consumption at the point of demand, Harselaar Business Park can alleviate grid pressure and mitigate grid congestion on the national electricity grid while ensuring energy resilience for local businesses. Recent research from Liander, the regional DSO, indicates up to 60% of energy being freed by implementing an MCEH compared to individual traditional connections (Liander, 2025)

Realising integrated locally generated energy systems seem opportune to resolve capacity grid issues, which are hindering the region's sustainable growth potential (Liander, 2023). Additionally, it reduces its dependence on external and geopolitical energy developments, positioning the park as a leading example of a future-ready MCEH. Specifically, the initial phase of the MCEH project of the Harselaar aims to realise an integrated energy system for 60 business units on 30 square hectares of newly realised business sites, positioned South-West of the current Harselaar business zoning (darker blue area) in Figure 8. Figure 8 indicates the solar (yellow sections), wind (blue upright sections) and orange gas installations (orange sections).

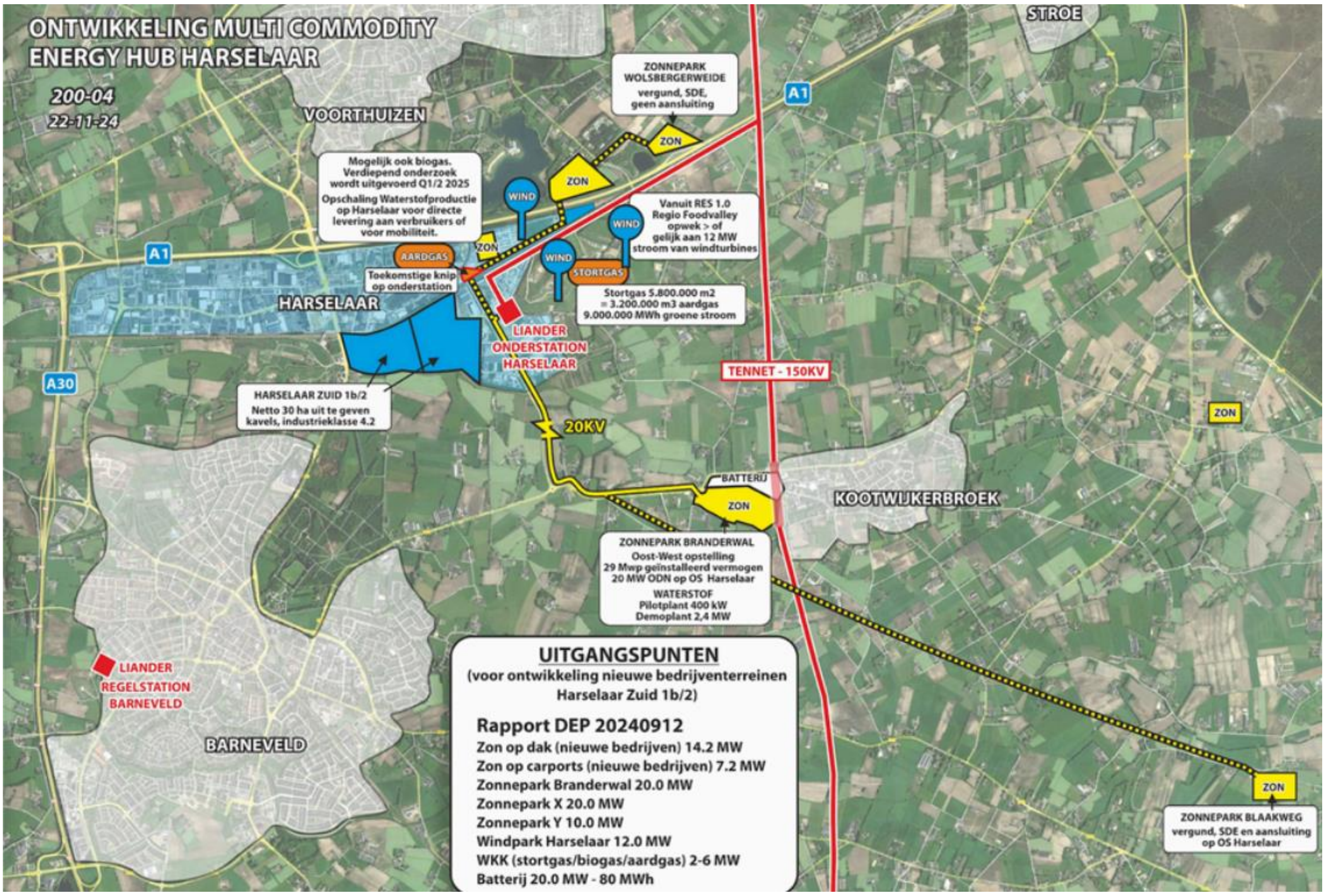

Figure 8 Development map of Harselaar MCEH, 22-11-24 (Hub Director 1, 2025)

The Harselaar case is characterised by driven local entrepreneurs and a closely knitted municipality that shares an interest in the energetic developments of the Harselaar region (Hub Director 1, 2025). This research has been performed over five months of the project, while deeply embedded in the early collaboration stage with these stakeholders. Although a vast amount of data has been gathered, the actual implementation of the partnership did not fit within the time scope of the research; hence, the process towards collaboration has been documented.

Niche analysis: categorisation of the Harselaar MCEH

With the overarching landscape context clarified, it is important to describe and analyse the implementation of the MCEH by combining document analysis and the ICES framework of Koirala et al. (2016). The initial categorisation is presented in Tables 5.1 and 5.2. Of which the results indicate a variation of existing energy carriers and possible future energy developments, expanding or implementing new energy systems. The findings will further be substantiated within the stakeholder analysis of 4.2.3.

Table 5.1 Categorisation of MCEH

Technologies	Household level	Community level
Local Generation- Existing developments	• Solar Thermal • Solar PV rooftop • Internal combustion	• Combined Heat and Power • Solar thermal • Electrolyser H_2 • Internal combustion engines
Local Generation–future developments	• Solar Thermal • Solar PV rooftop	• Wind turbines • Fuel cells • Biomass/gas
Demand side flexibility–existing developments	• Electric vehicles • Electric and heat storage • Battery energy management systems • Home building smart energy systems	• Community electric and heat storage • Community (smart) energy management systems
Demand-side flexibility–future developments	• Battery energy management systems	• Large-scale batteries

Technologies of the Harselaar MCEH

Table 5.2 Technologies of an MCEH

Perspective	Categorization
Activities	- Local generation, storage, conversion, demand response - energy exchange, sharing, trading - Collective pricing
Scale	- Meso: neighbourhood (Harselaar 1b/2 area) - Macro: whole of Harselaar + municipality and RES region
Grid connection	- Grid-connected, integrated connection
Initiatives	- Led by private enterprises - Led by the government - Public-private partnership
Location	- Developed countries - Rural, greenfield development
Topologies	- Point of common coupling

4.2.2 Stakeholder mapping of the Harselaar project

Once the case and MCEH are described and categorised, the following section analyses the stakeholders involved in the Harselaar case. The analysis uses two frameworks of Koirala et al. (2016), actors' type and Fassin et al. (2008) stakeholders' type, to analyse and map the interrelations between stakeholders as substantiated within chapter 2.4. The findings are summarised in Tables 6.1 and 6.2

Competitive parties

Table 6.1 Competitive stakeholder mapping

Stakeholder	Actor type (Koirala et al., 2016)	Stakeholder type (Fassin, 2008)
Private party 1	Energy producer. Energy suppliers, Technology providers	Internal stakeholder
Private party 2	Energy producer, Technology providers	Internal stakeholder
New Business owners Harselaar 1b/2	Community level	Internal stakeholder
Hub director 1	Aggregator	Internal stakeholder
Oost NL	Technology provider, Government, policy makers and regulators	Stakewatcher

Regulated parties

Table 6.2 Regulated stakeholder mapping

Stakeholder	Actor type (Koirala et al., 2016)	Stakeholder type (Fassin, 2008)
Municipality of Barneveld	Government, policymakers and regulators	Internal stakeholder
National government/Ministry of Climate and Green Growth	Government, policymakers and regulators	Stakekeeper
Province of Gelderland	Government, policymakers and regulators	Stakewatcher
Liander	Distribution System Operator(DSOs)	Internal stakeholder
Tennet	Transmission system Operators(TSOs)	Stakewatcher
Oost NL	Policy makers and regulators	Stakewatcher
Authority Market and Consumer (AMC)	Government, policymakers and regulators	Stakekeeper
Knowledge institutions	Technology providers	Stakekeeper

Stakeholder mapping

In combining the above-mentioned actors, this research has created Figure 9, which represents the stakeholder mapping for Harselaar's case, using Fassin's (2008) model. The model is based on three layers: the internal PPP between Municipality, private party one and two (indicated by the darker blue arrows), the overarching MCEH of Harselaar (inner circle) and the outer layer (outside the inner circle).

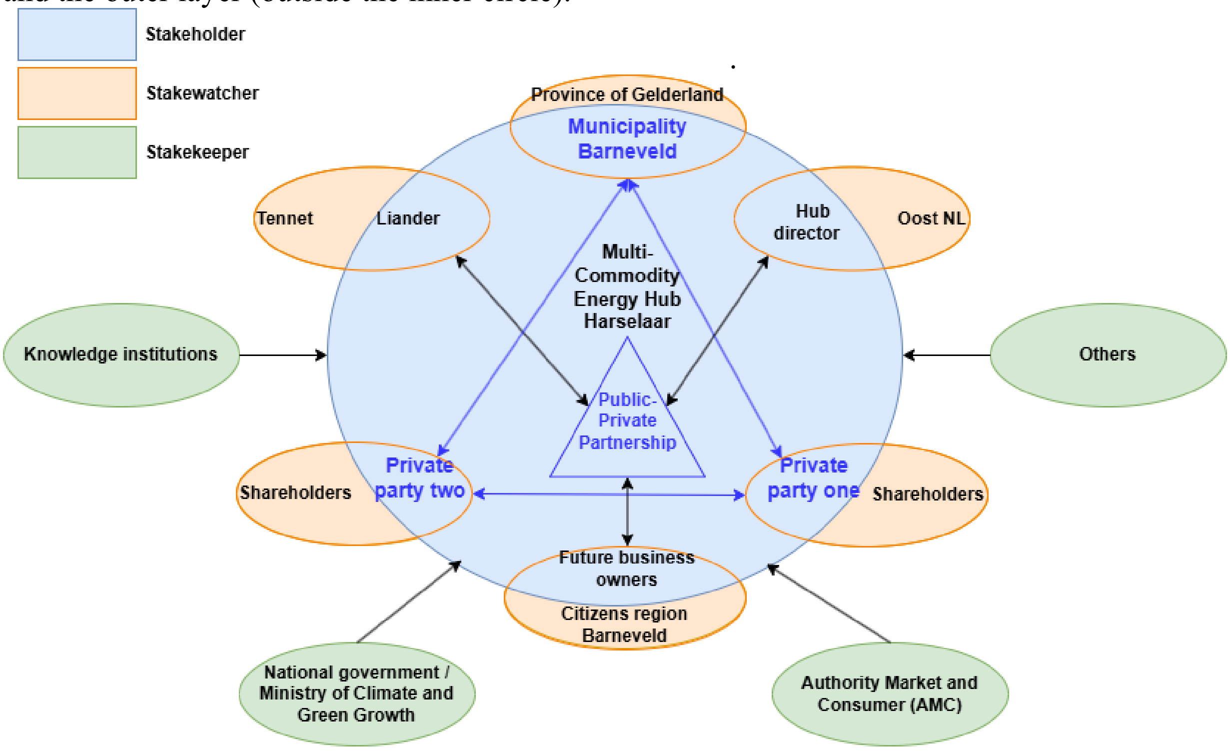

Figure 9 Stakeholder mapping of the Multi-Commodity Energy Hub, the Harselaar

4.2.3 Stakeholder analysis

Having identified and mapped the stakeholders and their interrelations, this section provides a detailed analysis of the inner stakeholders in the inner (light blue) circle. The analysis begins with an organisational introduction and assessment of stakeholders' internal or external position. Followed by their knowledge of relevant policies, policy stance, and available resources. Next, their broader interests are discussed, specifically distinguishing between private interests and system interests, following Koirala et al.'s (2016) framework. Furthermore, project dynamics are described, including underlying discourses, power levels and leadership roles concerning the implementation of an MCEH and PPP. The final section provides key insights and remarks on the stakeholder analysis.

All the sections are substantiated with quotations gathered from primary data. Finally, an elaborate overview of the stakeholder analysis is presented in Appendix F, showcasing the stakeholder table using Schmeer's (2000) stakeholder analysis framework (Appendix A).

The analysis data is obtained by conducting desk research and semi-structured interviews. However, due to the scope and limitations of this study, not all parties could be interviewed and elaborately analysed. Hence, this analysis focuses on the internal PPP stakeholders, Liander and Oost NL, due to their important involvement in MCEH projects.

<u>Stakeholder analysis (1): Introducing the actors</u>

The stakeholder landscape of the Harselaar MCEH reflects a diverse mix of public, private, and semi-public actors, each with distinct mandates, capacities, and motivations.

Private party one (PP1**)** is a private renewable energy company, specialised in energy projects with a focus on the production, storage, and transportation of energy. The company aims to provide accessible, sustainable, and clean energy for all, while offering a green impetus to residents, business owners, and municipalities (PP1, 2025). As the main producer and converter of energy, as well as its investments and motivation for the MCEH and PPP, PP1 is indicated as an *internal stakeholder.* PP1 brings a high level of knowledge for energy systems and extensive energetical assets including (1) a 20 MW solar park, (2) a pilot electrolyser project (400 kW, plans to scale to 2.4 MW) and (3) investments in permits and development for large-scale battery storage (80 MW capacity).

