Governing the Energy Commons:

Addressing Grid Congestion Using Ostrom's Design Principles in Energy Hubs

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Five months of research, along with many more months of reflections on (energy) commons, and the support of many people, have culminated in this thesis on energy hubs. This thesis is rooted in the GPE curriculum, is complemented by practical experience in the energy transition sector and is inspired by the work of Elinor Ostrom. Her ideas are deeply embedded in GPE thinking and have always left a strong impression on me. Ostrom's ideas inspired and challenged me to explore the *what*, *why*, and *how* of governing energy commons. I am truly grateful for the opportunity to have written this thesis.

I would like to thank my supervisor, Martijn, for his constructive feedback, exchange of ideas, and the motivating peer sessions he facilitated.

I am also grateful to the participants of this thesis for their time, their insights, and their inspiring drive to advance the energy transition in the Netherlands.

Special thanks to Kay, Bas, Rolph, and Kasper for the early sparring sessions, which helped me to contextualize the field of energy hubs and refine my research design.

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Abstract

The Dutch electricity grid is under increasing pressure due to the rapid pace of the energy transition and the unpreparedness of grid infrastructure. These developments result in grid congestion. Organizations and renewable energy projects throughout the Netherlands are facing long waiting list to obtains grid connections. Building additional infrastructure is hindered by long planning procedures and personnel shortages, while grid upgrades impose significant socialized costs. In short, the Dutch energy system (the common) is dealing with a tragedy (grid congestion). In response, affected parties are organizing themselves in collectives to address grid congestion. These organizations - commonly referred to as energy hubs – collectively govern energy generation, consumption distribution and storage, in cooperation and coordination with local and supralocal actors such as system operators.

Building on prior research by the Elinor Ostrom Workshop of governing common pool resources, as well as polycentric governance theory, this thesis explores how Dutch energy hubs collectively manage aspects of a decentralizing electricity grid. This research is guided by three key research goals: (1) Understanding how energy hubs function as commons governance systems, in relation to Ostrom's design principles for sustainable common pool resource governance. (2) Examining the applicability of Ostrom's design principles on governing energy commons, as well as proposing adaptations of these principles to better fit the characteristics of energy commons. (3) Exploring interactions between local, regional and national levels of the energy system, focusing on both technical and governance aspects of energy commons.

This thesis adopts a multiple case study design, utilizing cross-case analysis and synthesis to compare results to current commons literature. Data is collected through semi-structured interviews with key actors and is triangulated with document analysis and spatial analysis.

Main findings include:

A. Empirical practices in the studied energy hubs generally align with Ostrom's design principles. However, for principles regarding congruence of provision and appropriation, accountability, monitoring and conflict management (DP 2, 4 5 and 6, formal mechanisms are not always necessary and can be supported instead by social capital or 'naoberschap', formed through the initiation process of the energy hub.
B. Autonomy within polycentric governance appears crucial for the establishment of energy hubs and the shifting roles of institutional actors that are required in the changing energy landscape. While energy hubs alleviate grid congestion for their participants, they can impose an insider-outsider distinction. This arises from techno-legal requirements and the extensive process of establishing an energy hub. Adequately accommodating new entrants is still being researched with regards to the hub's sustainability of common pool management and a free-rider dilemma.
C. Energy hubs are still dependent on upstream grid developments. The current quantity and magnitude of energy hubs is not sufficient yet to reduce grid stress beyond the energy hub. This requires a dense and meshed network of local flexibility which balances energy supply and demand. This network would not necessarily have to adopt the energy hub model since it is not the most optimal solution for all cases due to the resource intensive process and fiats needed from external parties.

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1. Introduction

The energy transition in the Netherlands is progressing at a higher pace than the electricity grid is designed for. Due to the volatility of renewable energy sources such as solar energy or wind energy, and the swift electrification of the built environment, the Netherlands is facing grid congestion on high, medium and lower voltage levels (van der Holst, 2024).

Grid congestion halts the connection of largescale energy generation or energy users to the local or national electricity grid. This results in delays in economic development and limits efforts by the industrial sector to reduce carbon emissions in production processes (De Boer, 2023; De Boer, 2021). Furthermore, grid congestion impacts the development of new residential areas (ACM, 2024). Generally, grid congestion challenges the Netherlands' shift to a post fossil society (De Boer, 2021).

National and regional grid operators, known as transmission system operators (TSO) and distribution system operators (DSOs) are working on grid extensions in the form of additional cables and transformer stations. However, this is a time, cost and space-intensive process (de Winkel et al., 2025; Duivenvoorden et al., 2021). In addition, there is a shortage of technically trained personnel to install the grid extensions. (de Winkel et al., 2025; Helmholt et al., 2024).

Apart from grid expansions by the central operators, other grid congestion mitigation and adaptation measures are taken, including but not limited to:

1. Flexibility. Levelling out electricity generation and consumption peaks (de Winkel et al., 2025). Using energy in a different time frame. Possibly with the help of a battery. In other words, steering on flexibility of assets and consumption patterns (Hennig et al., 2023).
2. Better use of existing infrastructure (Landelijk Actieprogramma Netcongestie, 2022).
3. Agreements between companies and the grid operator. These agreements include conditions for using grid infrastructure within certain timeframes (Hennig et al., 2023)

Given the lengthy procedures for strengthening the grids, which will eventually enable connections, various industrial parks are organizing themselves into energy hubs. Energy hubs are local networks in which energy production, consumption, storage and distribution are coordinated between participants (Mohammadi et al., 2017).

Energy hubs are a form of self-organization in a network that governs energy commons. These hubs can locally contribute to reducing grid congestion problems. In the Netherlands, there is significant societal interest in energy hubs in the context of grid congestion and sustainability objectives that impose organizations to invest in sustainable technologies (Landelijk Actieprogramma Netcongestie, 2022).

This thesis aims to make a theoretical contribution to commons literature as well as providing empirical insight into the emerging phenomenon of energy hubs. The following chapters will successively explain the current state of the literature, the relevance, the problem definition, the question formulation and the objectives, the conceptual model, methodology, results and conclusions.

2. Relevance

Chapter 2 outlines the problem of grid congestion and the relevance of researching potential solutions to grid congestion as well as their practical implementation. Furthermore, this reviews the current state of commons and polycentric governance literature, highlighting key theoretical issues and omissions relevant to this thesis.

2.1 Societal Relevance

Grid congestion instigates business parks, neighborhoods and renewable energy projects to rethink current and future connections of commodities, devices and buildings, since they can currently not always get connected to the electricity grid. Energy hubs serve as an example of how grid congestion can be addressed locally and how energy generation, consumption and infrastructure can be coordinated and managed in an equitable and integrated manner (Bauwens et al., 2024; Wolsink, 2020). Energy hubs can provide a grassroots solution to grid congestion by balancing electricity generation, consumption storage and distribution locally using IT (Lavrijssen et al., 2023).

As of 2023, the industrial sector accounts for 45% of the Netherlands' total final energy consumption. (EBN, 2025). This includes heat (gas and steam) and oil, fuels or other resources. However, with the energy transition, the industrial sector is shifting to electric heating (when feasible) and hydrogen, while phasing out fossil fuels (Rijksoverheid, 2023). These developments require more electric energy, pointing to the current bottlenecks in the electricity grid as also identified in chapter one.

Society's interest in energy hubs is substantial, as also illustrated by the national stimulation program for energy hubs (€ 166 million) (Jetten, 2024). However, the implementation of energy hubs runs into complications in practice. To organize an energy hub, a business park must have a high degree of organization, a legal entity must be established, and energy hub participants must be activated to participate in a joint trajectory without clearly defined outcomes in sight (Landelijk Actieprogramma Netcongestie, 2022).

2.2 Scientific Relevance

Common pool resources, also called commons, consist of resources that are non-excludable but rivalrous (Marzban et al., 2022). The Dutch energy system exhibits characteristics of a common pool resource. Network operators have an “aansluitingsplicht”, an obligation to provide electricity connections to applicants (Lavrijsen et al., 2023). This connection must be available continuously throughout the year, uninterrupted. In relation to commons, this means that the Dutch electricity grid is not excludable. This principle is known as the copper plate principle. The sustainability of the copper plate principle is under discussion due to the limited operational capacity for grid extensions and the increase in flexible assets for electricity generation and consumption (Blom et al., 2022).

The electricity grid is rivalrous as currently illustrated by the waiting list for new connections that consists of over 10.000 parties (de Winkel et al., 2025). Additional connections compete with each other (Wolsink, 2020). Even within an Energy Hub, this rivalry persists. Each unit of energy can only be used once within a shared grid (Wolsink, 2020). This makes the ‘commons lens’ an adequate angle of analysis to research energy hubs.

Energy commons research is underrepresented within the broader commons literature, which typically focuses on water, grazing lands, forests, fisheries and animals (Agrawal et al., 2023). Energy commons research focuses primarily on the local scale, but scaling up is necessary to avoid the inevitable problem of scale: what works locally does not always work at larger scales (Burke, 2021). Bauwens et al. (2024) indicate that integration between different scales should be further explored. Energy Hubs or communities locally affect the commons problem (grid congestion). However, grid congestion goes beyond the local scale. Therefore, this thesis aims to map the interactions between different scales of the Dutch electricity grid and examines current practices of the upscaling energy hubs.