Private party two (PP2**)** operates in logistics, concrete production, and waste management. Additionally, PP2 possesses 80% of the land position of the new Harselaar 1b/2 zoning area and operates a combined heat and power (CHP) asset. Hence, indicating it as a *direct internal stakeholder*. Although energy is not central to its core business, its levels of knowledge for the energy system are noted to be moderate, while its regulatory and institutional knowledge is considered high. To assess PP2's role in more detail, the company's real estate manager was interviewed.

The Municipality of Barneveld, characterised by its agricultural zoning and is responsible for regional planning, infrastructure, and economic development in the region of the Harselaar (Regio Foodvalley, n.d.). The Municipality of Barneveld is classified as an *internal stakeholder* in this project due to its public vested interest and responsibilities for the development of the Harselaar zoning area, of which it owns 20% of the designated B1/B2 section (Municipal official). Overall, its knowledge is widely spread across varying sectors, hence having moderate knowledge of the energetic system. The municipal official for economic affairs has been interviewed.

The Hub Director is a neutral intermediary and facilitator guiding the MCEH's development by aligning interests and fostering collaborative momentum. Initially appointed by Oost NL, the hub director opts to operate for the overarching PPP consortium once development begins. Given the direct involvement of the MCEH and stakeholders, the hub director is seen as *an internal stakeholder*. Although not a direct member of the PPP, he possesses high levels of knowledge concerning the PPP and its energetic developments. The Hub director of the Harselaar was interviewed to assess his role.

Oost NL is a regional development agency focused on economic resilience and innovation in the provinces of Gelderland and Overijssel. Its Smart Energy Hubs program supports hub initiatives by facilitating partnerships, offering guidance and overseeing pilot projects in the region. Currently, Oost NL possesses an indirect role and is seen as an *external stakeholder,* but may convert to an internal stakeholder depending on transforming support. Due to its overarching view and leadership role in the SEH project, Oost NL is considered to possess high levels of knowledge. Two business developers from the energy team were interviewed to further analyse Oost NL.

Liander, one of the Netherlands' largest DSOs oversees electricity and gas distribution that supply millions of households and businesses in regions, including Gelderland and North-Holland (Liander, 2025). As a semi-public entity under Alliander, Liander does not hold a direct stake in the PPP but plays a key enabling role in regulation and infrastructure. Liander possesses high levels of technical, energetic and infrastructural knowledge. As such Liander invests over one billion euros in grid enhancements annually confirming its financial resources (Alliander, 2024). To analyse Liander, an advisor on the energy transition was interviewed.

<u>Stakeholder analysis (2): Private interests and system interests</u>

The interests of stakeholders vary across a spectrum from self-interested private goals to broader aims linked towards the regional energy, economic, and landscape system (Koirala et al., 2016).

PP1 pursues both commercial and systemic interests. Privately, it seeks commercial viability and returns on energy investments: "*If we were to invest in an energy distribution system, it has to be profitable*." The owner also notes an intrinsic drive for innovation: "*We have a weak spot* *for innovation and development*." Systemically, PP1 aims to decentralise energy supply in Barneveld by locally producing, converting, and sharing energy. In doing so, it produces energy for the 1b/2 zoning, reducing grid pressure and supporting local renewable energy solutions.

In comparison, PP2 is primarily driven by private interest related to their 80% land possession of the to be newly developed Harselaar business zoning 1b/2. Its systematic engagement is tied to enabling an energy connection for land development and meeting the regulatory obligations of its CHP installation, tied to its waste dump. Overall, the company displays reactive motivation within the MCEH collaboration however, PP2 remains limitedly inclined to invest in energy innovation.

The Municipality of Barneveld is mainly driven by public systematic interests, while private interests as increased land value and business activity, are also important. Systemically, it aims to secure affordable, reliable power to support regional development, ensure energy autonomy, and balanced market prices. The municipal official underscores these interests: *"This is urgent for me. I have to help these businesses. Without electricity, you cannot run a business"*. Additionally, he emphasises the importance of competitive pricing: "*The businesses should get here what they would receive elsewhere."*

The Hub Director embodies system-level interest as a neutral actor. His systematic goal is designing a governance framework that enables inclusive, equitable, and sustainable cooperation of the MCEH between the public-private consortium. His private motivation is closely aligned with personal history linked to the region, particularly through collaboration with the municipality. He enables a broad systems focus, not only bound to technical progress, but to establishing fair contribution models and a resilient organisational backbone for the whole project lifecycle (Hub Director 1, 2025).

Oost NL, functioning as an indirect public organisation, showcases high system interests. Its engagement is framed by long-term goals of economic resilience and innovation in the energy transition. BD1 describes its approach as "*We like using the hubs as experimental space*." Oost NL also safeguards the early business environment, supporting pioneers even in the absence of a fully functioning business case. Although an external actor, Oost NL occasionally provides loans, reinvesting financial returns to support future projects. Its interest lies in enabling replicable, sustainable energy transitions.

Liander operates with minimal private interest, given its status as a publicly owned and regulated grid operator. Its primary interests are systemic: maintaining an efficient, stable grid that benefits societal and economic objectives. While collaboration must meet cost and pricing conditions, Liander supports decentralised energy hubs for their role in reducing peak demand and depressurising the grid (Focus group 2, 2025). The advisor energy transition sees high potential in aligning the Harselaar case with long-term energy efficiency, in doing so operating a "*Knife that cuts both ways [...] less usage means less operating costs.*". This indication reinforces the systematic interest Liander showcases.

Stakeholder analysis (3) underlying discourses, power levels and leadership roles
PP1 is perceived as one of the frontrunners and initiators of multi-commodity level innovations. Its proactive stance and infrastructure assets signal a high level of power within the MCEH initiative. The company's project leadership are reflected in its proactive actions, "*We could put a shovel in the ground tomorrow and start cabling*", despite institutional uncertainty. Although ambitious, PP1 acknowledges the prolonging of the project lifecycle duration. Nevertheless, PP1 embraces a pioneering discourse, asserting the need to lead in a dynamic energy landscape: "*We are required to take the initiative within unknown ground*."

By contrast, PP2 assumes a more reactive position, having different priorities. Energy management is secondary to its business model, with its only energetic asset being the CHP unit. While owning 80% of the Harselaar B1/B2 zoning land grants its spatial leverage, PP2's influence within the MCEH energy system is modest. Additionally, PP2 expresses hesitance towards the PPP. Stemming from energy not aligning with its core operations and previous negative experiences with public partnerships. As stated by its real estate manager: "*The collaboration was rather stiff; hence, I am not very enthusiastic about a new public-private partnership*".

The Municipality of Barneveld expresses urgency to act in supporting fair regional energy accessibility to maintain a healthy business environment. While it demonstrates moderate initiative, leadership remains limited. Its power remains constrained by resource and knowledge asymmetries, holding only 20% of the land and lacking technical expertise. The municipal official notes: "*Especially larger parties such as PP1 and Liander have an overabundance of knowledge in comparison to the municipality*." Nevertheless, it can offer early-stage funding and assist planning processes.

The Hub director is seen to have an unifying role, maintaining momentum and collaboration between parties. He carries the story outward and keeps internal momentum high. The director is a key enabler holding significant project knowledge, facilitation and mediation skills, enabling to design of the collaboration structure. Acting as a process manager and mediator, the director defines himself as a "*figurehead*," underscoring his leadership role. His focus on trust: "*The process is very important [...] however, it starts with the trust*" reflects the importance of a supporting intermediary, especially given the tensions between PP2 and the municipality.

Oost NL functions as an indirect initiator, initially hiring the hub director to explore the potential of the Harselaar hub. Although its role is supportive rather than directive, it provides leadership through strategic input and funding mechanisms. With moderate power and limited by public institutional boundaries, Oost NL favours systemic goals, emphasising knowledge dissemination and regional resilience. In doing so, depressurising the energy grid and striving for energy innovations. BD2 supported this ambition by mentioning, "*I do not see grid congestion ever being resolved [...] you need one of the alternative energy carriers.*"

Liander operates from a position of facilitation authority but refrains from initiating or leading collaborations for decentralised projects. Its advisor stated: "*We are not going to pull the cart, we are not an imitative taker*", confirming its external role and facilitative role. In contrast, Liander acknowledges the importance of projects like the Harselaar, stating it as "*Societal completely logical.*", highlighting its potential to collaborate if the societal mandate is aligned. Additionally, Liander possesses high levels of indirect power due to its regulatory influence and control over the energy grid. However, Liander's prerequisites to collaborate mention external leadership, as noted: "*There has to be a very clear project director*," emphasising the need for well-governed innovation initiatives.

Stakeholder analysis (4): key insights and remarks

Overall, **PP1** stands out as a clear frontrunner, driven by commercial interest with a systemic commitment to decentralised energy innovations. It possesses substantial technical assets and demonstrates initiative despite institutional uncertainty, presenting both high influence and indirect leadership within the MCEH initiative.

In contrast, **PP2's** involvement is not mainly driven by energy innovation. Rather, by developing the 1b/2 zoning and complying with regulatory CHP regulations. Although it holds spatial power, past negative experiences shape a cautious approach, limiting its involvement and indicating an overall moderate influence.

This dynamic is further complicated by the **Municipality of Barneveld.** The municipality functions both as a regulator and a co-developer while holding 20% of the zoning land. It aims to ensure energy security, affordability, and economic prosperity. However, faces resource and knowledge imbalances compared to private parties. While possessing early-stage funding and support planning, the municipality is wary of this discourse, indicating a moderate leadership role.

To align these stakeholders' interests, sustain momentum, and translate ambitions into physical structures, the **Hub Director** functions as an intermediary. Initially appointed by Oost NL, the director aims to function within the PPP collaboration as a figurehead, positioned as a mediator and process designer, emphasising trust as a foundation for collaboration. As such, portraying significant symbolic and strategic influence.

Finally, both **Liander** and **Oost NL** function as external but influential stakeholders. The latter is an enabling partner, supporting the initiative through strategic funding, coordination, and appointment of hub directors, showcasing moderate influence. Rooted in systemic interests, Oost NL brings legitimacy, expertise, and a flexible framework to scale energy innovation.

Here, its "learning by doing" approach enhances knowledge dissemination and bridges public-private initiatives. While Liander's MCEH involvement, as the regional DSO, is critical for grid integration and regulatory consent. While lacking leadership incentives, its deep systemic knowledge, technical authority and regulatory role give it high indirect power. Liander's involvement depends on alignment with its societal role of facilitating safe and scalable infrastructure.

Concluding, the stakeholder constellation of the Harselaar MCEH reflects a complex interplay of public, private, and semi-public actors, each possessing distinct purposes, interests and discourses. The analysis across public and private interests, systemic goals, power dynamics, and leadership roles highlights the duality of promise and fragmentation in PPP projects.

4.3. Step 3A: Socio-Technical influences and barriers in the implementation of Public-Private Partnerships for Multi-Commodity Energy Hubs

The following section evaluates how the socio-technical regime influences and constrains the implementation of an MCEH. Drawing on Geels' (2011) five sub-regimes, the analysis varies in results, emphasising the influence of the policy, socio-cultural, and user & market regimes, while the technological and science sub-regimes are mentioned in lesser volume.

4.3.1 Technological sub-regime

Technological sentiment

The technological sub-regime rules refer to technical standards, product specifications (e.g., emissions, weight), and functional requirements. While normatively, how companies define themselves within their industry (Geels, 2011). It moderately influences the implementation of PPPs in MCEHs. This is closely related to the dynamic energy environment, issued with continually evolving renewable technologies. As such, BD2 noted, "*a dynamic environment offers chances or challenges*."

Overall, technological developments are not perceived as a major long-term barrier to MCEH or PPP implementation. Participants generally express optimism regarding technological opportunities. A private owner remarked, "*Technically, we can resolve everything, and that is beautiful*", while the Senior BD similarly stated, "*Technology is never the issue; technology is present. However, you never know if it will be sufficiently or swiftly enough developed*." These findings support broader indications, that while technological innovation offers major opportunities, the unpredictability of its adaptation can hinder partnership performance (Khan et al., 2020).

Dynamic environment

Additionally, the energy sector's dynamic nature requires constant technological adaptation. As such, successful niche-innovations require a flexible business case (Brogaard, 2019; Khan et al., 2020). However, pioneering technical developments often involve high initial costs and specialised expertise, which hinders public actors who manage public funds (Yescombe & Farquharson, 2018). Such uncertain returns and elevated risks function as key barriers to public-private innovations (Antonio et al., 2016). This barrier was highlighted by a business park coordinator: "*We were one of the first cases [..] and ever since 2023, so much has happened.*"

To mitigate risks associated with the technological sub-regime, thorough research into future phasing and flexibility for innovation remains critical (Martiniello, 2020). Additionally, technological development is deeply intertwined with the policy and science sub-regimes, where regulatory processes and scientific findings can either accelerate or hinder technological progress (Cruz et al., 2022; Marskamp et al., 2024).

4.3.2 Science sub-regime

The science-based regime refers to research programmes, professional boundaries and academic norms. Although correlated with the technological and policy sub-regimes, its direct influence on the implementation of MCEHs using PPPs appears limited. The science-sub-regime primarily emerges in the research and development stage of MCEHs, where it addresses uncertainties and uncertainties by conducting research (Yescombe & Farquharson, 2018). As such, rationalising the choices for implementation or abolishment of niche-innovations. Additionally, it substantiates justification for public-sector participation in innovative energy projects (Nel, 2018). This is emphasised by a hub director: "*That is why the development phase is so important. So, we can show that we can develop a smart future-proof system and that ensures a respectable kw/h price.*"

Thus, the science sub-regime serves as a fundamental layer, providing the decisiveness and legitimacy necessary for early-stage implementation of PPPs for MCEHs (Brogaard, 2019).