Within commons research, Agrawal et al. (2023) identify the tendency to research commons from an institutionally stable perspective. However, transitional institutions have the potential to foster sustainable resource use. Dieperink and Bos (2025) for example, find that law and regulation in the Netherlands is evolving with the introduction of the Energy Bill and the adaptation of grid codes by the Authority for Consumers and Market (ACM). By altering the grid codes, more jurisdictional space is given to distribution system operators (DSOs) to implement flexibility measures on the grid such as a Capacity Restriction Contract (CBC) (Van der Holst, 2024). These new jurisdictional frameworks and the transitional state of institutions that interact with energy hubs call for additional research regarding energy commons. Other scholars note that the role of system operators is evolving. In addition to the traditional role of grid management and asset upgrades, system operators are now tasked to facilitate the development of new technologies and business models contribute to regional planning (Duma et al., 2024), unlock flexibility and manage grid congestion (Winkel et al., 2025), and prioritize connection applications based on societal urgency (Dieperink & Bos, 2025).

These transformations define one of the research goals of this thesis; to analyze the effects of dynamic institutions on common pool management, thereby addressing Agrawal et al.'s (2023) critique on the dominant focus on institutionally stable settings in commons research.

A theoretical issue that emerged in the past decades of commons research is the difficulty to measure successful commons management (Araral, 2014; Cox et al., 2010*).* Ostrom (2015) considered robustness: *"institutions that enable individuals to achieve productive outcomes in situations where temptations to free ride and shirk are ever present."* (Ostrom, 1990, p.15). Later research opts for case or field of study specific success markers such as *transaction costs* (Economics) (Alston & Andersson, 2011) or recognition of authority (environmental policy) (Andersson et al., 2014*).* Trust and reciprocity are seen as other recurring success determinants (Araral, 2014).

The debate on defining successful commons management could be related to the identification of relevant propositions for commons management. Since the initial publication by Ostrom, authors from different fields have made extensions on the design principles (culture, justice, politics) (Agrawal et al., 2023). The 'original' design principles should therefore be seen as a guide towards commons thinking rather than a 'final set of propositions' (Agrawal et al., 2023, p. 533). Therefore, this thesis proposes adaptations to the design principles based on studied practices and the characteristics of the common pool resources, in this case electricity and the electricity grid.

Finally, this thesis aims to make a theoretical contribution to polycentric governance theory. Energy hubs manage a larger resource system that requires cross-scale cooperation, described by Cox et al. (2010) as *nesting*. Yet, Energy hubs as "islands" do not necessarily help to counter grid congestion in the region, or at the provincial or national level (Bauwens et al., 2024). This calls for research on the conditions under which polycentric systems 'deliver' and under which conditions learning curves from elsewhere can be shared (Bauwens et al., 2024, p.139). Furthermore, the theoretical advantage of polycentric governance - experimentation - can be closely researched through the case of an energy hub (Bauwens et al., 2024).

3. Research Problem

Energy hubs have the potential to locally alleviate electricity connection limitations imposed by DSOs and provide ways to use existing infrastructure more efficiently. Current research shows gaps in the understanding of energy hubs' integration into multiple scales. Electricity commons problems cross jurisdictions and the local scale. Energy Hubs require efforts to organize, distribute capacity and timeframes, make legal obligations and have control mechanisms to prevent misuse. Energy hubs are a polycentric governance answer to common pool resource problems on the Dutch electricity grid. However, scientific literature omissions are found in the upscaling of local practices to a larger scale.

This thesis tries to better understand the commons governance principles that are being exercised in existing energy hubs in the Netherlands to translate these practices into principles. Additionally, this thesis aims to make an approach to an adaptation of Elinor Ostrom's Design Principles applied to energy commons.

4. Research Questions

To contribute to identified research gaps and to create an adaptation of Elinor Ostrom's design principles, the main research question of this thesis is:

How do Dutch energy hubs govern multiscale energy commons using Ostrom's design principles?

Four sub questions have been formulated to answer the main research question:

1. What are the operational characteristics of energy hubs on industrial parks in the Netherlands?

   This research question serves the purpose of identifying the physical assets of the energy hubs, as well as network topology and the level of integration with the regional and national grid.

2. What are the governance structures of energy hubs on industrial parks in the Netherlands?

   This research question identifies the cooperation agreements, legal arrangements and involved parties within energy hubs.

3. How do energy hubs interact with supralocal actors within a polycentric governance framework?

This research question examines the independent decision-making centers and monitoring, sanctioning and conflict resolution arenas in the polycentric governance of energy hubs.

4. What is the effect of Ostrom's design principles on commons management in energy hubs?

   This research question assesses the individual contributions of Ostrom's design principles on sustainable management of common pool resources to practices on Dutch Energy Hubs. It addresses the theoretical gap in defining indicators for successful commons management, as identified in chapter 2.2.

The research scope is limited to energy hubs on Dutch industrial parks with the condition that they are in operation. This also includes pilot projects. Energy hubs that are still in the design and negotiation process are not included in this study.

5. Theoretical Framework

The key terms this thesis entails are: energy hubs, commons, Ostrom's design principles and polycentric governance. This chapter includes a definition and demarcation for the applicability of these terms in this research. Furthermore, an operationalization of the concepts is provided.

5.1 Energy Hub

According to Eladl et al. (2023) an energy hub is an integrated energy system wherein energy generation, consumption, distribution and conversion are tuned to individual components' characteristics and needs. Energy hubs can include heat, gas, electricity, hydrogen, biomass or other energy sources and carriers (Eladl et al., 2023). When more than one energy carrier is utilized within an energy hub, this is defined as a hybrid energy hub (Nazar & Hagifham, 2009). Due to this thesis' focus on grid congestion, the primary scope will be on electric components of Energy Hubs. This does not mean that hybrid energy hubs are excluded from research. However, this research will predominantly highlight the electric components within a (hybrid) energy hub.

Energy hubs take form on a variety of scales, such as industrial, residential, commercial, agricultural (Mohammadi et al., 2017), utilities, individual buildings (Sadeghi et al., 2019) or offshore (Thommessen et al., 2021). As described in chapter 2.2, this thesis takes a key interest in industrial energy hubs.

From a planning perspective, energy hubs can be seen as organizations of "active energy users that maximize the benefits and minimize the costs using optimization procedures in producing and sharing energy coming from different carriers" (Rossi et al., 2024, p.5). This extends the rather technical definition of Energy Hubs provided earlier, by including a degree of organization with active participants. Wolsink (2020) further stresses the urgency of a flexible adaptive organization, breaking tradition with the "standard" hierarchical centralized electricity regime.

Summarizing the relevant characteristics of energy hubs, in this thesis, the term energy hub is defined as an organization on an industrial site that cooperates to balance electricity production, consumption, storage, and grid usage.

5.2 Commons

Goods and resources are traditionally divided into public, common, club and private goods. This distinction is made on the relative ease of excludability, and rivalry (Agrawal et al., 2023). Excludability refers to the question of barring one to use a good. Rivalry regards whether using a resource or good depletes the possibilities for others to use a resource or good (Agrawal et al., 2023). As argued in the scientific relevance, the electricity grid shows characteristics of a common good because users cannot effectively be excluded from using the good (Lavrijssen et al., 2023) and the grid is enduring rivalry, meaning one person's usage of the grid reduces the space for other users on the grid (Marzban, 2022; Wolsink, 2020).

The provision of public and common goods inherently comes with the risk of free riding. (Bauwens & Mertens, 2018). When activities of actors (DSOs expanding the grids) benefit the larger pool of users of the grid, the risk exists some participants will free ride (Ostrom, 2009). This means that individuals display strategic behavior and strive for self-interest with regards to the provision of public goods, leading to inadequate and inefficient provision of these goods (Xia & Xu, 2024; Rayati et al., 2020). An example of this is a 'zombie connection application'. A term used to describe speculative grid connection requests by parties (Tweede Kamer der Staten-Generaal, 2024).

Traditionally, the state steps in to provide a top-down provision of common resources (Bauwens & Mertens, 2018). However, the provision can be insufficient due to a lack of information (Bauwens & Mertens, 2018). This is evident from the requirement for DSOs to provide thorough investments to the ACM, resulting in reactive behavior (Gerritsen et al., 2023). Furthermore, the grid congestion is partially a result of the

To overcome commons dilemmas, scholars have developed different 'third way' solutions, between state and market (Ostrom, 1990). This thesis focuses on the notions of polycentric governance, established by Michael Polanyi (1951) and later Elinor Ostrom (1990), (Huitema et al., 2019).

5.3 Governing Energy Commons

In this section, the concepts 'energy hubs' and 'commons' will be related to the research question of how energy commons are governed in energy hubs. Energy systems are common resources, as discussed in chapter 2.2. Commons are non-excludable but rivalrous resources and entail a free-rider and collective action dilemma.

This thesis synergizes two theories to address multiscale energy commons problems: Ostrom's design principles of common pool resources management and polycentric governance. Hence, this study takes a special interest in principle eight: nested (polycentric) enterprises, since energy hubs are part of a larger common pool resource spanning multiple jurisdictions, namely the national energy grid. Sections 5.4 and 5.5 will elaborate on these theories.

5.4 Elinor Ostrom's Design Principles

This section provides an operationalization of Ostrom's design principles. The design principles were established in Ostrom's seminal working: Governing the Commons (Ostrom, 1990). A design principle describes an "element or condition that helps to account for the success of these institutions in sustaining the CPRs (common pool resources)" (Ostrom, 1990, p.90). Within the operationalization a distinction is made between insiders and outsiders (of the energy hub). Which provides a useful distinction of analysis units when researching polycentric governance (chapter 5.5) (Aligica & Tarko, 2012). Internal refers to formal participants of energy hubs.

1. **Clearly defined boundaries** delineate the limits of the common pool resource and its users as well as the units of extraction per user (Ostrom, 2022). Namujju (2024) physical and social boundaries. **(a)** The physical boundary is indicated by the material extent of the electric network, known as Network topology (Netbeheer Nederland, n.d.) and the connectedness to the national or regional grid (Lavrijssen et al., 2023). Social boundaries **(b)** imply membership of the cooperation that manages the common pool resource (Namujju, 2024). Social boundaries are measured by scrutinizing the participators in the legal entity of an energy hub. Facilitating parties, such as governmental bodies or private companies such as aggregators or energy service companies (ESCo's) can be members too if they are formally part of the energy hub.

2. **Congruence: rules and local conditions** (Namujju, 2024). This principle investigates the agreements on who can access which quantity of a resource, at what time, and in which location (ACM, 2023; de Graaf et al., 2024). Otherwise described as the harmony of appropriation and provisioning (Araral, 2014) **(a)**. The agreements on common pool usage in time, quantity and location are assessed by inspecting energy usage agreements within the energy hub and between the energy hub and DSOs. Furthermore, this design principle reviews the proportionality of division between costs and benefits in relation to capital input (Namujju, 2024; Cox et al., 2010) **(b)**. This is operationalized by researching the provision rules (statutory, contractual, or cooperative) between companies on the energy Hub (de Graaf et al., 2024, p.79).

3. **Collective action agreements** set out the participation of users in decision-making processes concerning the common pool resource (Namujju, 2024; de Graaf et al., 2024). It is operationalized by inspecting:
    a. Agreements on data sharing
    b. Agreements on collective ownership
    c. Agreements on collective investments
    d. Agreements on opting in and out of the energy hub (de Graaf et al., 2024)
    e. Collective choice agreements (Poteete et al., 2009)

4. **Monitoring** considers the behavior of users regarding the common pool resource (Ostrom, 1990). Two dimensions are operationalized: **(a)** Agreements on monitoring the use of commons within an energy hub (Ostrom, 1990). And **(b)** External monitoring of agreements on supra local levels between the energy hub and the DSO/TSO (Netbeheer Nederland, 2023, p.6). Included in external monitoring is the monitoring of physical conditions of the common pool resource (Namujju, 2024). With the assistance of IT technologies, individual assets and the state of the electricity network are monitored in real-time (El Afifi et al., 2024). This could be described as monitoring grid stability.

5. **Sanctions**, described by Ostrom (2015) and Cox et al. (2010) as graduated punishments for transgressing agreements, while permitting misunderstandings and mistakes that result in infringements (Poteete et al., 2010). This thesis considers **(a)** internal sanctions within the energy hub and **(b)** external sanctions by the TSO, DSO or ACM hub (Ostrom, 1990; RVO, 2024).

6. **Conflict resolution mechanisms**. According to Ostrom (2015), successful management of commons requires low-cost access to local conflict solving arenas. In the case of energy hubs, this research specifically considers the agreements about conflict solving made in established Energy Hubs **(a)** (RVO, 2024). Additionally, it assesses the presence and use of external conflict resolution mechanisms (**b)**.

7. **Recognition and rights to organize**. This principle examines if the right to govern the common pool resource is recognized by external higher authorities (Ostrom, 1990; Namujju, 2024). Further attention is given to the degree of autonomy of higher-scale authorities.

8. **Nested enterprises (Polycentric Governance).** Within this thesis, principle 8 forms a key principle since it considers the polycentricity of the energy hub. A dimension of polycentric governance is the coordination with supralocal developments (Ostrom, 1990) - otherwise described as mutual adjustment - as well as provision and monitoring (design principle 4) (Haryanto et al., 2022) (De Graaf et al., 2024). Furthermore, this principle includes the adaptability and accountability of a polycentric governance system (sanctions and conflict resolution arenas, see principle 5 and 6) (Sovacool 2011, pp. 3840-3841). Other elements of the polycentric governance principle are local action (principle 3), experimentation, trust and overarching rules (principle 7) And will be discussed further in chapter 5.5.

To summarize, principle 8: nested enterprises, encompasses and integrates the majority of Ostrom's design principles.

To assess the effect of the principles on energy commons management in Dutch energy hubs, this thesis will compare empirical findings with the meta-analysis by Cox et al. (2010) which synthetizes a large number of studies on commons management across different sectors.

5.5 Polycentric Governance

Common pool resources that are a component in a larger commons system, such as the national and European electricity grid, are organized in nested polycentric cooperations (see also design principle 8 in chapter 5.4) (Gruby & Basurto, 2013; Goldthau, 2014). In this research, polycentric governance refers to "how people and institutions make and enforce decisions concerning … energy use and electricity supply when jurisdictions and scales overlap. Polycentric forms of climate and energy governance involve multiple scales (local, regional, national, and global), mechanisms (centralized command and control regulations, decentralized and local policies, and the free market), and actors (government institutions, corporate and business firms and civil society …" (Sovacool, 2011, p.3833).

Huitema et al. (2019) emphasize that the independence of centers in a polycentric system does not imply isolation from external actors. In line with this, Kellner et al. (2024) observe that the role of the state - sometimes wrongly equated with monocentric governance - is not to be underestimated in the functioning of polycentric governance systems. This is because the state administers the rule of law and thus facilitates the activation of Energy Hubs or communities (Kellner et al., 2024). In the case of energy hubs, examples are the recent advancements of the energy law, the updates of the energy codes and arrangements between DSOs and a collective of electricity grid users (Dieperink & Bos, 2025; Netbeheer Nederland, 2023).

Key actors in the polycentric governance of energy hubs on business sites, as identified by de Graaf et al., (2024) are: companies, Energy Service Companies (ESCo's, measuring, optimization and maintenance) aggregators (trading electricity or flexibility services on national markets), competent authorities, DSOs and the TSO (Tennet). Since this thesis investigates polycentric governance, and thus multilevel decision-making centers, the Authority for Consumers and Market (ACM) will be included in this list. An overview of actors involved in Energy Hubs is given in table 1, portraying the polycentricity of energy hubs.

Governmental	**System operators**	**Regulator**	**Companies in Energy Hub**	**Private parties**
Competent authorities, being:	TSO	ACM	Companies organized by a juridical entity	Aggregator
a) Municipality	DSO			ESCo's
b) Province				

Table 1: *Actors involved in Energy Hubs (Author, adapted from de Graaf et al., 2024)*

Operationalization

Huitema et al. (2019) have identified five building blocks of polycentric governance systems (table 2). This research will adopt these building blocks as an analytical entry point for design principle 8: nested enterprises (see chapter 5.4).

Proposition		Description
1.	Local Action	Self-organizing governance initiatives
2.	Mutual adjustment	Collaboration of units within PG system
3.	Experimentation	Experimentation and innovation. Learning by doing.
4.	Trust	Trust building is accelerated in self-organizing systems
5.	Overarching rules	PG systems work best when there is an overarching framework

Table 2: *Five building blocks of PG systems, adapted from Huitema et al. (2019, p.21)*

1. Local action concerns the self-organization of the energy hub. This proposition assumes that the most efficient governance response to commons issues will happen at the most local level (Huitema et al., 2019). This proposition is also described as 'institutional fit'. That is, a match between the characteristics of the common and the temporal, geographic and social dimensions of the self-organized solutions (Carlisle & Gruby, 2017). The proposition 'local action' will be examined by analyzing the developed arrangements for commons management.

2. Mutual adjustment: the spontaneous collaboration of units within a polycentric governance system. This means that supra local developments are accounted for in individuals' actions (Huitema et al., 2019). Thereby ensuring that exogenous adaptations, such as legal frameworks or physicals upgrades of the grid, are considered by all involved actors (Huitema et al., 2019).

This proposition is examined by mapping the centers of decision making geographically, jurisdictionally and functionally in line with Carlisle and Gruby's (2017) operationalization:

1. The number of decision-making centers or units
2. The jurisdictional overlap of decision-making centers
3. The functional overlap of decision-making centers
4. Joint decision-making
5. The geographical (scalar) overlap of decision-making centers. Split out in cross scale (vertical) and inter scale (horizontal) overlap.

In the aforementioned dimensions of polycentric governance units, it is important to assess is the role - more specifically the rights and responsibilities - that an actor possesses within the polycentric network (Aligica & Tarko, 2013).

3. Experimentation and adaptation. This dimension investigates how energy hubs, their respective DSOs and ESCos, and ACM carry out parallel experiments in the fields of energy management, governance and institutional approaches. The term 'parallel' emphasizes the multiplicity of policy and governance experiments taking place simultaneously (Jordan et al., 2018). Assessed is how this experimentation is facilitated in the polycentric governance setting by looking at the financial and regulatory support hubs receive and how best practices are converted into propositions for other energy hubs (Huitema et al., 2019). Experimental governance is trialed in a bounded jurisdiction (in this case energy hubs or grid operator service areas) to eventually be scaled up to a higher jurisdiction (Jordan et al., 2018). This 'knowledge sharing' is a widely underscored benefit of polycentric governance (Ostrom 2010, Huitema et al., 2019; Kellner et al., 2024; Jordan et al., 2018; Voß & Schroth, 2018).

4. Trust. Continuous interactions and shared learning processes are attributed to fostering trust between actors in a polycentric governance framework (Huitema et al., 2019, Kellner et al., 2024). Ostrom (2015) theorizes trust, built up by repetitive interactions between problem owners, results in a turn from participants' discount rates from high to low. This reflects a shift from the presumed prioritization of short-term benefits moves to a longer-term view on the collective action problem (Ostrom, 1990).

Trust is measured by studying how trust varies between actors and reviewing the relation between monitoring and trust.

5. Overarching rules. While decision making centers in this framework operate semi-autonomously, an overarching set of standards is needed to settle disputes and facilitate predictability and consistency in adjusting to the actions of other actors and external developments (Huitema et al., 2019). Thus, this proposition reviews the interaction between autonomy and recognition of polycentric networks.

This dimension is operationalized in the aspects: recognition of the self-governing body (energy hub) and its activities regarding the management of the common, external monitoring, conflict resolution mechanisms and sanctions. This operationalization can also be recognized in design principles 4 to 8 (see chapter 5.4).