4.3.3 Policy sub-regime

<u>Policy goals and system pressures</u>

The policy sub-regime, intertwined with other sub-regimes through regulatory processes shaping transitions (Geels, 2011), emerges as the most influential sub-regime. This is seen by its influence exerted by policy goals and systematic pressures on the niche-innovation, shaping it to align with broader planning agendas, particularly sustainability and spatial-economic development, both reliant on infrastructure. As such, BD2 states that: "*[The grid] Is nearing the limits of our current energy systems [...] that is something you first see withdrawing at electricity*". Particularly, at the municipal level, policy priorities focus on safeguarding the business climate. A municipal official highlights the urgency: *"I have to assist these businesses, and to do so, we have to have a place where there are the commodities. Otherwise, there is no point."*

Governance structures and regulatory instruments

Such policy goals and systematic pressures are directly controlled by governance structures and regulatory instruments. The energy sector is characterised by complex legal frameworks established by multiple public and semi-public bodies (Oduro et al., 2024). DSOs and TSOs regulate energy grids, and the Authority for Consumers and Markets (ACM) oversees reliability and market fairness (ACM, 2025). Specifically, local grid adaptations are subject to laws and regulations, as one hub director mentions: "*We are building a system that most likely needs to be approved by the ACM. So that is also the legal testing of the energy system*".

However, regulating public bodies as the ACM are perceived by private actors as overly procedural and risk-averse, contributing to delays in the energy transition (Cruz et al., 2022). A provincial official notes: "*It is not in our nature to take risks, we would rather cover all risks till the final detail […] it is unfitting in our taskforce and our DNA*". Such administrative processes formulate discourses of disruptions to project development progress, with little risk mitigation (REM PP2, 2025). Marskamp et al. (2024) similarly note that municipal involvement in energy hubs suffers frequently from slow decision-making. Here, one provincial official stressed: "*As a province or municipality, you would like to be involved in due time to proceed with certain cases within the given time*". Overcoming these institutional constraints requires transparent communication, well-designed time-framing and phasing of one's project (Rossi et al., 2019).

Institutional uncertainty

Beyond grid regulation, broader national policy pressures, such as decarbonization targets and preferential treatment for certain energy modes (hydrogen) over others (solar or wind), further complicate MCEH development. Such developments are noted as "typical" in the dynamic energy environment while being among the leading causes for project cancellations in PPP infrastructure initiatives globally (Marcelo et al., 2019). Specifically, one private energy producer illustrates the challenge of synchronising entrepreneurial incentives with policy-regulated innovation liability frameworks: "*We could not find an insurer who wanted to insure our risks […] then it is better not to proceed with it*". Martineze et al. (2023) further emphasise this effect of perceived stability and predictability on private sector willingness to invest and co-develop innovative energy systems.

4.3.4 Socio-cultural regime

The socio-cultural regime significantly influences energy innovations such as MCEHs and the collaboration necessary to facilitate them. While technical and policy frameworks define the boundaries of feasibility, the socio-cultural regime determines what is socially acceptable. Here findings indicate that successful implementation of MCEHs via PPPs also depends on the ability of public and private actors to negotiate shared discourse, connect cultural divides, and co-create long-term visions built by community identity and evolving norms (Seyfan & Smith, 2007).

Energy decentralisation and cultural values

A shift in cultural values of the respondent's social acceptance is observed towards more decentralised energy systems. As one early hub director mentioned: "*The whole energy system is being turned upside down, energy used to come from five or six large factories, currently we are producing and consuming everywhere*". This change in sentiment is further strengthened by entrepreneurial leaders, as one private actor states: *"We are a frontrunner [...] however, if you are in front, you will have to keep taking the initiative within the dark*". These leaders lead the change; such attitudes align with broader European discourses on citizen-driven energy models (Bauwens et al., 2016; Cruz et al., 2022).

Shared purpose, trust, transparency and friction

In addition to the findings of purpose and responsibility sharing in chapter 4.1.3, the data reveals the importance of trust and normative alignment. Seyfan and Smith (2007) emphasise the need for shared purpose, consensus and transparency in hybrid governance PPPs. This is emphasised by BD2, who stated: "*The goal towards which you are working together requires a collective purpose [...] otherwise everyone is in it for themselves, and then you have nothing*". Nevertheless, prior experiences and policy-related frictions often challenge trust-building. To mitigate friction, fragmentation and underperformance, both literature and interview data suggest early, transparent, trust-based dialogue (Brogaard, 2019; Cruz et al., 2022; Hub director Harselaar, 2025; Provincial official, 2025).

Local identity and communicative structures

Finally, within the implementation of local energy systems like the Harselaar MCEH, a local identity is rooted in presenting itself as a unified community. This moral imperative of framing energy governance as a community duty reveals the impact of the decentralisation narrative as a legitimiser (Simone et al., 2025). This identity is expressed both legally, through collaboration structures, and socially, through collective visions. As a municipal official noted: *"Then we could say: everybody who fits the picture is allowed to partake."* These narratives underscore the interplay between legal constructs and community-driven narratives that are essential to the legitimacy and resilience of MCEHs and PPPs (Marskamp et al., 2024).

4.3.5 User & market regime

Business case and market constructions

The final sub-regime is deeply embedded within the user-market legal and institutional architecture. It shapes MCEH implementation via a user-firm relationship governed by laws and market rules. Notably, several respondents here emphasise the necessity of a viable business case. One private owner remarked: "*If we were to invest in an energy distribution system, it has to be profitable.*", highlighting the importance of commercial feasibility in sustaining private sector engagement (Salci & Jenkins, 2018; Wang & Ma, 2020). Although business cases vary, all participants must perceive tangible benefits over their current situation to sustain intrinsic motivation.

Finance

Financing remains one of the largest requirements to incentivise niche-innovations, specifically niche-innovations which cannot rely on market forces. External financing via public subsidies, green loans or other forms of funding is essential (Polzin, 2016; Xu & Xu, 2024).

Overall, these subsidies can enhance the implementation of a niche innovation. However, structural limitations exist, as a business park coordinator notes: "*There are a lot of subsidies […] however, there was no use for us as you need to have requested them beforehand. I tried requesting them retroactively, but that was not permitted"*. This highlights the mismatch between public and private time phasing and processes (Ferrara & Lange, 2013), indicating the complexity in achieving effective utilisation of subsidies for comparable energy projects (Taheri et al., 2025).

Liability, risk and long-term investments

Closely tied to the business case are decisions on finance, liability, risk and long-term investments. Generally, in PPPs, governments struggle to retain control of key infrastructure goals while avoiding disproportionate liability (Hodge et al., 2018). This is emphasised by a business park coordinator: "*If it went wrong, it is not the case that the municipality, due to the contract, has become co-owners and co-problem owners […] they should not carry all the risk*". This risk aversion is enhanced by power imbalances by asymmetric resource and public-sector expertise. A municipal official admitted: "*We possess too little knowledge to be a proper and balanced partner towards Liander (DSO)*". As such, the municipality is afraid to draw the shortest end in the collaboration. Applying flexibility constructions, as mentioned by Klijn en Koppenjan (2016), may assist in strengthening trust and securing more balanced partnerships.

4.3.6 Conclusions: Barriers to the Implementation of Public-Private Partnerships in Multi-Commodity Energy Hubs

The technological sub-regime is generally viewed as an enabler. Stakeholders express optimism about technical feasibility, although early-stage uncertainty, high costs, and minimal public sector risk tolerance remain challenging. Additionally, the science sub-regime contributes by providing legitimacy during the development stage, resulting in reduced uncertainty and innovation justification. This indicates its supportive regime influence for implementation.

Controversially, the policy sub-regime poses significant barriers. While certain national and regional goals support MCEHs, others, such as legal complexities, regulatory delays, and institutional risk aversion, hinder progress. Institutional uncertainty is noted to weaken private sector's project trust, resulting in disrupting energy transitions. As such, it is crucial to address institutional uncertainty indicators such as shifting policy priorities, unclear financing frameworks, and regulatory strictness in early-stage MCEH management.

In contrast, the socio-cultural regime emphasises the importance of building trust, shared vision, and cultural acceptance. While decentralisation trends support local energy initiatives, success depends on transparent communication. Specifically, the alignment of stakeholder values is noted to enhance community purpose and identity. Community identity is seen to further strengthen legitimacy and resilience for niche-innovations as MCEHs.

The user & market regime highlights the importance of a viable business case for private sector participation. However, challenges arise during financing, risk allocation, and the submission of subsidy requests. Public actors' limited capacity to take on risk and fear of liabilities further complicate and slow partnership and project process.

In sum, MCEH implementation through PPPs requires more than technical expertise; it demands institutional adaptability, cultural support and cohesion, and supportive market conditions to overcome systemic socio-technical barriers. Overcoming barriers clears the path towards successful transitions from niche-innovations to embedded development in the socio-technic regime and energy landscape. These critical barriers and influences function as initial external indicators for determining the contextual critical success factors, as mentioned in 4.5.

4.4 Step 3B: Preconditions, To PPP or not to PPP?

Following the project description and stakeholder analysis, the next step is to determine whether collaboration is necessary, feasible, and what form aligns with stakeholder interests. In the case of the Harselaar MCEH, collaboration is not only necessary but crucial. The core stakeholders, PP1, PP2, and the Municipality of Barneveld, each possess unique resources, expertise, and objectives that individually cannot achieve the MCEH implementation. This mutual dependency strongly suggests that a collaborative approach is essential. This section concludes by summarising it preconditions found, required for PPP implementation of the Harselaar case.

<u>Shared purpose and cross-partner dependencies</u>
Although the core parties possess different resources and knowledge, a stable and effective partnership requires alignment around a long-term, shared interest. Here BD2 emphasises, "*Which is very important, is that you have shared interests. So, a purpose with each other [...] otherwise you are not going to get anywhere, because everyone is in it for themselves.* This underscores the necessity of aligning public and private interests to leverage complementary strengths and distribute risks, which is a key principle in PPPs (Rossi et al., 2019).

The Harselaar case presents cross-partner dependencies and collective purpose: developing a new locally produced and integrated energy grid, which facilitates the future new business zoning 1b/2 of the Harselaar. In doing so, the project's viability rests on combining:

(1) Private generation capacity; (mostly PP1 and smaller accounts for PP2).
(2) Land and local network infrastructure (PP2 and municipality).
(3) Public facilitation and mandate (municipality).

These developments align with low-carbon infrastructure PPPs where public actors turn to PPPs as a result of resource constraints and innovation needs, while private actors provide investments and knowledge under the right conditions (Casady et al., 2024).

In this sense, Barneveld's limited capacity constraints for the next 10 years indicate PP2's inability to develop new lots, provided with energy. Hence, emphasising the need for a different localised solution and energy grid. Both PP1 and PP2 have expressed a willingness to invest, contingent on the strength of the business case (PP1, 2025; PP2, 2025). Even PP2, initially hesitant, acknowledged that collaboration is preferable to receiving no energy connection for its Harselaar B1/B2 landholdings. The REM of PP2 refers to the situation as: "*Given the circumstances, this is the best that we can achieve however, I am not cheering that this should be the future*". Such an interlocking requirement of resource and risk sharing is a classical justification for a PPP approach (Filipkowksa & Węgrzyn, 2019).

<u>Time frame: project life cycle planning</u>

Once shared purpose and urgency have been determined, the following determent whether to PPS or not is aligning one's timeframe. Participants from both public and private parties varied in their perspectives on the project context and its duration. Initially, parties discussed different time frames for a new grid connection of the 1b/2 zoning. Likewise, different questions arose as to what would happen when a possible partnership was to be concluded. The REM of PP2 assesses the MCEH as a temporary solution, whereas other parties regard it as a future-proof integrated energy solution. Hence, it is key to align the project life cycle and have a pre-determined plan to structure one's partnership. The Hub Director 1 emphasises this: "*The municipality still wants to realise 28 lots by 2027 [..] but you already have to think in the developing phase, how does this unfold in the realisation and exploitation phase*".

<u>Risk, reward, resource and responsibility sharing</u>

The division of risks, rewards, resources and responsibilities is decisive in the Harselaar case, with fair risk-reward mechanisms being central to PPP negotiations. All three parties confirm the necessity to take on some risk, as one private owner describes: "*Of course, you must take your shares of the risk and investment"*. Likewise, a municipality adds, "*You can share the risk, but then also the respective reward*". These repeated mentions underscore the importance of aligning risk allocation, distribution of rewards/compensation, resource contribution and responsibilities. However, definitive formal agreements have been lacking in group meetings

(Focus group 3, 2025). Hence, this precondition will be preliminarily examined by data from individual interviews and observations.

Generally, the project is structured into work packages aligned with varying phases. Given its early stage, their content is restricted. However, the hub director has described initial expectations for risk allocation, resource division, and responsibilities: "*We have to define what needs researching in the initial phase […] and secure capital for that*." This is verbally acknowledged by all three parties who state to invest in the exploratory and development phases, covering process management, research money, legal support, and related activities (Focus group 3, 2025).

This forms the basis of resource contributions for the initial PPP. Given current uncertainties of the project thus far, the hub director mentions: "*We are limiting it, so we need a certain amount of money for the upcoming year to research these initial packages*". Indicating, risk is being limited by phasing the project's investments.

Beyond investments, parties have suggested contributing energy assets to the system. Private party one is intrinsically willing to supply its produced energy to the new business zoning and structure its assets in a suitable legal format. Here, the owner mentions: "*We think with the assistance of a battery station, we can depressurise the Barneveld's energy grid*". Similarly, PP2 is open to providing energy from its CHP if the business case is commercially viable (Hub Director 1, 2025; REM PP2, 2025). Nevertheless, viability requires initial research to be conducted, as party two cautiously states: "*I am not directly opposed to discussion entities"*

Finally, recent developments have raised concerns about risk allocation. PP1 is developing a large set of batteries, aimed at enhancing the flexible energy profile of its energy park, essential to the MCEH. Unfortunately, securing insurance has proven challenging, as the owner mentioned: "*We could not find an insurer that wanted to cover our risks [...] if there is no insurer who covers the costs, then you should not start developing it*". This indicates the constrictions large-scale energy asset investments face due to policy and user & market regime barriers. However, the owner remains optimistic, citing ongoing adaptations by insurers and regulators.