6. Conceptual Model

The theoretical framework outlines the theories of common pool resource management and polycentric governance and defines this thesis's understanding of energy hubs. Based on this framework the following conceptual model has been designed (figure 1).

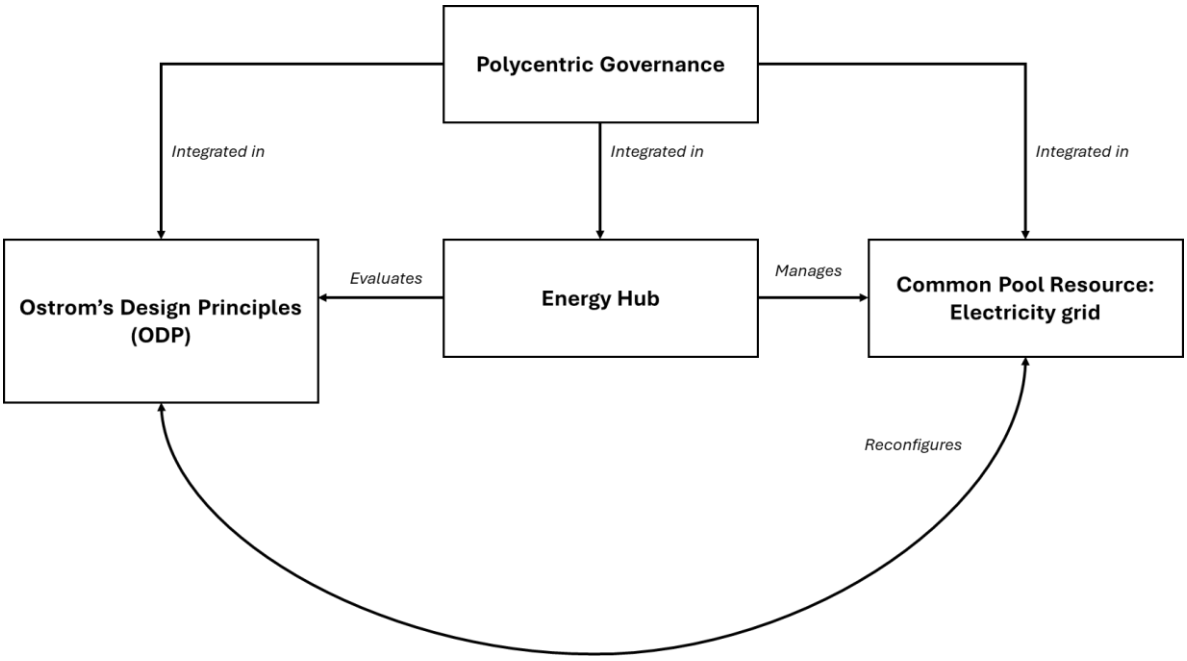

Figure 1: *Conceptual model of Thesis (Author)*

The common pool resource - the electricity grid - is governed by an energy hub in a polycentric governance system. Because the electricity grid operates across multiple jurisdictions and scales, decision-making on managing the electricity commons is decentralized among various independent decision-making centers involving public, private, and regulatory actors at different levels. This polycentricity is practiced within the energy hub. Ostrom's design principles (as operationalized in chapter 5.4) of managing common pool resources are integrated into the energy hub's cooperation agreements, decision-making, monitoring, sanctioning and conflict resolution arenas. Moreover, the right to govern is recognized by higher authorities and these principles are practiced in the energy hub in a polycentric setting.

To explore the manifestation of these theoretical concepts in empirical settings, this thesis discusses the following sub questions, that each can be linked to the model:

1. Sub question 1 scrutinizes the operational characteristics of energy hubs, signified by 'Energy Hub' in the conceptual model.
2. Sub question 2 analyzes the governance structures of energy hubs on industrial parks, identified as 'ODP' in the conceptual model.
3. Sub question 3 investigates how energy hubs interact with supralocal actors in a polycentric governance framework, indicated by 'Polycentric Governance'
4. Finally, the arrow that loops back from Common Pool resource to ODP is research question 4: how do energy hubs relate to Ostrom's design principles.

7. Methodology

This chapter explains the research design of the thesis. It entails a description and discussion of relevant research methods, data collection, sampling methods, a case selection strategy and data analysis.

7.1 Research Design

The research objectives of this thesis are to contribute to a better understanding of polycentric governance principles that are being exercised in existing energy hubs in the Netherlands and to make an adaptation of Ostrom's principles. Energy hubs and supporting legislative structures have emerged relatively recently, meaning this thesis is of an exploratory kind. Rule (2024) describes how a case study fits this exploratory character.

Energy hubs and polycentric energy governance possess a complex and dynamic character, for which a case study can be a suitable method (Spooner & Myres, 2024). This thesis chooses a collective (multiple) case study, focusing on three cases. It is important for a case study to have a sound boundary of observation that decides which cases are included, and what factors are relevant for the case study (Cresswell, 2007). Section 6.1 about Energy Hubs provides this boundary. Additional criteria can be found in chapter 7.4.

In a multiple-case study, it is common to first do a *within-case study* (Sub question 1), before doing a *cross-case analysis* (Sub question 2 and 3), to finally present *assertions* about the cases (Sub question 2 and 3) (Cresswell, 2007). Cross-case analysis can help build new propositions of frameworks (Vohra, 2024), as is the aim of this study. To enhance readability, the within-case and cross-case structure is applied per subchapter instead of presenting three separate case studies.

To further analyze the results of the data gathered within the cases, and to answer sub question 4, this thesis will take Ostrom's commons management design principles as a framework, and then using abduction, extend the framework or possibly reject or rewrite the framework, applied to energy commons (Spooner & Myres, 2024).

7.2 Data Collection

This thesis utilizes multiple sources of data, starting in the research proposal with scientific literature regarding energy hubs, smart grids, polycentric governance and grid congestion measures. This was supported by grey literature, consisting of policy documents, research reports and legal documents. To answer the research questions, primary data will be gathered using semi structured interviews. For this, an interview guide will be designed based on the theoretical framework to assist the interviewing process while ensuring the interview will not be guided too much to ensure a 'natural flow' (Spooner & Myres, 2024). To enrich the collected sample, additional non-interview data will be gathered such as policy documents and reports, enabling a detailed description of the cases (Spooner & Myres, 2024).

7.3 Sampling Methods

This section describes the case sampling method, case selection criteria and the respondents sampling strategy that will be used in this thesis.

7.3.1 Sampling Method

To select cases for this thesis, a maximum variation sampling strategy will be used to generate contrasting characteristics and conditions of the research unit while simultaneously allowing for finding common patterns (Teddlie & Yu, 2007). This case selection strategy enables a cross-case analysis (see chapter 7.1) by incorporating a 'compare and contrast strategy' (Teddlie & Yu, 2007, p.81). The execution of this thesis 'maximum variation sampling strategy is provided in chapter 7.4. Due to time constraints, the thesis will focus on three energy hubs on business sites.

7.3.2 Respondents Sampling Method

The selection of interviewees will be done through purposive sampling, Purposive sampling is "intentional selection of informants based on their ability to elucidate a specific theme, concept, or phenomenon." (Michalos & Robinson, 2014, p. 5243). To start the exploration of each specific energy hub, a key individual, for example the park manager, is identified (de Graaf et al., 2024). Consequently, through purposive sampling, additional stakeholders were identified that can provide insights into the dimensions of the eight design principles that have not been sufficiently covered yet (Michalos & Robinson, 2014). Data collection of each case consists of at least one key individual from the energy hub and a representative of the respective DSO. Representatives of Tennet and ACM will be interviewed to clarify the governance of energy commons on a supra local scale.

Table 3 presents the interviewed stakeholders and their respective functions as well as the duration of the interview.

Name	Function	Duration interview (mins)
ECAH-A	Stakeholder Manager	60
ECAH B	Chair of Port Authority and ECAH	60
Lage Weide-A	Initiator Energy Hub	60
Pannenweg-A	Initiator Energy Hub	60
Liander-A	Energy Hub Coordinator	45
Liander-B	Energy Transition Consultant	45
Stedin-A	Regional Manager	30
Enexis-A	Stakeholder Manager	45
TenneT-A	Program Manager Congestion Management	30
ACM-A	Project Leader Congestion Management	30

Table 3: *Interviewed respondents*

7.4 Case Selection Strategy

To ensure variation of cases, energy hubs were selected based on varying sizes of participating organizations, various types of companies on the energy hubs and a variety of legal constructions utilized within the energy hubs. Another selection criterion was the severity of grid congestion in the area. For example, in the Flevopolder, Gelderland and Utrecht, additional coordination with TSO TenneT is required since energy hubs might influence the grid stability beyond the scale of the hub (RVO, 2024). A general criterion for the selection of cases is the operational state of the energy hub, which has to be in the exploitational phase (RVO, 2024). Cases that are still in the explorational, design, or negotiation phase are not selected as cases for this research.

7.4.1. Selected Cases

The Energy Hub in the port of Amsterdam: Energie Coöperatie Amsterdamse Haven or ECAH, is included in this study because of the type of industrial activities and the fact that it is situated on a major seaport is expected to result in significant energy usage. Another inclusion determinant is the number of participants, with 28 being relatively high. Furthermore, this energy hub is an analytically relevant because of the geographical size of the hub and the multiplicity of energy usage agreements (*Collectief- capaciteitsbeperkende contracten*, C-CBC's) with DSO Liander, implying that there are multiple energy hubs in the Port of Amsterdam. This multiplicity adds an extra layer of polycentricity.