<u>Towards a PPP form: A flexible, stepwise partnership</u>

Selecting an appropriate PPP structure for the Harselaar project requires balancing public interests, such as energy security, decarbonization, and economic development, with private goals like business growth, profitability, and asset utilisation (Wojewnik-Filipkowska & Węgrzyn, 2019). The PPP must function as a vehicle that delivers reliable, affordable energy while offering a viable business case for PP1 and PP2. It must also remain flexible in light of stakeholder history and uncertainties. In this context, a tailored voluntary agreement model appears most fitting (Zhang et al., 2018).

The project's scale and complexity further shape the PPP structure. For low-complexity projects, alternative collaboration formats may offer simpler solutions. However, as BD 2 noted, *"A PPP is obviously a pretty complex construction, because you commit to longer-term agreements with each other."* The Harselaar project exhibits a higher degree of complexity due to the diverse set of public and private stakeholders and their interdependent interests (Verweij, 2015). Moreover, the MCEH represents a niche innovation, focused not solely on shared purchasing (e.g., PPAs) but on building an integrated local energy system from the ground up.

To manage this complexity, stakeholders favour a flexible, phased partnership structure that fosters trust. A municipality official described the form as "*A collective entity (fund) where the core actors provide equal contributions*". This structure facilitates joint funding for studies, business case development, and trust-building, particularly important given a private party's prior negative PPP experience. Emphasising flexibility, transparency, and phased commitment, this bottom-up approach aligns well with voluntary PPP models. These approaches are particularly effective for improving energy efficiency and innovation in contexts where traditional top-down command and control approaches prove to be lacking (Zhang et al., 2018). All of the above are aligned with the cooperative member structure, which has been positively agreed upon by all internal stakeholders (Focus group 3, 2025).

<u>Preconditions to PPP</u>

The following section summarises the preconditions in Table 5, revealing that the Harselaar does not yet meet all the preconditions. This gap is the result of limited early-stage collaboration and a lack of group discussion sessions. Hence, upcoming focus groups are advised to address key topics such as project lifecycle planning and the distribution of risks, rewards, and responsibilities. Current analysis suggests potential disruption in the risk/reward alignment and responsibility allocation. Private party two indicated participation for the energetic system depends on a commercially more interesting business case than its current agreement with the energy distributor. Likewise, this party mentioned about responsibility: "*Once we no longer own the land position, then our involvement in the project can be abolished*". Reflecting short-term oriented responsibility for the project, which may hinder longer-term collaboration.

Table 5 Preconditions for PPP implementation

Precondition	Comply with the precondition?	Improvement required	Context/suggestions
Cross-partner dependencies	Yes	No	-
Shared purpose	Yes	No	-
Timeframe: Project life cycle planning	Semi	Yes	Formulate collective life cycle planning instead of the hub director.
Risk/reward sharing	No	Yes	Discuss the details of the business case in focus groups.
Resource/asset contribution	Semi	Yes	Narrow down the details of risk/reward per asset.
Responsibility sharing	No	Yes	Deliberate in focus group number one.
Structure/model	Yes	No	Cooperative is the verbally agreed-upon legal structure.

4.5 Step 4: Critical success factors for operational success of The Harselaar case

Having framed the preconditions, the cooperative between actors requires a specific tailored focus on critical success factors. These factors can either enhance or deteriorate operational collaboration. This section outlines the key CSFs identified as essential for the operational success of the Harselaar MCEH by combining the socio-technical regime influences and elements of suitable PPP formats. The section ends by summarising the CSFs for the Harselaar case, indicating its performance and possible improvements.

Transparent communication, trust building and mutual commitment

Trust is a fundamental enabler of long-term collaboration in PPPs. It creates mutual commitment, mitigates fears of opportunism, and strengthens internal organisational connections (Vale de Paula et al., 2024). However, trust is not inherent; it requires openness and time to develop.

Specifically, the Harselaar case presents a rich history between actors which requires caution for future collaboration. One of the parties mentions developing its business project from the ground up without any assistance from the municipality (Private party 1, 2025). Likewise, a second private party stated that the municipality lacks internal expertise and resources as it "*Will just hire its knowledge*". This is further amplified by describing the public and private partnering as "*The collaboration was very tough as of day one. It never became a success*".

In response, the hub director mentions it is key to rebuild the trust between public and private actors to succeed in partnering. He notes the need for parties to "*put a line under experiences from the past"* and *"shake hands again and say, okay, we need each other […] and we're going to do this together"*. Early-stage trust-building in teaming efforts via joint meetings is therefore critical. Within these meetings, it is essential to create a comfortable safe space where effective communication and acknowledging individual interests form to collective purpose (Rossi et al., 2019; Wang & Ma, 2020).

Collective risk allocation and risk management

As mentioned previously, the fair distribution of risks is key. However, results portray additional emphasis on collaborative risk management when realising the business case of PPP projects. Literature consistently emphasises their role in fostering trust and long-term stakeholder commitment (Marcello, 2019; Weis & Sarro, 2013).

To address these concerns, a shared understanding of risk boundaries must be developed. These risk boundaries can be formulated in a risk allocation matrix, clarifying the responsibilities for financial shortfalls, cost overruns, supply failures, bankruptcy, and withdrawals. Such agreements must be formulated according to each party's role and capacity. A consensus here was noted around the need for a safety net to ensure hub continuity. One private party warned: "*It cannot be that the whole park suddenly has no power […] so there must be something written for that*". These findings align with Klijn and Koppenjan (2016), who emphasise the importance of contingency planning in PPPs. This topic is further elaborated upon in the next section on phasing and exit strategies.

Project life cycle: Go's/No-go's and exit clauses

Closely linked to risk management and pre-determined planning are back-up and exit clauses, which are seen as an essential strategy in the Harselaar case. A municipal official expressed caution on full dependency on private parties by the municipality: "Y*ou have to make very businesslike agreements… There must also be an exit-strategy in there. Yes, certainly*". His public concerns for energy security and accessibility are further substantiated by advocating a step-in right clause, which allows the municipality to take over assets or operations to keep the energy supply and hub running. This step-in right allows to safeguard the public and reflects a commitment to protect regional interests in the event of private withdrawal.

Additionally, stakeholders identified setting go/no-go's using checkpoints over the project timeline as valuable to reassess viability and project progress. The preset conditions institutionalised by exit clauses and phasing checkpoints create flexible mechanisms lowering entry barriers, limiting greater loss and reinforcing stakeholder trust (Buso et al., 2021). Although this CSF can generally be applied to any given point in a project's lifecycle, general categorisation of project phasing has been formulated by EIGEN (2023a):

1) *Exploratory phase*: This phase aims to investigate which local circumstances can and should be accounted for and whether sufficient momentum can be created among companies to set up a forerunner for an energy hub.

2) *Developing phase*: This phase aims to arrive at the best feasible design with which an Energy Hub can be realised.

3) *Realisation phase*: This phase aims to realise the smart Energy Hub for the integration of large-scale generation of electrical energy from renewable sources.

4) *Exploitation phase*: This phase aims to operate the Energy Hub and ensure business continuity.

Currently, the Harselaar partnership is transitioning from the exploratory to the development phase but lacks a formal go/no-go decision point. According to the hub director, such a checkpoint is near: "*Ultimately, we'll say, 'Okay, now it is a go for the entity (likely a cooperative)".*

Additional pioneering factors

In addition to the established critical success factors that were confirmed by both literature and primary data, multiple new pioneering CSFs were noted that influence the operational implementation of an MCEH.

Closely aligned with transparent communication is the importance of *clearly defining the roles and responsibilities*. In the Harselaar case, initial ambiguity existed about the operational and organisational roles: Who will operate the hub? Who will bring in what assets? Who is responsible for initial investments? This unclarity needs to be addressed as clarity about roles, decisions, rights and limits of authority is directly linked to operational success (Osei-Kyei & Chan, 2015). As a municipal official underscored: "*I think we will be in the governing entity; however, we will not be in the exploitation as a municipality*". While role clarity is essential, maintaining flexibility in partnership structuring remains equally important. A private stakeholder affirmed this by stating openness to: *"whatever structure fits best."*

Another CSF is seen in the involvement of neutral facilitating actors, such as regional development agencies or hub directors. These actors help broker trust and understanding between core stakeholders. This is emphasised by BD 2 of Oost NL: "*We are just much more flexible [...] our position is often a bit less strong in such a consortium, but we are indeed parties that give confidence to other parties*". Additionally, these intermediaries exhibit high degrees of technical, policy and science knowledge, which assists in dealing with socio-technical regime influences. Several participants noted that without a neutral intermediary nudging the collaboration, the project might have stalled in its exploratory phase.

Finally, an indirect influential factor was noted in the *underlying mindset and adaptive capacity* of actors. Specifically, in dynamic environments as the energy transition, a mindset focused on innovation and adaptability is essential to foresee experimental projects. Here, stakeholders are required to adapt to new information, regulatory changes from varying regimes (Geels, 2011). This is emphasised by the hub director: "*What we are doing is so new… and now all of a sudden you have to collaborate on this*".

<u>CSF assessment of the Harselaar case</u>

Table 6 summarises the critical success factors assessment for the Harselaar case, categorised by implementation phase, urgency, and required improvements. Overall, the PPP appears operational post-implementation but currently lacks collective risk allocation and clearly defined roles and responsibilities. The latter requires direct improvement, if parties are to proceed in focus groups to implement the PPP and a legal entity. While some basic risk allocation is required in the entity's statutes, no extensive collective risk mechanisms are required in the initial exploration and development phase (EIGEN, 2023a)

Table 6 Harselaar's Critical Success Factors assessment

Critical success factor	Implemented?	Urgent CSF?	Direct improvement required?
Transparent communication	Yes	Yes	Sustain
Collective risk Allocation	No	No	Basic risk allocation is required
Project life cycle	Yes	Yes	Sustain
Clearly defined roles and responsibilities	No	Yes	Improvement required
Neutral intermediary	Yes	Yes	Sustain
Underlying mindset and adaptive capacity	Yes	Yes	Sustain

4.5.1 Roles of stakeholders

Clarifying stakeholders' roles was acknowledged as a CSF in PPPs to enhance operational efficiency and build trust (Osei-Kyei & Chan, 2015). This is further supported by formulating clear collective purpose between PPP stakeholders to mitigate opportunism and foster adaptive capabilities (Klijn & Koppenjan, 2016). Having assessed this knowledge and the findings, Table 7 defines the roles of the stakeholders for the Harselaar project. A distinction is made between *organisational roles*, which pertain to governance and collaboration, and *operational roles,* which concern the practical execution of MCEH activities across the project lifecycle. Finally, the timeline column estimates the duration of the stakeholder involvement.

Table 7 Stakeholders' roles Harselaar

Stakeholder	Internal partner	Public /private	Organisational role	Operational role	Exit timeline
Municipality Barneveld	Yes	Public	• Pioneering/scouting role • Regulatory gatekeeper • Public authority	• Zoning & permitting authority • Facilitator of business park development • Public risk manager • Steward of public interests	Long-term
Private party 1	Yes	Private	• Technical lead and infrastructure operator • Developer of multi-commodity energy system	• System integrator • Energy producer and provider • Technology advisor • Commercial risk holder/financer	Long-term
Private party 2	Yes	Private	• Owner of land/strategic infrastructure • Energy producer	• Local land host • Energy producer (CHP)	Medium-term
Hub director	No	Private	• Process guidance • Governance facilitator/neutral chair	• Stakeholder mediator • Vision keeper • Time-frame facilitator	Long-term
Province	No	Public	• Strategic financer/innovation enabler • Policymaker	• Regulatory liaison • Pilot coordinator • Facilitator via incentives or intermediaries	Long-term
Oost NL	No	Public/ private	• External advisor/ development agency • Potential board member	• Knowledge broker • Gap financer • Monitoring and evaluation pilots	Flexible
Liander	No	Public	• Regulator as DSO • Contractual partner GTOs • Possible collaboration /technically for innovative grid	• Grid operator and capacity allocation • Facilitator GTOs • Collaboration possibilities for technology and innovation	Long-Term

4.6 Step 5: Organising and structuring the PPP for the Harselaar case

Finally, the PPP should be fundamentally grounded to be implemented and be qualified to establish a structure and legal entity, if deemed suitable. Findings from the document and literature analysis suggest the cooperative format to be the most suitable organisational entity, offering a balance between flexible and operational collaboration. This aligns with the underlying values of the voluntary agreement approaches by Zhang et al. (2018).

This cooperative organisational structure was evaluated through individual interviews, multiple focus groups with legal advisors and all internal stakeholders of the PPP. The model received broad support and consensus (Focus group 3, 2025).

In modelling the cooperative structure for the Harselaar case, this thesis assesses Energiesamen's (2025) knowledge document on legal entities for Dutch heating districts. The cooperative structure entails lots of flexible, tailor-made adaptations to seek the best fit for the purpose of its shareholders. Dirkzwager (2024) and Energiesamen (2025) outline three fundamental versions:

1. The cooperative as owner
2. The cooperative as the majority shareholder
3. The cooperative with a joint venture

Based upon the prior findings and integrative analysis of these models, in combination with the specific context of the Harselaar case, this research identifies a modified cooperative joint-venture model to be most suitable. A proposed conceptual visualisation of the overarching MCEH system is provided in Figure 9.

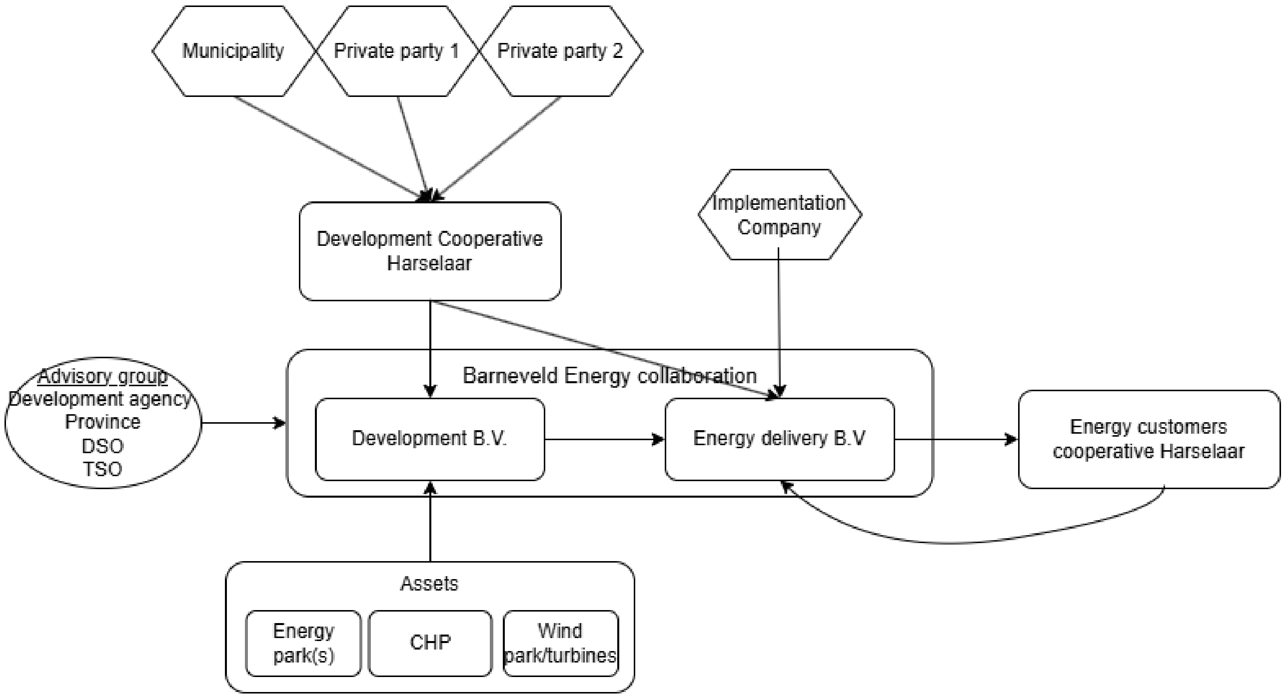

Figure 9. The organisational structure of the Harselaar MCEH

Elaboration on the model

The cooperative joint-venture model is seen as the most fitting structure where multiple limited private companies (Besloten venootschap, B.V.) can operate collectively while remaining legally distinct. This is useful when the shareholders of the cooperative do not all desire to hold shares of both private limited companies, while also allowing external parties, such as the implementation company, to provide services or hold ownership (Energie Samen, 2025). Liander indicated its willingness to function as an implementation company if it is beneficial to its societal goals (Focus group 2, 2025). Additionally, compared to cooperatives, the private-limited company offer faster deliberation processes and greater commercial flexibility (Dirkzwager, 2024; Focus group 1, 2025). In this sense, these entities function independently while remaining aligned and governed by the overarching incentive of the cooperative, guaranteeing its collective purpose.

Development cooperative Harselaar Step 1

First, the central governing body, Development Cooperative Harselaar, is composed of the core PPP partners: the Municipality of Barneveld, PP1, and PP2. This marks the first formal step of establishing a legal entity for the total energy system. These parties are responsible for the initial cooperative statutes, representing the cooperative shared purpose, values and governance visions.

Barneveld Energy Collaboration Step 2

The development cooperative Harselaar divides its operationalities into two limited private companies: the development and the energy delivery companies.

- The energy development company is appointed to (re)develop the multi-commodity energy system to meet customer demand in the Harselaar zoning. The company can attract or develop new energy system assets to match these needs via individual agreements, either through ownership, renting it or integrating its services into the whole.
- The energy delivery company is appointed to formulate a balanced business case for the energy customers on the Harselaar 1b/2 zoning, providing them with energy. Here, it facilitates commercial transactions between producers, energy distribution managers and end-users.

Harselaar Customer Energy Cooperative Step 3

In order to agree to a group transport agreement (GTO), the energy customers will be organised in a collective entity, likely a cooperative. This allows for collective sharing and efficient distribution of energy. Participation in a collective entity is required for inclusion under a GTO, which facilitates joint liability and responsibility (Energy Community, 2024; Kennisplatform Energiehubs, 2025). This cooperative is referred to as the "*Harselaar Energy Cooperative*"

Advisory board step 4

Once governance and operational structures are in place, external stakeholders can be integrated into the model. The findings indicate that indirect parties such as the province, Oost NL, Liander and TenneT could contribute knowledge and expertise to MCEHs through an advisory board. These parties are not directly shareholders or members of a cooperative rather, they advise the Barneveld Energy Collaboration through the development cooperative Harselaar.

5. Conclusion, discussion and reflection

This research examined how public-private partnerships may assist the implementation of multi-commodity hubs. In doing so, conducting a case study at the Harselaar MCEH, in cooperation with the Oost NL initiative. This final chapter presents the conclusions of this research by summarising the sub-question findings to answer the main research question. This is followed by discussing theoretical and methodological reflections and the study's limitations. Finally, recommendations for future research and praxis are suggested.

5.1 Conclusion

SQ 1: How can multi-commodity energy hubs mitigate grid congestion and support the energy transition in the Netherlands?

The findings indicate that multi-commodity energy hubs (MCEHs) present an effective short- to medium-term solution for relieving grid congestion while longer-term supporting the energy transition to a more sustainable decentralised Dutch energy landscape. These hubs integrate various energy carriers that enable local production, storage, consumption and balancing of local energy behind the meter. In doing so, it reduces dependency on the national grid by optimising locally generated energy via renewable sources, which supports broader decarbonisation and energy goals.

In addition to their technical value, MCEHs rely on institutional arrangements that foster collaboration. PPPs emerge as selectively applied yet increasingly relevant tools in sustainable energy development. Among the reviewed cases, traditional PPP forms presented 50% of the cases in which hybrid models, such as voluntary agreements, PPAs and technology partnerships, were most commonly used to support energy efficiency, security and innovation.

SQ 2: What is the utilised share of public-private partnership constructs in sustainable energy projects, and what elements are determinants for the suitability of these projects within the energy transition?

The suitability of PPPs varies depending on stakeholder and project scale, context and required legal form. Document analyses suggest the use of cooperatives, private-limited companies and associations are most commonly used. Overall, the findings showcase five elements essential for tailoring effective PPPs: (1) forming shared purpose between public and private bodies, (2) applying flexible (legal) forms (SPVs, voluntary agreements), (3) using adaptable time frames and phased implementation, (4) clearly defined stakeholders' roles and (5) balancing risk, reward, resource and responsibility sharing. The success of adjusting these five elements hinges on implementing governance structures that enhance contractual flexibility and institutional learning. When applied effectively, PPPs offer a robust collaborative framework to mobilise capital, accelerate process deployment and achieve long-term energy transition objectives in the Netherlands by amplifying complementary public and private strengths.

<u>SQ 3: Which stakeholders are involved in the development of multi-commodity energy hubs, both generally and for the Harselaar, and how do these stakeholders align, conflict, or influence the project's progress?</u>
Generally, MCEHs engage with a wide range of stakeholders, including both private and public stakeholders, including governments, energy companies, system operators, businesses, neutral intermediaries, consumers and so on. While each possesses differing interests and priorities, a key determinant for MCEH implementational success is seen in stakeholder alignment. In the Harselaar case, for instance, overlapping interests in economic growth, energy security, and commercial feasibility required careful coordination. As such, challenges emerged for PP2 due to differences in purpose of primary business and project goals, while stakeholder commitment is required. Additional variations in governance expectations, institutional experience, and risk appetite underscore the importance of building trust, creating shared value from the outset and mediating these interrelations. Conclusively, stakeholder management is key for early-stage MCEH implementation and requires thorough attention from an intermediary to avoid delays or abolishment of a possible PPP.

<u>SQ 4: How does the socio-technic regime influence the realisation of public-private partnership arrangements in multi-commodity energy hubs, and how can possible barriers be addressed?</u>
Beyond internal collaboration, MCEH implementation is shaped by external socio-technical regimes. Among Geels' five regime types, the technological and science sub-regimes did not function as primary barriers. However, their inherent uncertainty, coupled with limited R&D funding and evolving innovation cycles, can hinder niche-innovations. In comparison, the policy sub-regime was found to be the most influential, marked by institutional rigidity, fragmented oversight, and risk-averse administrative cultures, all of which delay decision-making and hinder innovation. One notable delay was seen in the development of a large battery station for PP1, which experienced policy restraints, leaving them unable to insure its energy project.

In contrast, the socio-cultural regime highlights discourses about shared purpose, local identity and trust, specifically crucial in early-stage PPP formation. Misaligned values and communication norms, formed by (historical) experiences, undermine cohesion between public and private actors. However, strong local narratives and early engagement can foster legitimacy and enhance process development. The Harselaar case is noted to have developed such a local narrative, where collectively producing energy is the sole option to provide energy to the 1b/2 zoning in the short-term future, given DSO and TSO constraints.

Finally, the user and market regime set boundaries for commercial viability, financing and liability concerns. Market rules often seem to lead to a mismatch with public processes and funding structures, resulting in unequal or misunderstood partnerships. Ultimately, even for an autonomous niche development as a local MCEH, overcoming the socio-technical regime transition influences requires technological, procedural and structural governance with phased timelines and incentives to embed flexibility, trust and community ownership.

<u>SQ 5: What critical success factors determine the operational success of implementing public-private partnerships within multi-commodity energy hubs?</u>

Once internal and external influences are measured and tailored to the project's context, the operational success of an MCEH depends on several CSFs. Findings indicate that during the exploratory and development phases, transparent communication enables trust-building and mutual commitment, which is essential. These CSFs can be addressed by seeking early joint engagement using an intermediary to align stakeholders' interests towards a shared purpose. In addition to purpose, it is important to strengthen trust by allocating risks and rewards fairly based on stakeholder roles and responsibilities within the partnership.

Additionally, recurring findings indicate contingency planning and safety mechanisms to help reduce entry barriers and ensure continuity over the project's lifecycle. Hence, implementing phased timeframes using go/no-gos and exit or step-in clauses are essential CSFs against sunk costs.

Moreover, to address the dynamic environment of the energy transition, stakeholders require an adaptive mindset allowing them to be open to change, handle regulatory changes and establish reflective learning. This flexible mindset needs to be implemented in PPP governance however, clearly defining roles and responsibilities is essential. Connecting both requires active process guidance from neutral intermediaries such as Oost NL and hub directors, who initiate dialogue and foster trust. Implementing these CSFs allows for early evolution from informal agreements to resilient collaborative structures that deliver decentralised energy systems.

<u>Research question</u>

This research set out to answer the following research question:
To what extent can public-private partnerships assist the implementation of multi-commodity energy hubs in order to mitigate grid congestion and support the energy transition within the Netherlands?

Assessing the prior findings, this thesis concludes that public-private partnerships can play a significant enabling and assisting role in the collaborative implementation of multi-commodity energy hubs in the Dutch energy landscape. Foremost, PPPs allow multi-stakeholder cases to pool resources, allocate risk and organise efforts towards shared purpose energy objectives.

The Harselaar case illustrates how PPPs can facilitate decentralised energy systems in challenging environments under the right conditions. If managed correctly, PPPs are a key solution, addressing dynamic environments with technical uncertainty, policy fragmentation and stakeholder diversity. While PPPs require complex preconditions to be grounded, if tailored to their sectoral and case context, PPPs offer a structured pathway to MCEH development. As such, this thesis notes that cross-partner dependencies, a sense of urgency, project lifecycle planning, clear governance, mutual trust, and shared purpose are essential preconditions for PPP success. Therefore, while PPPs support the advancement of the energy transition and niche-innovations while mitigating grid congestion, a thorough preliminary assessment of the project and contextual boundaries is required. When performed with due diligence, commitment and transparency, PPPs may function as catalysts for innovation and cooperation in Dutch energy sector niche-innovations as MCEHs.

5.2 Discussion

5.2.1 Methodological Reflection

This study adopted a qualitative single-case approach to explore the Harselaar MCEH, grounded in both positivistic and constructivist epistemology. The design allowed researching the dynamic case, complex stakeholder perspectives and evolving socio-technical regime influences that shaped the PPP. The combining of multiple frameworks and data collection methods, both primary and secondary proved especially valuable in the dynamic, unknown, continuously evolving context of the energy transition.

Triangulated data collection, using semi-structured interviews, focus groups, observations, literature and document analysis, allowing for determining validated legal structure and critical success factors across diverse perspectives. Member checks with respondents further strengthened accuracy and correctness of the data. Unfortunately, arranging the focus groups has proven challenging due to busy stakeholder planning schedules hence, only one focus group with the internal partnership has been conducted instead of the scheduled two.

Although methodological considerations have been comprehensive in the research, the single-case design lacks generalizability. Nevertheless, the aim was not to generalise but to explore; hence, improvements could be made in the form of comparative or longitudinal future studies. Finally, research bias was mitigated by reflectivity and triangulation of the data. Overall, the implemented methodology proved effective in yielding practical and theoretical insights into PPPs and MCEHs.