Energy Hub Lage Weide was included because of the use of a Groepstransportovereenkomst or Group Transport Agreement, later (GTO). The types of industrial activities form another interesting aspect of Energy Hub Lage Weide. Finally, the fact that Energy hub Lage Weide has a relatively small number of participants, yet the participants are individually of significant scale, making this hub suitable for analyzing high intensity actors in a compact network.

Pannenweg II hosts relatively light industry, small and medium sized enterprises (SME) and services, and is therefore significantly different to the other selected cases in terms of business activities and energy consumption. Furthermore, a different consumption pattern is presumed due to these business activities. Finally, Pannenweg II is unique in relying on existing legal possibilities or cooperating and trialing local energy management with the DSO. Instead, the energy hub independently developed solutions outside of formal frameworks, assisted by an ESCo. in a pilot but rather fixing the issue outside of existing tools and measures that are available. Furthermore, generated solar energy is shared from peer to peer within the energy hub.

7.5 Data Analysis

To analyze the data, cross case synthesis will be used. The characteristics of individual cases are connected into relationships that describe similarities and differences (Vohra, 2024). Tabulations and graphs will be produced to showcase linkages and dissimilarities (Vohra, 2024). This process will be led by an abductive approach that stresses the redevelopment of theories rather than solely testing theories as in deductive approaches (Dubois & Gadde, 2002).

Practically this means the original framework could be redirected through the course of the study based empirical findings. When doing abductive analysis, it is important to write down a detailed clarification of readjustments (Dubois & Gadde, 2002, p.558). The coding of qualitative data also follows an abductive approach. First a broad codebook is generated based on polycentric governance and Ostrom's design principles. This is applied to the data, resulting in researcher familiarization with the content (Vila-Henninger et al., 2024). Second, new codes are inductively drafted from the studied data, enriching and restructuring the initial code groups (Vila-Henninger et al., 2024). Third, the transcripts are revisited again using the redrafted codebook to study the content using a different theoretical lens, a process called alternative casing (Vila-Henninger et al., 2024, p.977). Since in this thesis polycentric governance is embedded in the broader design principles, initial coding is focused on Ostrom's design principles.

The evolving framework directs the search for empirical data. Dubois and Gadde (2002, p. 555) further find that: "Empirical observations might result in identification of unanticipated yet related issues that may be further explored in interviews or by other means of data collection", *w*hich is in line with chapter 7.3.2. which describes how additional data will be collected based on the gaps of earlier interviews.

The rationale for opting for abductive analysis rather than a deductive one, is that deductive analysis risks becoming constrained by the adopted frameworks (Brinkmann, 2014). Concludingly, the exploratory nature of this thesis and the research topic calls for the identification of new dimensions and concepts while taking the initial theory as a starting point. For this purpose, abductive analysis is a well-suited tool (Dubois & Gadde (2002, p.555).

8. Case Description

This chapter described the cases that have been studied in this thesis. The aim of this section is to provide background information on the history and activities in the selected industrial parks, ambitions of the industrial parks, as well as exogenous and endogenous pressures on the parks.

8.1 Energiecoöperatie Amsterdamse Haven

The Energy Hub in the Port of Amsterdam is formally organized in the *Energiecoöperatie Amsterdamse Haven.*

The Port of Amsterdam, more specifically *Westpoort* on the west of Amsterdam is the second largest Dutch port after Rotterdam. The harbor is a hub for the transshipment of whole stock resources, (bio)fuels, logistics and small- and medium sized enterprises (SMEs) (ECAH-A personal communication, 2025; Van den Berghe et al., 2023). Originally, Amsterdam's docks were nearer to the city center, and later on the Oosterdokeiland, east of the city center. After the construction of the IJ Canal in 1876, the ports subsequently started moving westwards. The latest, most westward development is the Afrikahaven, completed in 2001 (Van den Berghe et al., 2023).

The port's ambition is to be climate neutral in 2050, implying net zero emissions. Part of this strategy is the phasing out coal by 2030 (Port of Amsterdam, 2024). The vision document further states that current business activities will be supplemented by circular economy (waste and rest materials). Additionally, infrastructure for hydrogen and electric shipping will be developed (Port of Amsterdam, 2024). The port is selective in the establishment of companies due to the limited availability of terrain (Port of Amsterdam, 2024). In 2013, the development, management and exploitation of the Port has been privatized in the public limited company Port of Amsterdam, in which the municipality is the only shareholder (Port of Amsterdam, N.D).

The vision documents for 2040 and 2050 had to be approved by the municipality and the supervisory board of Port of Amsterdam (Port of Amsterdam), In Westerpoort, land is given out by the Port of Amsterdam in a ground lease construction which allows for steering towards collective goals such as becoming a Net-Zero port in 2050 (Port of Amsterdam, 2024; ECAH-A personal communication, 2025). Other mechanisms that stimulate greener business operations are EU Carbon taxes (ECAH-A, personal communication, 2025).

Becoming climate neutral in 2050 implies electrification of industrial and logistical processes. However, grid congestion in Westerpoort is severe (Liander-B, personal communication), as further discussed in chapter 9.1. The impossibility of upgrading individual grid connections could mean companies' future will be elsewhere (ECAH-A personal communication, 2025). However, relocating is a costly operation (ECAH-A personal communication, 2025). Additionally, new companies cannot be connected to the grid by DSO Liander (van Dijk et al., 2025; Liander-B, personal communication, 2025). These pressures have resulted in cooperation on the theme of energy in the port, and eventually into the establishment of Energiecoöperatie Amsterdamse haven (ECAH).

Stakeholders on the Energy Hub are the members of ECAH, Port of Amsterdam, Liander, the Municipality of Amsterdam, partly through the Port of Amsterdam (ECAH-A personal communication, 2025). In lesser extent ECAH cooperates with TenneT. The project is financially supported by Rabobank and the port of Amsterdam. Other partners include Noordzeekanaalgebied, Rijksdienst voor ondernemend Nederland (RVO, Netherlands Enterprise Agency) and knowledge pacts with other energy hubs (ECAH-A personal communication, 2025).

8.2 Energy Hub Lage Weide

The largest industrial park of the province of Utrecht, Lage Weide stretches 308 hectares and hosts logistics, construction, utilities, food and IT companies. The specific section that makes out the energy hub hosts construction, food and logistics. Similar to *Westerpoort*, the industrial terrain was established after the construction of a canal, the Amsterdam-Rhine Canal in the late 19th century. (Lage Weide, 2020)

Lage Weide has set goals for 2030: reducing energy consumption through retrofitting and behavior changes by 40 percent and generating 50 percent of the total final energy consumption on site by utilizing available roofs for solar panels. (Hartkamp, 2024). However, in 2021 the park manager of Lage Weide identified that the limits of the grid could become an obstacle for expansion and electrification of business operations in Lage Weide:

"I believe that on this industrial site, security of supply and affordability of energy will be crucial for now and the coming years"

(Lage Weide-A, personal communication, 2025).

Consequently, Lage Weide started measuring energy consumption and production patterns of 19 companies in 2022 to identify the potential of establishing an organization in which energy and grid capacity can be shared (Lage Weide-B, 2025). Lage Weide also surveyed future plans of these companies to estimate the accumulated demand for grid capacity. Later, the province, DSO and TSO were involved in supporting the organization of the energy hub. An arrangement was made with the technical consultancy company Groendus for measurement and energy management. The result of the feasibility study concluded that a hub on field 19 with 5 companies - Stiho, Van Heezik, Picnic, Platra and IJzervoort - was viable (Hartkamp, 2024).

8.3 Energy Hub Pannenweg

De Pannenweg is a relatively newly developed business park in the municipality of Nederweert in Limburg. Establishing companies are required to become members of the park management cooperation Pannenweg (Gemeente Nederweert, 2012).

The business park has signed a covenant to share knowledge, reduce energy consumption and install more renewable energy sources. Pannenweg II has been asked by the municipality of Nederweert to install solar panels on all their roofs. With this request, the municipality of Nederweert aimed to optimize space needed for energy generation and prevent the usage of agricultural soil for land intensive solar fields (Pannenweg-A, personal communication, 2025). De Pannenweg's efforts to install solar panels on businesses were however halted by Enexis due to grid congestion in the area, limiting possibilities for feeding solar power into the grid (Pannenweg-A, personal communication, 2025).

The site took autonomous action by setting up a project team of technical experts that installed measurement systems to monitor energy patterns in high frequency (Pannenweg-A, personal communication, 2025). The electricity is traded on an energy trading platform and is managed by an energy management system, virtually bypassing grid congestion. (Pannenweg-A, personal communication, 2025).

Table 4 sums up the characteristics of the selected hubs for this research.

Case	Energiecoöperatie Amsterdamse Haven	Energyhub Lage Weide	Energyhub Pannenweg II
Foundation industrial Park	Late 19th century (on this location)	Late 19th century	2012*
Initiation energy hub	2022	2022	2022
Start operations energy Hub	2024	2024	2024
N companies on park	1710	2282	53
N companies in energy hub	29	5	45 peer 2 peer 15-17 GTO
Types of companies	Heavy industries, bulk resources, (bio)fuel, logistics	Food, manufacturing, logistics	Manufacturing, light industry, services
Juridical entity of energy hub	Energy cooperation	Energy cooperation	Park management (cooperation) and private company
DSO	Liander	Stedin	Enexis
Agreement with DSO	C-CBC	GTO, C-CBC with TenneT	GTO

Table 4: *Case characteristics*

**Business activities were happening on de Pannenweg before 2012. Since 2012, most of the parcels have been developed and since this 2012 land use plan, establishing companies are obliged to become a formal member of park management de Pannenweg (Gemeente Nederweert, 2012).*

9. Results

This chapter presents the results of data collection and analysis and subsequently answers the sub questions. Section 9.1 starts with a description of the operational processes on the energy hubs, using a techno-economic lens. Section 9.2 provides an assessment of internal governance practices. Section 9.3 discusses external decision-making dynamics and polycentric governance. Sections 9.1, 9.2 and 9.3 are all concluded with a set of sub conclusions.