5.2.2 Reflection on results and theory

This thesis contributes to the energy transition discussion by applying three theoretical frameworks: ICES, PPPs and the MLP. Combining the three theoretical frameworks constructs a holistic integrated lens, allowing analysis of PPPs for the implementation of MCEHs in the Dutch energy context.

ICES theory (Koirala et al., 2016) evaluates the potential for efficiently integrating multiple commodities in one locally integrated energetic system on the community level. However, technical solutions alone are insufficient; effective implementation depends on contexts and tailored partnerships. Hence, hybrid PPPs (Cruz et al., 2022) were researched, emphasising voluntary agreements over strict contractual agreements seemed most suitable for a flexible multi-actor format. Within this PPP, success remains on sharing a form of trust and ownership over the region, both socially and economically, in-between partners. To complement micro- and meso-level insights, the MLP (Geels, 2011) positions the Harselaar MCEH within the macro-level Dutch energy landscape. It clarifies how sub-regime pressures interact with niche-innovations, as the MCEH, and shows how PPP functions as an intermediary. Implementing an MCEH via a PPP is seen functioning as an institutional bridge, integrating sub-regime influences with niche-innovations. These influences, imposed by varying stakeholders on different research scales, position MCEHs into the polycentric energy governance debate. Negotiating and deliberating in a bottom-up fashion characterise collaboration, which is noted by some as a promising energy collaboration approach (Burke & Stephens, 2017; Anfinson et al., 2023).

Using these frameworks, this thesis constructed a new approach to analyse PPP implementation for MCEHs. This stepwise assessment, described in the analysis chapter, allows transcending theory to practice, assisting practitioners such as hub directors, entrepreneurial companies, public institutions and others who are considering implementing a PPP.

It further adds to the discursive energy debate by specifying a distinct cycle of transitional theory, following the conceptual model. Where a niche-innovation, implemented via PPPs, functions as a new catalyst for change in the Dutch energy transition. It continuously enacts transitions for both the (sub)regime(s) and the PPP elements, which alter discourses, perspectives and operationalities of energy sector actors (Bosman et al., 2014; Ulrich et al., 2023). Understanding these energy landscape transitions allows for more rapid adaptations towards alternative decentralised energy solutions, mitigating grid congestion and accelerating the energy transition.

In this regard, MCEHs are seen as technical-social systems, facilitated by adaptive PPPs, embedded in multi-level transition dynamics. Given their social embeddedness, the success of results will most likely vary. Nevertheless, this integrated lens enhances our understanding of how local energy solutions can be realised and scaled. Findings of the Harselaar both showcase the potential and challenges associated with partnering in MCEH projects. These developments lay barren to the dynamic changing energy environments, as such, the Harselaar case is merely the beginning of large energetic changes in the overarching energy landscape.

5.2.3 Recommendations for future research

To build on this study's findings and advance understanding of MCEHs and PPPs, several research directions are proposed.

Future studies may perform longitudinal and comparative studies**,** tracking MCEH-PPP projects over time to assess partnership evolution across the four hub phases. This could reveal how voluntary agreements adapt, stakeholder roles change, and what long-term impacts on cost efficiency, lifecycle optimisation, risk-sharing, and societal value pertain. Parallel comparative studies could further assist to generalise findings.

In further extension, while this research has focused on a business zoning, future research may research other hub typologies (RoyalHaskoning DHV, 2022) or varying governance structures, to test or refine findings of the Harselaar case. Foremost, the focus per hub "family" varies, including heat transition, residential or heavy industry hubs, etc. Likewise, exploring alternative PPP models and stakeholder configurations may prove interesting for identifying optimal, context-specific solutions.

This and comparable research primarily rely on qualitative insights, adding quantitative research to complement and strengthen these insights may be valuable. Research may involve analysing the five elements of PPPs and varying sub-regime influence. Additionally, once more data is available, agent-based simulations can be implemented to forecast physical energy system modelling with behavioural simulation as investment decisions, regulation choices, or cooperation behaviour (Chappin & Dijkema, 2008; Chassin, 2014).

Finally, this thesis has opted to assist the collaboration process for the Harselaar case. Unfortunately, the scope and timeframe of this research did not allow for conducting research during the official partnering of the parties. Hence, follow-up research should examine the actual partnering and full-scale developments of the new energetic system for the Harselaar 1b/2 business park zoning. This would allow us to validate or refine the findings made in the preliminary research.

5.2.4 Recommendations for praxis

Drawing on the lessons from the Harselaar MCEH, recurring themes in stakeholder management, project governance and legal structures emerge that are key to successfully implement PPPs. Which allows this research to formulate multiple recommendations for the praxis.

For complex, multi-stakeholder cases such as the Harselaar, it is recommended that a neutral intermediary, as a hub director, be appointed to manage the project. This position requires high social and managerial skills to align and maintain purpose throughout the whole project lifecycle between stakeholders. Specifically, early involvement of all parties, combined with transparent communication and formalised feedback loops, fosters trust and mitigates delays.

Further sustainment of momentum and reinforcement of value can be achieved by highlighting early project wins, linked to time frame milestones.

Alongside project and stakeholder management, effective governance begins with selecting a structure suited to the project's scale and maturity. The Harselaar case included bottom-up incentives from one of the private parties to seek co-creation for shared objectives and to build trust. Once trust and purpose are established, formalising voluntary collaboration into a legal entity expresses unified external representation, clearer internal role division and consensus over project lifecycle. Transitioning from informal alignment to legally formalised governance supports adaptive, trust-based development.

Seeking the best fit for such collaborative structures and strategies remain difficult, ass each MCEH project operates under distinct conditions. Hence, exploratory due diligence during early stages, to tailor partnerships is essential. Hence, it is recommended to perform joint research among parties to help initiate shared understanding and collaboration which serves as the foundation of the future PPP formation.

Finally, the dynamic nature of the energy transition calls for a paradigm shift. Traditional, rigid PPP frameworks, often focused on land exploitation, are no longer adequate ways of thought. Future locally integrated community-scale energy projects require public involvement during specific phases of the project's lifecycle. For municipalities and DSOs, this implies stepping out of their comfort zones and adopting more proactive, collaborative roles. Although change is not imminent, it is inherent to successfully empower the energy transition and address grid congestion.

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Appendices

Appendix A: Further elaboration of frameworks and analysis methodology

Explanation of Multi-Level Perspective model (Geels, 2011)

The socio-technical Dutch energy regime

The socio-technical regime forms the 'deep structure' that accounts for the stability of an existing socio-technical system (Geels, 2004). It refers to the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems. According to Geels (2004), existing regimes are characterized by lock-in mechanisms influenced by innovations that occur incrementally, with small adjustments accumulating into stable trajectories. These trajectories are further divided into sub-regimes: (1) Technological. (2) Science (3) Policy, (4) Socio-cultural, and (5) User and market.

Socio-technic regime sub-regimes

First, rules within the technological sub-regime refer to technical standards, product specifications (e.g. emissions, weight) and functional requirements.

Secondly, science-based rules refer to research programmes, professional boundaries as well as academic values and procedures.

Thirdly, policy regime refers to policy goals and interaction patterns between industry and government regulated through administrative regulations and procedures which structure the legislative process of technology. These are mostly framed among government documents within the Regional Energy Strategy (RES) and the Routemap "Smart Energy Hubs" (RES Regio Foodvalley, 2023; Rijksoverheid, 2024).

Fourthly, cultural values are the values and ways users interact with firms presented via the ways information is spread such as media (Lundvall, 1988). Sustainability within the energy transition has seen a shift in sentiment and cultural values, showcasing the dynamic state of this sub-regime (Kularbphettong et al., 2024).

Lastly, rules for the user and market regime are based upon the interlocking role relationships between users and firms constructed through the creation of market via laws and rules. These five sub-regimes collectively influence the Dutch energy regime as can be seen in Figure 1.1.

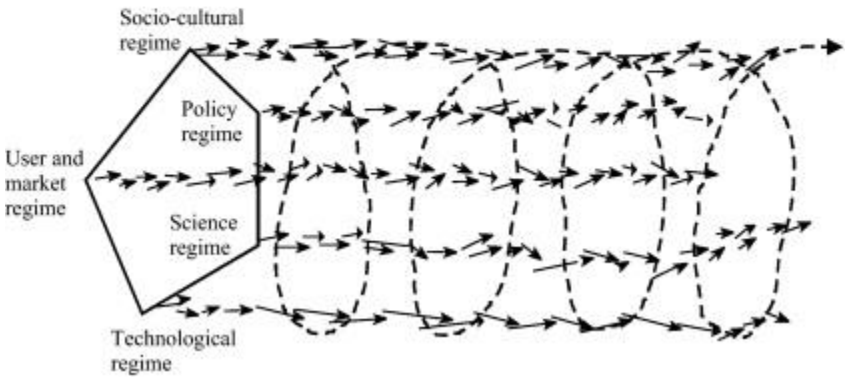


Figure A1 Socio-technical regime

Niche(s) within the Dutch energy system

Niches are described as protected spaces where uses have special demands and are supportive of emerging innovations. These innovations deviate from the regular socio-technical regime. Niches are crucial for transitions as niche actors aim to replace the current regime with its promising novelties (Schot & Geels, 2008). In this research the focus of niches within the Dutch energy system will be limited towards the use of multi-commodity energy hubs adapted using ICESs as the central niche innovation (Koirala et al., 2016). Literature defines three core processes that occur during the niche development to gain momentum, and become more precise and broadly accepted: (1) articulation and adjustment of expectations or visions, (2) building of social networks and (3) Learning and articulation processes on various dimensions (Kemp et al, 1998; Schot & Geels,2008)

The socio-technical energy landscape

The final analytical level represents the wider context that influences both niche and regime dynamics (Rip & Kemp, 1998). In which the 'landscape' represents not only the technical fundamentals that sustain society but refers to collectively structured demographical trends, political ideologies, societal values, and macro-economic patterns. Together these trends and patterns create a single 'landscape' category, that actors at niche and regime levels cannot influence in the short run (Geels, 2011). Combining all three levels Geels (2011) has structured the MLP in Figure A1, which will be used to assess the implementation of multi-commodity hubs as a niche innovation in the Dutch energy transition.

Hub categorisation (Koirala et al., 2016)

Table A1 Categorization of ICESs (Koirala et al., 2016)

Perspective	Categorization	References
Activities	Local generation, storage and demand response Collective purchasing Energy exchange and trading	[3,65]
Scale	Large/macro: city, region Medium/meso: neighborhood Small/micro: household/buildings	[55,60,66]
Grid Connection	Grid connected Off-grid	[7]
Initiatives	Led by citizens Led by private enterprises Led by government	[65]
Location	Developed countries – urban Developed countries – rural Developing countries – urban Developing countries – rural	Own assessment
Topologies	State of the art integration of DERs Integration through common point of coupling Autonomous	Own assessment

Table A2 Technologies in ICESs (Koirala et al., 2016)

Categories	Technologies	
	Household level	**Community level**
Local generation	Micro-CHP Reciprocating engines Internal combustion engines Fuel cells Heat pumps Pico-hydro Solar PV (rooftop) Solar thermal Micro-wind	Community CHP Reciprocating engines Internal combustion engines Fuel cells Heat pumps Biomass Geothermal Micro-hydro Community PV Solar thermal Community wind
Demand side flexibility	Flexible appliances (e.g. dishwasher, washing machine) Electric vehicles Electric and heat storage Battery energy management system (BEMS) Home/building energy management system (HEMS)	Community electric and heat storage Community BEMS Community energy management system (CEMS)

Table A3 Interests of different actors in ICESs (Koirala et al., 2016)

	Actors	Interests Private interests	System interests
Competitive parties	*Households*	Use of local, affordable and clean energy at a low cost	Sale surplus and purchase deficit energy
	Communities	Reduction in energy related costs, provision of local energy	Emission reductions, energy independence, energy supply security, resiliency
	Energy producers	Investment in local energy system (profit maximization)	Sale local generation
	Energy suppliers	Profit from deficit energy supply, portfolio optimization	Increase renewables in their portfolios, new roles and business models
	Energy service companies (ESCOs)	Profit from energy efficiency, operation and management of local generation	Role in energy efficiency improvement activities as well as operation and management of local generation
	Technology providers	Sell technologies to transform the existing energy landscape both production and consumption (e.g. circular economy)	Promotion of local generation as well as demand side management technologies
	Aggregators	Business model for generating profit, Maximize the value of flexibility in the markets (both with capacity and energy)	Role in making system more efficient
	Balance responsible parties	Portfolio optimization, balance energy procurement at lowest cost,	Provision of accurate scheduling to the system operator
Regulated parties	*Transmission system operators (TSOs)*	Maintain larger system balance of supply and demand at lowest cost to the consumers	Maintain larger system balance of supply and demand
	Distribution systems operators (DSOs)	Distribute energy to the neighborhood with safe, reliable and affordable grid,	Avoid grid congestion, defer network investments, self-balancing energy islands in smart grids
	Government, policy makers and regulators	ensure competition for affordable energy for end-users	Sustainable energy supply, transition to low-carbon energy system, energy security

Stakeholder analysis (Schmeer, 2000)

Definitions of Stakeholder Characteristics and Instructions for Filling in Stakeholder Table

A. I.D. Number

The distinct number given to each stakeholder on the questionnaire.

B. Position and Organization

The position the stakeholder has and the organization for which he or she works.

C. Internal/External

Internal (I) stakeholders work within the organization that is promoting or implementing the policy; all other stakeholders are considered external (E).

D. Knowledge of Policy

This column is divided into two parts. The first part, D1, is the level of accurate knowledge the

stakeholder has regarding the policy under analysis. This knowledge should be rated from 3 to 1: 3 = a lot; 2 = some; 1 = none. Final rankings should be reviewed to ensure consistent scoring among all of the stakeholders.