Section 9.4 provides a reflection on the functioning of the commons and their enabling or limiting conditions for energy commons management. Because of this setup, principles are discussed in a nonlinear manner, meaning they do not follow the original sequence of Ostrom's design principles. Table 5 summarizes the places where principles will be discussed.

Design principle	Operationalization	Discussed in
1. Clearly defined boundaries	a) Physical boundaries	9.1
	b) Social boundaries	9.2
2. Congruence	a) Harmony of appropriation and provision	9.2 and 9.3
	b) Proportional cost/benefit allocation	9.2
3. Collective action agreements	a) Data sharing agreement	9.2
	b) Collective ownership	9.1 and 9.2
	c) Collective investments	9.1
	d) Opting in and out	9.2
	e) Collective choice agreements	9.2 and 9.3
4. Monitoring	a) Internal monitoring	9.2
	b) External monitoring	9.3
5. Sanctions	a) Internal sanctions	9.2
	b) External sanctions	9.3
6. Conflicts resolution arenas	a) Internal conflict resolution arena	9.2
	b) External conflict resolution arena	9.3
7. Rights and recognition	Rights and recognition	9.3
8. Polycentric governance	Polycentric governance	9.3

Table 5: *Ostrom's design principles and corresponding chapters*

9.1 What are the operational characteristics of energy hubs on industrial parks in the Netherlands?

This research question serves the purpose of identifying the physical assets of the energy hubs, as well as network topology and the level of integration with the regional and national grid. This chapter opens with a comparison of grid topologies and interconnections with higher grid levels after which the severity of grid congestion is assessed per case (principle 1: clearly defined physical boundaries). Subsequently, the hub's assets for energy monitoring, generation and storage are compared (principle 3c: agreements on collective investments). Third, agreements on ownership and investments are discussed (3b and 3c). Finally, cross-case differences are highlighted, and sub conclusions are provided.

9.1.1 Grid Topology

This section compares the grid topology between cases. Grid assets data was obtained from the TSO and DSOs' websites (Liander, N.D.; Stedin, N.D.; Enexis; N.D.; TenneT-F, N.D.). The data was processed using ArcGIS Pro, after which the author added additional context. After presenting the geographic topology, the grid situation is further interpreted and compared in chapter 9.1.2.

The port of Amsterdam is connected to the national grid through one converter station from TenneT: Hemweg 150 (HW150). From there the grid is subdivided into lower voltage connections from Liander. Excepted from this is substation Ruigoord which is linked to the national grid through 180 KV station Vijhuizen in the bottom-left corner of figure 2. For this energy hub, relevant substations are from west to east: Ruigoord, IJpolder and Westhaven, indicate by yellow dots. These yellow dots mark substations on which a collective capacity limiting contract (C-CBC) is effectuated. Further symbology is explained in figure 3.

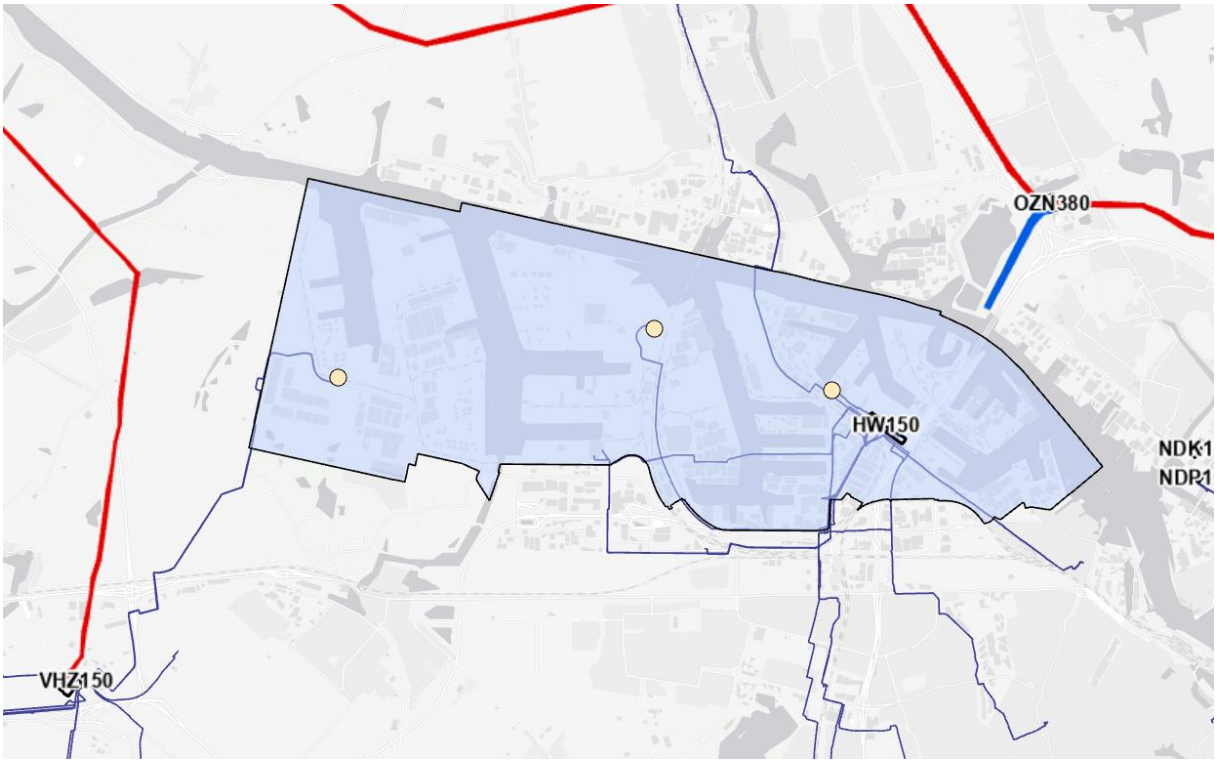

Figure 2: *Grid topology of the Port of Amsterdam and Energiecoöperatie Amsterdamse Haven (author)**

** Not all parts of the regional grid (<50 kV) are displayed to support the readability of the map.*

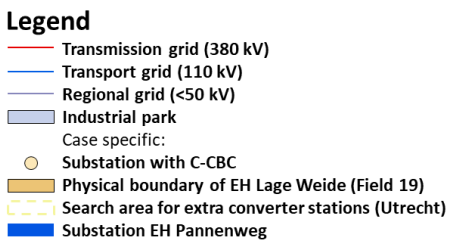

Figure 3: *Legend for the grid topology maps of each case (figure 2, 4 and 5) (author)*

Lage Weide

Figure 4: *Grid topology of Lage Weide (author)*

Energy Hub Lage Weide (figure 4) is operational on 'field 19' indicated in orange. This implies that the companies on field nineteen are connected to the same grid loop and are therefore able to share this part of the grid (Lage Weide, personal communication, 2025). The hub is connected to the national grid through 150 kilovolt sub station 'Utrecht Lage Weide'. This grid segment's stability depends significantly 380 KV and 150 KV stations Breukelen Kortrijk, situated 8 kilometers northwest of the industrial park (Tennet-B, personal communication, 2025). Both Breukelen-Kortrijk stations form a significant bottleneck in this service area (TenneT-A, personal communication, 2025; Lage Weide-A, personal communication, 2025; Stedin-A, personal communication, 2025). Furthermore, the higher voltage transport grid is related to substation Soest, which in turn is connected to large scale wind parks in Flevoland (Stedin-A, personal communication, 2025).

This illustrates a major supra provincial challenge of this particular pocket of the national grid; the FGU-pocket (Flevoland, Gelderland, Utrecht). The higher voltage grid in these provinces is interconnected, with no separate pockets in place to ensure stability (TenneT-A, personal communication). Besides, the region is characterized by a geographic variety of consumption, usage and flexibility potential, with substantial wind production in Flevoland, a high concentration of residential areas in the province of Utrecht and relatively little industry, meaning relatively little potential for flexibility measures (TenneT-A, personal communication). The layout and connections of the FGU-pocket result in a waterbed effect. Electricity follows the path of least resistance and therefore overloading one station does not result in alleviating affects from bypasses or other substations (TenneT-B, personal communication, 2025).

Aside from station upgrades at Breukelen-Kortrijk, among other locations, TenneT is working on subdividing the FGU pocket into smaller pockets (TenneT-B, personal communication, 2025).

Relevant for Lage Weide apart from the developments at Breukelen Kortrijk are two new stations in Utrecht Noord by both TenneT and Stedin and a new station at Amersfoort Noord by Stedin. The initial search area of the Utrecht Noord stations is depicted by the yellow dotted line. Theoretically, following these upgrades, Lage Weide will no longer be affected by grid congestion (Stedin-A, personal communication, 2025). TenneT recently announced a minimum four-year delay for the grid upgrades in Utrecht Noord, caused by difficulties in the acquisition of land (TenneT-D, 2025).

Figure 5*: Grid topology of Energy Hub Pannenweg (author)*

Energy hub Pannenweg (figure 4) consists of two fields, making up a ring which is connected to the distribution station indicated in dark blue. The hub is situated in the middle of Limburg. Different to the FGU region, Limburg's grid consists of one pocket, stretching from Boxmeer (Noord-Brabant) to the south of the province. In execution of TenneT's strategic directive to divide the national grid into 40 smaller pockets, Limburg's grid will be split into three parts from north to south, respectively served by high voltage stations: Boxmeer, Maasbracht and Graetheide (TenneT-A, n.d.; TenneT-B, N.D.; TenneT-E, N.D.). 150 KV station Nederweert is first linked to 150 KV station Bugennum and then to Maasbracht. Westwards, the connections are laid out in the direction of 150 KV station Maarheze and later 380 KV station Eindhoven). For grid congestion to be alleviated in this segment, a new substation in Maasbracht, Graetheide and a connection between them must be developed, as well as an extra high voltage lines from Maasbracht to Eindhoven (Tennet, 2025).

9.1.2 Level of Grid Congestion

To assess the severity of grid congestion, table 6 compares the individual requests for distribution (inwards and outwards), the associated capacity and the time needed for the TSO and DSO to expand the substations. A distinction is made in waitlists for supplying electricity to the grid (feed-in) as well as taking electricity from the grid (consumption). In this table, an upgrade is defined as being sufficient to tackle bottlenecks in the respective service area. Complete alleviation of congestion can depend on stations further upstream.

Substation	Consumption waiting list (MW)	Feed-In waiting list (MW)	Planned DSO consumption upgrade completion	Planned DSO feed-in upgrade	TSO upgrade completion
Port of Amsterdam/ ECAH					
Ruigoord 10-1i	10.9	/	2033	/	2036
IJpolder 10-4i	38	/	2027	/	2036
Westhaven 10-1i	20.7	/	2027	/	2036
Westhaven 10-2i	12.4	/	2027	/	2036
Basisweg 10-1i	21.2	/	2028	/	2036
Energy Hub Lage Weide					
Lage Weide	19.1	18.1	2034	/	2033
Pannenweg Nederweert					
Nederweert	20.2	37.4	2023	2023	2032-2034

Table 6: *Comparison of grid congestion and planned upgrades All data adopted from Netbeheer Nederland Capaciteitskaart (13 may, 2025)*

Cross-case comparison of grid congestion

The extent to which the selected energy hubs experience grid congestion differs. This is influenced by the complexity of the grid and the interdependencies. Understanding how the grid is built up is needed for insight into this. The Dutch electricity grid consists of 4 hierarchical layers that interact with each other, ranked from higher to lower voltage (van Oirsouw, 2012):

1. The transmission grid serves as an interconnector with European grid and transports electricity generated by central power plants. In figure 2, 4 and 5 this grid is indicated by a red line.
2. The transport grid or sub transport grid serves as a link between transmission and regional distribution and serves as provincial network. In figure 2, 4 and 5 this grid is indicated by a blue line.

   The first two levels in the hierarchy are operated by TenneT, the transmission system operator.

3. The regional distribution grid, fed by transport grids, holds decentral electricity generation such as wind energy and industrial consumers. In figure 2, 4 and 5 this grid is indicated by a purple line.
4. Local distribution grids distribute the energy on smaller connections.

These grids operate on different voltages and stations are in place to convert electricity flows between different voltage levels and grids (Oirsouw, 2012).

The port of Amsterdam predominantly experiences congestion on the consumption side. However, electricity feed-in cannot easily be added due to bottlenecks upstream on the transport grid and transmission grid in Noord-Holland.

Lage Weide experiences both consumption and feed-in congestion. In addition, the pocket FGU makes it such that cascading effects happen, making the FGU pocket severely affected by congestion issues (TenneT-A, personal communication, 2025; Stedin-A, personal communication, 2025)

The Nederweert sub-pocket, part of Enexis' Limburg service area is facing lengthy waiting lists from the DSO and TSO. TenneT's first announcement of grid congestion was in Brabant and Limburg in medio 2022 (TenneT-A, personal communication, 2025). Still, TenneT recently announced grid extensions in Limburg are expected to be delayed by a maximum of two years, showing the prospective dates of completion are prone to delay, mainly due to planning and permit procedures, as observed earlier by Winkel et al., (2024).

Solutions for grid congestion

Apart from grid expansions, distribution system operators and transmission system operators advocate for a continued flexible approach to utilizing grid capacity:

You don't enter a group contract (GTO) for temporary purposes. That's not the intention (…) we really want them to continue using the network flexibly. Because that's much better than just having overloaded networks at peak times.

(Enexis-A, personal communication, 2025)

A respondent from TenneT sees the role of energy hubs as local solutions for energy generation and usage of strategic importance in relation to grid extensions:

That would of course be brilliant, because then the large electricity network will no longer be the aorta, but that will actually become the back up (…) in times of need. That would be by far preferable, and that could save a lot of money.

(TenneT-A, personal communication, 2025).

Furthermore, the optimization of current grids could reduce costs and the spatial footprint of grid extensions (TenneT-A, personal communication, 2025). Moreover, grid expansions are extensive processes with obstructions related to land acquisition and community resistance (TenneT-A, personal communication, 2025). As illustrated earlier in the case of Utrecht and Limburg.

9.1.3. Finances

The scrutinized hubs in this thesis received a variety of national subsidies meant for innovation, as well as funding from the Rabobank (ECAH-B, personal communication, 2025; Lage Weide-A, personal communication, 2025; Pannenweg-A, personal communication, 2025). The hubs have mainly used these funds to establish the organization of the hub and to develop an energy management platform. Subsidies and external funding are expected to remain intact until the hubs obtain a sufficient financial position to sustain operations. However, mother organizations such as the port of Amsterdam or the hubs themselves finance some of the operational costs (ECAH-B, personal communication, 2025).

The port company invests time and money in it, for example through me. And it has also borne other costs in the past, until the moment comes that the Energy Cooperative itself has sufficient resources and members, to cover its costs.

(ECAH-B, personal communication, 2025)

Other assets such as a real-time meter are sometimes financed by the participating companies. *(ECAH-B, personal communication, 2025; Lage Weide-A, personal communication, 2025; Pannenweg-A, personal communication, 2025).* Interestingly, the participants of Lage Weide have all contributed through the form of human resources and specialist knowledge, demonstrating that apart from regarding energy as a common good, collective expertise is also treated as a common:

… we eventually also said: we don't know exactly how to do it, but who has the experts within their own organization who can help us take steps forward?

(Lage Weide-A, personal communication, 2025).

Responding to this request, the energy hub's participants provided in-house specialists on the domains of energy, finance as well as legal expertise and a notary (Lage Weide-A, personal communication, 2025). This illustrates that commons cooperation on a certain theme can lead to other cooperative approaches to development.

Chapter 9.2 will further discuss cost benefits allocation.

9.1.4. Assets

ECAH relies on companies' individual assets for energy generation, consumption and storage.

We prefer for assets to be owned by the companies. Otherwise, de facto you will become the owner of a battery with forty people. This adds another responsibility for the assets. We suffice with ownership at other parties. Possibly we could get assets ourselves later, but this is not the preferred scenario.

ECAH-A, personal communication, 2025.

This contrasts to de Pannenweg's recent installation of collective owned batteries (Pannenweg-A, personal communication, 2025). This investment is enabled by the hub's BV entity which is suited for making collective investments. Energy hub Lage Weide is currently not planning to do collective investments and focuses on day-to-day operations of the energy hub Lage Weide, personal communication, 2025).

ECAH's energy generation (solar, wind and gas power plants) is owned and exploited by businesses in the Port of Amsterdam (ECAH-A, personal communication, 2025). Energy hub Lage Weide resorts to company owned solar panels and electricity supplies by the distribution network (Lage Weide-A, 2025). Individual companies are researching the possibility of adding gas powered back-ups to stay within the bandwidth of the GTO (Lage Weide-A, personal communication, 2025).

9.1.5 Sub Conclusions

Sub question 1: *What are the operational characteristics of energy hubs on industrial parks in the Netherlands?* investigates the physical boundaries of the common pool and the techno-economical operations within these boundaries, executed by the energy hubs.

Ostrom's design principle 1: clearly defined boundaries, is not the decisive factor in energy hubs' addressing of the commons dilemma. The grid is complex due to interconnectedness and upstream interdependencies. As described in the theoretical framework: the electricity grid is a component in a larger commons system and therefore requires embedding in supralocal governance structures (chapter 9.3). Hence it cannot be said that the physical boundaries of the hub are very distinct.

For grid congestion to structurally be alleviated, energy hubs depend on DSOs and TSO. Yet, with the general energy system becoming increasingly decentralized and fluctuating, experts argue grid congestion is here to stay, rendering flexibility from consumers, producers and grid operators a necessity.

Observing the local grid within energy hubs as a common resource, its physical characteristics are subject to change due to station and network upgrades, as well as the potential opting in and out of companies within the hubs. While not the immediate priority yet, DSOs indicate that upgrades must align with the groups formed through the establishment of energy hubs (Stedin-A, personal communication; Liander-A, personal communication; Enexis-A, personal communication-B). Careful additional research is required when future upgrades will be implemented to assure the continuity of the energy hubs.

In terms of ownership and collective investments, energy hub Pannenweg stands out in collectively owning assets. This is partly due to the juridical form of this energy hub is a limited company (BV).

9.2 What are the governance structures of energy hubs on business parks in the Netherlands?

This research question identifies the cooperation agreements, legal arrangements and involved parties within energy hubs. Therefore, this section also addresses the social boundaries of the common pool resource (design principle 1). Related to the social boundaries are agreements on opting in and out of the energy hub (principle 3d). Subsequently, collective choice agreements (principle 3e) or internal decision making is analyzed. This chapter further focuses on design principle 2: congruence, rules and local conditions. And finally assesses the cluster of principles: monitoring, internal sanctions and dispute resolution within the energy hub (design principles 4, 5 and 6), after which sub conclusions are drawn.

9.2.1 Social Boundaries

Juridical entities

Energie Coöperatie Amsterdamse Haven is organized in an energy cooperation. The cooperation can strive towards a general commercial benefit. In this case of ECAH this benefit is reducing electricity costs (ECAH-A, personal communication, 2025). A limited company construction is specifically not chosen because of the relatively rigid opt-in-and-out structures (ECAH-B, personal communication, 2025).