E. Position: Supports/Opposes/Neutral

Position refers to the stakeholder's status as a supporter or opponent of the policy. The position

of the stakeholder can be obtained by gathering information directly from the stakeholder (i.e., self-reporting) and through information gathered indirectly from other stakeholders or secondary information (i.e., others' perceptions). Thus, the reporting in this column represents the self-reported classification (column E1), the classification by others (column E2), and a final classification considering both (column E3). The position of the stakeholder should be reported from this final classification (column E3). Stakeholders who agree with the implementation of the policy are considered supporters (S); those who disagree with the policy are considered opponents (O); and those who do not have a clear opinion, or whose opinion could not be discerned, are considered neutral (N). Those whoexpress some, but not total, agreement with the policy should be classified as moderate supporters (MS). Finally those who express some, but not total, opposition to the policy should be classified as moderate opponents (MO). Thus, in column E1, the position of the stakeholder as they state it in the interview should be entered (S, MS, N, MO, or O). In column E2, the position of the stakeholder as perceived by other stakeholders and/or from secondary information should be entered with a reference to the ID number of the person who stated that opinion. For example, S 32 would mean that stakeholder number 32 stated in his or her interview that the stakeholder under analysis would support the policy. In column E2, the position of the stakeholder as others perceive it should be entered (S, MS, N, MO, or O) with the ID number for each opinion. Lastly, in column E3, the final determination for the position of the stakeholder should be entered (after entering data from all interviews). This position should take into account the self-reported position as well as other stakeholders' opinions. S, MS, N, MO, and O can be entered in this column.

F. Interest

The interest the stakeholder has in the policy, or the advantages and disadvantages that implementation of the policy may bring to the stakeholder or his or her organization. Advantages and

disadvantages mentioned by each of the stakeholders should be entered into this column in as

much detail as possible, since the information will be used primarily in developing conclusions and strategies for dealing with the stakeholders' concerns.

G. Alliances

"A union or relationship" (Webster, 1984). Alliances are formed when two or more organizations collaborate to meet the same objective, in this case to support or oppose the policy in question. Any organizations that are mentioned by the stakeholder in the questions related to this item should be entered in this column.

H. Resources

"A source of support or aid" (Webster, 1984). Resources can be of many types — human, financial, technological, political, and other. The analysts should consider the stakeholder's access to all of these resources. The resource category is divided into two parts: the quantity of resources that a stakeholder has within his or her organization or area, and the ability to mobilize those resources. The quantity of resources should be classified by the analysts as 3 = many, 2 = some, 1 = few and inserted into column H1 of the stakeholder table. Final rankings should be reviewed to ensure consistent scoring among all stakeholders. The ability of the stakeholder to mobilize resources should be quantified in terms of:

3 = the stakeholder can make decisions regarding the use of the resources in his or her

organization or area

2 = the stakeholder is one of several persons that makes decisions regarding the use of

resources

1 = the stakeholder cannot make decisions regarding the use of the resources.

This score should be inserted into column H2. For example, if the stakeholder has personnel that work for him or her, it can be concluded that the stakeholder has the ability to mobilize these resources because he or she has direct influence over them.

I. Power

“The capacity or ability to accomplish something;…strength, force or might” (Webster, 1984).

Here, power refers to the ability of the stakeholder to affect the implementation of the health reform policy due to the strength or force he or she possesses. Since “power” is defined here as the combined measure of the amount of resources a stakeholder has and his or her capacity to mobilize them, the two resource scores implied should be averaged, resulting in a power index between 3 and 1: 3 = high power, 2 = medium power, and 1 = little power. The final rankings should be reviewed to ensure consistent scoring among all stakeholders.

J. Leadership

“To direct the activity;…to start, begin;…front, foremost” (Webster, 1984). Leadership is specifically defined here as the willingness to initiate, convoke, or lead an action for or against the health reform policy. The stakeholder either has this characteristic ("yes") or lacks it ("no"). This is represented with "yes" or "no.

Appendix B: Operationalisation of theoretical concepts

Operationalisation of theoretical concepts (Cruz et al., 2022; Koirala et al, 2016; Mohamaddi et al., 2017; Palensky & Dietricht, 2011, Schmeer et al., 2000).

Public-Private-Partnerships			
Variable	**Definition**	**Indicators**	**Measurement**
Form of PPP construction	Traditional PPPs and hybrid PPP schemes within sustainable development are tested. Including	Purpose	Assess goals of PPP initiative - *Overview*
		Form	Traditional, contractual, voluntary agreements, hybrid set-ups *Overview*
		Time frame	Time (short vs long term) phases : Development stage Realization stage Exploitation stage *Documentation*
		Stakeholders	All multi-level actors involved directly in PPP - *Overview*
		Risk, reward, resource and responsibility sharing	Dynamics and underlying agreements of sharing (risk, reward etc.) *Scale of 1(very lacking) to 5 (very present) of dynamics*
		Critical success factors (CSFs)	Trust, accountability and risk levels *Scale of 1(Very lacking) to 5 (very present) of CSFs*
Operationality of PPP constructions	Collaborative governance factors that facilitate or depress cooperative between actors.	Starting condition	Starting resources & incentives - *Overview*
		(Governmental) leadership	Power levels Leadership characteristics Collaboration dynamics – *Yes or no*
		Institutional environment	Legal procedures and administrative agreements - *Documentation*
		Collaborative process	Cooperative activities, eg meetings of goal setting, implementation, reflection etc.- *Overview & presence*

		Barriers	Subjective experience of barriers- *Document*
		Finance	Financial feasibility – *Yes/no*
Multi-level analysis Dutch energy sector			
Variable	**Definition**	**Indicators**	**Measurement**
Socio-technic regime	The ‘deep structure’ that accounts for the stability of an existing socio-technical system. Including pressures caused by rules that orient and coordinate the activities of the social groups	Technological	Technical standards output KwH etc. - *Numerical*
		Science	Ongoing scienitifc research – *Presence yes/no*
		Policy	Governing influence – *Presence* yes/no
		Socio-cultural	Underlying discourses and values – *Overview/ documentation*
		User and market	User and Market influence, supply-demand costs-benefit – *numerical assessment*
Energy landscape	The collectively structured demographical trends, political ideologies, societal values, and macroeconomic patterns.	Energy trends and patterns	Habits and regularities – *Overview/ documentation*
		Energy values	Values to; power source, price, availability, sustainability etc. – *Scale of 1(very low value to) to 5 (very valuable to)*
		Energy challenges	Energy demand (output use?
		Energy discourses	Subjective - *Documentation*
Grid congestion	Grid congestion occurs when the transmission capacity of the power grid is insufficient to meet the power demand. This is mainly driven by the rapid increase in decentralized generated energy, such as solar and wind power.	Network operator capacity issues	New connections, budget issues, human capital issues – *Presence yes/no*
		Forecasting	Volatile grid pressure, high peeks low lows – *Numerical experience*
		High % renewable energy sources	% of RESs producing power to network - *Numerical*

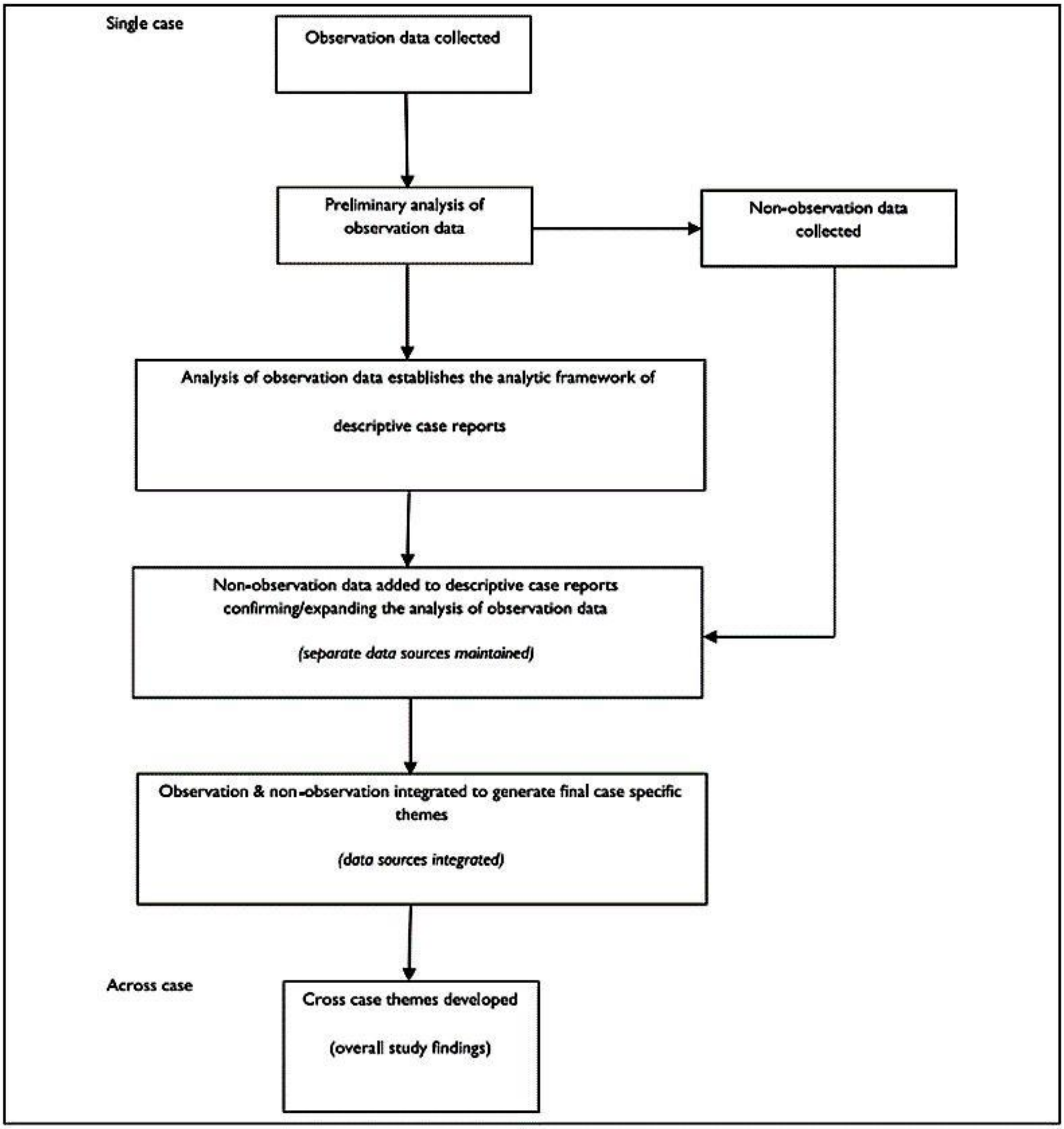
		Goal setting	Ambition, exogenous pressure (EU) – *Presence yes/no*
Multi-commodity energy hub (MCEH)			
Variable	**Definition**	**Indicators**	**Measurement**
Multi-commodity energy system (MCES)	Efficiently managing an integral network, having to deal with large amounts of differing power feeds from sources.	Energy management	Management visionary documents, Smart system modules - *Overview*
		Varying power feeds	Accumulating modes of power feeds – *Overview*
		Energy flexibility and adaptability	Checklist (5) TNO Flexibility report
		Energy optimisation	Energy efficiency, loss of energy -*Numerical & presence*
Energy hub	is a place where production conversion, storage, and consumption of different energy carriers take place	Energy production	KwH per household - *Numerical*
		Energy consumption	KwH per household - *Numerical*
		Energy storage	Electricity battery, EVs, gas/liquid tanks etc., - *Overview*
		Energy conversion	Common energy conversion methods (TU Delft, 2024) – *Overview*
Integrated Community Energy System (ICES)	Approach for local community energy initiatives which allow high-efficiency co-generation or tri-generation from renewable energy technologies, coupled with innovative energy storage and conversion solutions as well as electric vehicles and demand-side management measures.	High-efficiency energy generation/ usage	Co/trigeneration energy-*Presence, yes/no* *Efficient energy use, yes/no*
		Renewable energy sources (RES)	% of total energy production - *Numerical*
		Energy consumption	KwH per household-*Numerical*
		Energy storage	Electricity battery, EVs, gas/liquid tanks etc., - *Overview*
		Energy conversion	Common energy conversion methods (TU Delft, 2024) - *Overview*
		Demand side management	Home/building smart energy management - *Presence yes/no*

		Spatial levels	Regional level, community level, local level - *Overview*
		Actor's interests	See table 1.3 – *Overview & documentation*
Stakeholder analysis			
Variable	**Definition**	**Indicators**	**Measurement**
Stakeholder type	Three interconnected categorisations of actors who are influenced or have a relation to a corporation or project.	Internal stakeholder	Loyalty levels, interests, roles - *Overview*
		Stakewatcher	Loyalty levels, interests, roles - *Overview*
		Stakekeeper	Loyalty levels, interests, roles - *Overview*
Actor type: competitive party	Actors in the energy sector are inter-dependent in the realization of their goals. Different actors of ICESs have varied interests from ICESs.	Household, n Harselaar zoning these are business units)	Assessment of goals, actions and interests - *Overview*
		communities	Assessment of goals, actions and interests - *Overview*
		Energy producers	Assessment of goals, actions and interests - *Overview*
		Energy suppliers	Assessment of goals, actions and interests - *Overview*
		Energy servicecompanies (ESCO)	Assessment of goals, actions and interests - *Overview*
		Aggregators	Assessment of goals, actions and interests - *Overview*
		Balance responsible parties	Assessment of goals, actions and interests - *Overview*
Actor type: Regulated party	Actors in the energy sector are inter-dependent in the realization of their goals. Different actors of ICESs have varied interests from ICESs.	Transmission system operators (TSO)	Assessment of goals, actions and interests - *Overview*
		Distribution systems operators (DSO)	Assessment of goals, actions and interests - *Overview*

		Government, policy makers and regulators	Assessment of goals, actions and interests - *Overview*
Stakeholder characteristics	The analysis includes such stakeholder characteristics as knowledge of the policy, interests related to the policy, position for or against the policy, potential alliances with other stakeholders, and ability to affect the policy process (through power and/or leadership). (Schmeer, 2000)	Position(role) and organisation	Joh function - *Overviw*
		Internal/ external	Function within possible PPP construction – *Internal or external*
		Knowledge	Specific knowledge the stakeholder has regarding the policy under analysis. - *Scale of; 1: 3 = a lot; 2 = some; 1 = none.*
		Position	Stance on policy - *Supports/Opposes/Neutral*
		Interest	See table 1.3 – *Overview & documentation advatanges/disadvantages*
		Alliances	At least two parties that support or oppose the policy - *Overview*
		Resources	Two parts: the quantity of resources that a stakeholder has and the ability to mobilize those resources - *Scale of:* 3 = many, 2 = some, 1 = few
		Power	Combination of two parts of resources – *Scale of: 1: 3 = high power, 2 = medium power, and 1 = little power.*
		(Governmental) Leadership	Willingness to initiate, convoke, or lead an action for or against the health reform policy – *Yes or no*

Appendix C: Observational research; Sequence of data collection and analysis

Morgan et al.'s (2017) framework



Appendix D: Document analysis

Overview of analysed documents for share of PPS in Dutch energy projects

Author	**Title**	**Analysed data section(s)**	**Hyperlink**
Dirkzwager (2024)	Juridische vorm Smart Energy Hubs (SEHs).	Whole document	**Link 1**
EIGEN (2023a)	Beslisdocument oprichten exploitatiebedrijf v1.0.	Section 2. "Juridische structuur en besturingsmodel", p. 13,	**Link 2**
EIGEN (2023b)	Beslisdocument oprichten ontwikkelbedrijf.	Whole document	**Link 3**
EIGEN (2023c)	Blauwdruk voor het realiseren van Energy Hubs op bedrijventerreinen	Faseringen hubs	**Link 4**
Energie samen (2020)	Wind- en zonneparken realiseren samen met inwoners	p. 26-27	**Link 5**
Firan (2021)	Uitvoeringsagenda Smart Energy Hubs 2021-2023.	Whole document	**Link 6**
Firan (2024)	Afwegingskader Rechtsvorm Energy Hub Firan.	Whole document	Link 7
FREON (2024)	Haalbaarheid en aanvaardbaarheid van Energiehubs in Fryslân	p.4,24	Link 8
HIER (2023).	Lokale Energie Monitor 2023	Section 7. "Knelpunten energiebesparing"	Link 9
Liander (2025)	Stappenplan Energiehubs.	Verkennings en ontwikkelfase	Link 10
Local4local (2024)	Een vergelijking tussen energiegemeenschappen en smart energiehubs.	Whole document	Link 11
Ministerie van Binnenlandse Zaken en Koninkrijkrelaties (2019)	Reiswijzer Gebiedsontwikkeling 2019.	Section 6.7.4, p.44 – 58	Link 12
Ministerie van Economische zaken (2023)	Nationaal Plan Energiesystemen.	P.6, 17, 39-40	link 13
Next2Company (2023)	Verkenning Mini-Warmtenetten Eindrapportage.	p. 52-55	Link 14

NPLW (2024).	NPLW Handreiking Mini- en Kleinschalige Warmtenetten.	p. 42 – 46	Link 15
PVB (2024).	Leerervaring Energie-Hub Lage Weide Energy Hub.	Whole document	Link 16
RES (2023)	Voortgangsrapportage Regionale Energiestrategie Regio Foodvalley	Barneveld section	Link 17
Rijksdienst voor Ondernemend Nederland (2024).	Handelingsperspectief Gemeenten voor Initiatie van Energiehubs.	Varying energy hubs, p4-7	Link 18
Rijksdienst voor Ondernemend Nederland (2024)	Handreiking Stimuleringsprogramma Energiehubs 2024.	p.7, Appendix C	Link 19
Rijksdienst voor Ondernemend Nederland (2024)	Routekaart Samenwerken in Energiehubs.	p. 11	Link 20
Royal HaskoningDHV (2022)	Meerwaarde SEH Oost NL - Eindrapport.	p. 7	Link 21
Royal HaskoningDHV (2024)	De families van Energy Hubs in Nederland.	p.4, 83	Link 22
TKI Urban Energy (2020)	TKI Warmtenetten Georganiseerd.	p.29	Link 23
Van Rhee (2020)	Kansen van de energietransitie voor Oost-Nederland	p.40 - 44	Link 24

Appendix E: Literature analysis

Table E1 Exclusion criteria literature review.

Language	Not English or Dutch	Researcher only possesses ability to read Dutch or English texts.
Published date	Published before 2015	Prior to 2015 are less accurate and relevant sources
Subject area	Not Environmental Studies, Environmental Sciences, Green Sustainable Science, construction Building Technology, International Relations, communication, Engineering Civil, Engineering Electrical Electronic, Engineering Multidisciplinary, Geography, Multidisciplinary Sciences, Forestry, Meterologoy Atmospheric Sciences, Astronomy Astrophysics, Public Environmental Health, Food Science, Medicine, Physics and Astronomy, Materials science, Agriculutral and Biological Sciences	Non-related subject areas excluded after using search inquiries
Document type	Not conference review, note, letter, editorial	Papers from conferences need more revision to be of sufficient quality, editorial papers are an introduction and do not sufficiently go into depth. Nots and letters are not sufficiently peer to peer reviewed to be reliable.

Table E2 Search enquiries and results literature review.

Date of search	**Search terms**	**Scope**	**Number of articles**	**Number after exclusion/ used**
Web of science				
18-03	Dutch public-private energy partnerships OR public-private energy partnerships in the Netherlands	All fields:	14	2
18-03	Voluntary partnerships AND energy*	All fields	30,	11
19-03	Energy power purchase agreements	All fields:	9	9
19-03	Energy technology partnerships Netherlands OR Energy technology partnerships Dutch	All fields	70	27
Total				49
Scopus				
18-03	Dutch public-private energy partnerships OR public-private energy partnerships in the Netherlands	Article Title, Abstract, Keywords	5	4
18-03	Voluntary partnerships AND energy*	Article Title, Abstract, Keywords	106	33
19-03	Energy power purchase agreements	Article Title, Abstract, Keywords	15	14
19-03	Energy technology partnerships Netherlands OR Energy technology partnerships Dutch	Article Title, Abstract, Keywords	2	1
Total Scopus				52
Total WOS + Scopus		101		
Duplicates		-18		

Excluding after scanning/ reading abstract	Web of science – 28 Scopus - 33
Full article n/a	Web of science – 1 Scopus - 5
Excluded after reading	-6
Added afterwards via other methods: snowballing etc.	+ 11
Total	21

Table E3 PPP Literature Categorized by evaluated themes.

Category	Authors & Date	Title / Literature Source
General PPP applicability	Antionio et al. (2016)	Challenges for public-private partnerships in improving energy efficiency of building sector
	Cruz et al. (2022)	Unveiling the shades of partnerships for the energy transition and sustainable development: Connecting public–private partnerships and emerging hybrid schemes
	Klijn & Koppenjan (2016)	The impact of contract characteristics on the performance of public–private partnerships (PPPs)
	Marcelo et al. (2019)	Do countries learn from experience in infrastructure public–private partnerships? Public–private partnerships practice and contract cancellation
	Martinez et al. (2023)	Why go public? Public configurations and the supportive and divergent views towards public district heating in the Netherlands
	Nel, D. (2018)	An assessment of emerging hybrid public-private partnerships in the energy sector in South Africa
	Marskamp et al., (2024)	Rolneming gemeente bij energiehubs
	Petersen & Heurkens (2018)	Implementing energy policies in urban development projects: The role of public planning authorities in Denmark, Germany and the Netherlands
	Rossi et al. (2019)	The evolution of public-private partnerships in a comparison between Europe and Italy: Some perspectives for the energy sector
	Wang & Ma (2020)	Public–private partnership as a tool for sustainable development – What literatures say?
	Yescombe & Farquarson (2018)	Public-Private Partnerships for Infrastructure: Principles of Policy & Finance
Power Purchase	Martiniello et al. (2020)	Energy performance contracting and public-private partnership: How to share risks and balance benefits

Agreements (PPA)	Salci & Jenkins (2018)	An economic analysis for the design of IPP contracts for grid-connected renewable energy projects
	Taheri et al. (2025)	Physical vs Virtual corporate power purchase agreements: Meeting renewable targets amid demand and price uncertainty
	Weiss & Sarro (2013)	The importance of long-term contracting for facilitating renewable energy project development
Voluntary agreements and PPP	Cornelis (2019)	History and prospect of voluntary agreements on industrial energy efficiency in Europe
	Ferrara & Lange (2013)	Voluntary Programs to Encourage Diffusion: The Case of the Combined Heat-and-Power Partnership
	Veum, K.C. (2018)	Long-Term Agreements on Energy Efficiency for the non-ETS sector (LTA3, the Netherlands)
Technology, innovation and PPP	Brogaard (2019)	"Innovative Outcomes in Public-Private Innovation Partnerships: A Systematic Review of Empirical Evidence and Current Challenges”
	Khan et al. (2020)	The Impact of Technological Innovation and Public-Private Partnership Investment on Sustainable Environment in China: Consumption-Based Carbon Emissions Analysis
	Thompson et al. (2018)	"SME Knowledge Commercialization Through Public Sector Partnerships

Appendix F: Stakeholder Table using Schmeer's (2000) stakeholder analysis

A	B	C	D	E			F	G	H		I	J
ID #	Position & organization	Intern/ External	Knowledge	Position			Interests	Alliances	Resources		Power	Leader
			1 Level 3,2,1	1 Self	1 Others	1 Final	Advantages /Disadvantages-ages	Organizations mentioned	1 Quantity; 3,2,1	2 Ability to mobilize; 3,2,1	Resources average 3,2,1	Yes/No
				S, MS, N, MO, O	S, MS, N, MO, O	S, MS, N, MO, O						
1	PP1; Owner	Internal	3	S	S	S	-Commercial business case -Development 1b/2 zoning -Innovation - electricity supplier	Municipality Barneveld	3, in regard to MCEH assets and knowledge.	3,	3	Yes
2	PP2; Real Estate manager (REM)	Internal	2	MO	N	N	-Commercial business case -Grid connection Harselaar 1b/2 as owning 80% of area - Business CPH	Not directly in partnership	3, many resources in general, capital, knowledge etc. Less knowledge on energy specific	3	2 much power in general, less in energy specific	No
3	Municipality Barneveld; official	Internal	2	S	S/MS	S	-Grid connection development of Harselaar 1b/2 (owning 20% of area)	PP1, Province, other public bodies?	2-Financially healthy (limited financial support for backlash) -Has ground 20%	1 -Strict rules for funding	1 – relatively low power. Again rules etc.	No. Could be leader if incentives

							-Improving business climate -Fair energy prices/contract - Future proofing Barneveld energy access.		-No real assets	and execution.		
4	Oost NL: BD1 & BD2	Internal	3	S	S	S	-Support sustainable energy transitions. -Strengthen regional economic climate (through better energy infrastructure). -Promote innovation and scalable models. -Serve public interest rather than direct commercial gain	Appointed hub director for Barneveld. -Province of Gelderland: Strategic partner and funder. - Municipality of Barneveld: Indirect involvement and shared goals.	2 -Strategic knowledge and experience in hub development. -Access to networks and stakeholders. -Capital could consider revolving loans or co-financing in later stages. -Ability to fund feasibility or development studies	2	2, Does not lead, but enables and accelerates development -commissioning, advising, and sometimes financing. -Maintain neutrality and encourage local ownership.	NO. Oost NL's role is not to lead but to facilitate, project-based involvement (e.g., via regisseurs or finance) and a potential advisory role ownership should remain with local stakeholders, but Oost NL can fill roles others cannot.

5	Hub Director Harselaar	Internal	3	S	S	S	• Main interest, focusing upon the collective locally integration of a multi-commodity energy system for Barneveld . And future proofing Barnevelds energy access? • Focused on establish hing trust, transparency, and shared ownership among parties. • Advocates for fair and complementary role distribution, aiming for collective value creation.	• Strong working relationships with municipality, Energieon, Fink, and legal advisors (e.g. Dirkzwager).	2. Brings process knowledge, legal insights, and stakeholder management capacity. • Not a technical or financial resource provider but essential for coordination, facilitation, and stakeholder alignment.	3.	2. Holds significant informal power as the central connector and communicator. • Influential in setting the agenda, aligning parties, and driving the process forward. • Lacks formal decision-making authority over assets	Yes/no, Acts as a facilitator and driver, not the sole leader.
6	Liander; DSO	External	3	S	S	S	• Interested in aligning societal goals with efficient grid use and long-term system integrity. • Liander seeks to ensure that investment	• Ongoing relationships with Oost NL and municipalitie s.	3 Provides expertise on network infrastructure and regulatory frameworks. Offers process knowledge	2 Somewha t limited due to regulatory role	Holds indirect but significant power through regulatory gatekeeping and technical compliance requirements.	Liander does not take a leadership or initiating role in MCEH projects.

							in infrastructure delivers societal returns and remains efficient. • Has a strong interest in stable governance frameworks and clear expectations from all parties	• Relationships with TSO & DEP	and helps structure long-term efficiency planning,		Their power stems from being the required facilitator for connection and capacity validation	They emphasize the need for a process leader (e.g., hub director) and organizational clarity before committing operational support.

Appendix G: Assessment Framework: To PPP or not to PPP?

Framework applied to Smart Energy Hub project of Oost NL's site for knowledge dissemination