ECAH's highest decision-making body is the board, consisting of two industrial representatives and one individual from the Port of Amsterdam. A general member meeting is in place for decision making within the energy hubs. Within this, the board holds the highest mandate (ECAH-B, personal communication, 2025). Opting out includes a mandatory waiting period before effectively opting out. It is possible for new parties to enter ECAH. Becoming a member of the cooperative takes relatively little effort. However, participating in one of the contracts in the port between ECAH and DSOs requires a reiteration of calculation of the collective energy profile by the DSO (Liander-A, personal communication). Furthermore, the new party opt-in must fit in accordance with statutory agreements of ECAH (Liander-A, personal communication; ECAH-B, personal communication, 2025).

Energy hub Lage Weide emerged from a collaboration between Energie Coöperatie Utrechtste Bedrijven (ECUB) and park management Lage Weide (ILW) (Lage Weide, 2024). The hubs' social boundaries have been shaped and constrained by different factors. First: grid topology, companies must be connected to the same field of the grid (Stedin-A, personal communication, 2025). Second, flexibility potential on the prospected grid is of fundamental importance. In the case of this hub, flexibility is provided in the form of a cold store that can regulate the temperature and hence the energy input (Stedin-A, personal communication, 2025). Third, the desire to minimize investments (Lage Weide-A, personal communication, 2025). In cooperation with Stedin, 5 companies on field 19 were deemed most promising to form an energy hub (Lage Weide-A, personal communication, 2025; Stedin-A, personal communication, 2025). These five companies on field 19 formed an energy cooperation: Energy Management Coöperatie Utrecht, so a GTO could be agreed upon (Lage Weide-A, personal communication, 2025).

A key component in this hub is a freezing cell of which the temperature and hence the power input can be regulated, allowing for balancing between the limits of the GTO with Stedin (Lage Weide-A, personal communication, 2025; Stedin, personal communication, 2025). The case of Lage Weide illustrates how energy the physical boundaries and characteristics of energy commons are a critical determinant of who can be part of the energy hub, or in terms of Ostrom: the social boundaries of the common.

Stepping out of energy hub Lage Weide comes with a minimum opt-out phase of one year. The hub is currently working out how to treat possible new participants (Lage Weide-A, personal communication, 2025). The investments by frontrunner parties in time and effort are significant. Also, a critical look is needed into the profile of candidate members since more members add technical and organizational complexity (Lage Weide-A, personal communication, 2025).

At de Pannenweg, all companies on the terrain were automatically members of the business park cooperation, following the conditions of the location plan. Under this cooperation of 107 members are two groups: 47 members are part of the 'self-livery plus program', implying this group distributes self-generated solar power to grid neighbors, otherwise known as EAN-to EAN (Pannenweg-A, personal communication, 2025). A group of 15 to 17 companies will participate in the yet to be effectuated GTO with Enexis (Pannenweg-A, personal communication, 2025.

In case of new entrants into the GTO with Enexis, similar to the situation in Utrecht, the bandwidth has to be recalculated (Enexis-A, personal communication, 2025). The current proposal of the GTO includes a transitional phase of three years (Enexis-A, personal communication, 2025; ACM, 2025). When a party exits the agreement, it is up to the energy hub to redistribute costs and grid space (Enexis-A, personal communication, 2025).

Stakeholders and formal participants

Internal stakeholders

There is an important distinction between being part of the energy cooperation and participating in the Energy Hub's of ECAH.

"… a cooperative is not much more than like-minded people with the same problems coming together around a possible solution. And then you go on to see whether it's possible for companies to collaborate in sharing that common"

ECAH-B, personal communication, 2025

Moreover, ECAH currently has three C-CBCs on the substation Ruigoord, IJpolder and Westhaven, and is currently investigating the possibilities of a GTO and cable pooling (ECAH-A, ECAH-B, personal communication, 2025). According to this thesis' interpretation of an 'energy hub', the Port of Amsterdam is an Energy Hub, in which three smaller hubs are active.

At Lage Weide and Pannenweg, smaller groups within cooperative entities can also be identified (Lage Weide-A, Pannenweg-A, personal communication, 2025). Following this thesis definition of the term energy hub, these smaller groups, with a contract between the hub and the system operator or with an energy sharing contract, are observed as energy hub in this thesis.

External stakeholders

All the studied energy hubs indicate to share knowledge with a variety of (semi) governmental bodies (ECAH-A, personal communication, 2025 Lage Weide-A, personal communication, 2025 Pannenweg-A, personal communication, 2025). On a formal basis, a variety can be identified of the involvement of competent authorities in the energy hubs. No government entity is formally part of energy hub Lage Weide (Lage Weide-A, personal communication, 2025). Given the municipality of Amsterdam's 100% ownership of the Port of Amsterdam, and the Port of Amsterdam's position - albeit a minority position - in ECAH's board, it could be said that the competent authority has an indirect role in governing this energy hub. Finally, at the Pannenweg, a representative from Nederweert's economy department is formally a member of the cooperations' board (Pannenweg-A, personal

communication, 2025). In general, there is a tight cooperation between the business park Pannenweg and the municipality on other themes related to (social) sustainability on the park (Pannenweg-A, personal communication, 2025).

In none of the studied cases, the TSO or DSO is part of any formal steering authorities. For technical expertise that is required to run the hubs, contracts are made with ESCos to manage the energetic components and energy management system (ECAH-B, personal communication, 2025; Lage Weide-A, personal communication, 2025; Pannenweg-A, personal communication, 2025)

In the context of this thesis' focus on polycentricity and overlapping decision-making centers, being a formal part of the energy hub is not always necessary to facilitate its functioning. However, depending on the situation, a formal role for governmental bodies could accelerate planning procedures as seen in the case of energy hub Pannenweg (Pannenweg-A, personal communication).

9.2.2. Internal Decision-making

The energy cooperation ECAH serves as the representative and spokesperson for companies in the hub towards DSO Liander. The cooperation serves as a contracting party, enables technical coordination by engaging with a consortium of ESCo's and handles the financial settlement (ECAH-A, personal communication, 2025; ECAH, N.D.). A stakeholder manager is appointed to communicate with internal stakeholders, effectuate contracts and arrange the billing of energy and grid usage or the provision of grid space or electricity (ECAH-B, personal communication, 2025).

Energy hub Lage Weide's energy cooperation EMCU is the contracting party towards Stedin. Individual companies in their turn have a contract with EMCU (Lage Weide, personal communication, 2025).

Energy hub Pannenweg's operations are managed by a limited company: Energiehandelsplatform Pannenweg (EHP-P) (Pannenweg-A, personal communication, 2025). For the yet to be effectuated GTO with DSO Enexis, EHP-P is the representative party between the companies and Enexis (Pannenweg, personal communication, 2025). Decisions at EHP-P have to be justified towards the general members meeting of business cooperation Pannenweg (collectieve vereniging, CV):

The director of the energy trading platform is authorized to take decisions up to a certain amount of money. A strategic change must be submitted to the board of the CV.

…the companies are represented in the CV and the CV is accountable to the general meeting of members for its actions.

(Pannenweg-A, personal communication, 2025)

9.2.3. Harmony of Appropriation and Provision

Design principle 3B: harmony of appropriation and provision is perhaps the least clearly worked out design principle in the studied energy hubs. As illustrated by this quote from ECAH:

We can now steer [energy and the grid] and now is the moment that we will receive the contract which states how much we will receive. Then you have to agree with each other: will you receive something in advance for making grid space available? Or only if you are approached? We do not know that yet.

(ECAH-B, personal communication, 2025).

Another dilemma for ECAH is that it consists of three hubs. For some hubs different contracts with the DSO or other demand side management are more suitable or necessary (ECAH-A, personal communication, 2025; ECAH-A, personal communication, 2025). The cooperations statutes entail clauses for the creation of sub-assemblies according to the respective substations. These entities allow for the implementation of local preferences, in line with the theoretical advantages of polycentric governance systems that have to potential to leverage local knowledge for better fit solutions (Gruby & Basurto, 2013). One scale up at ECAH, this does imply a balance must be found in the distribution of time and resources into the different subgroups:

… if we say four companies in the westernmost part are going to work together in such a GTO, then they will have to bear the costs of time, of ECAH's personnel, legal costs and so on among themselves. Then the companies on the other side of the port don't have to contribute. So, we have to make that transparent and state: we want a project, and these companies are therefore contributing extra. This way, the rest will not be affected.

(ECAH-B, personal communication, 2025).

Lage Weide

Similar to ECAH, the energy hub Lage Weide is also in the process of setting up a cost division mechanism:

We are gaining more and more insight. […]. But what is the difficulty, but also the best thing about it, it has to be fair, reasonable and equitable.

So you can say, the moment you pitch in capacity, you want to get a lot for it, but on the other hand, you also want to get capacity yourself at times, then you don't want to pay the top price, so where is the limit?

(Lage Weide-A, personal communication, 2025)

Energy hub Lage Weide settles operational costs periodically and then, based on 'Naoberschap', a value that can be translated to 'helping one's neighbors (Erfgoed Gelderland, 2024). Lage Weide's representative states the following about the division of costs and benefits:

… Let's say you have five companies. Do you divide [costs and benefits] by five? Or do you divide by capacity? Or do you divide by usage? We don't have an answer to that yet."

(Lage Weide-A, personal communication, 2025)

A dilemma for all hubs is what to do with the possibility of parties opting in later. It is hard to quantify the costs that went into the initiation and design phase. Furthermore, new members must fit in the physical structure of the common (see also chapter 9.1).

Pannenweg

This hub's GTO is not operational yet. However, grid space is set to be distributed strictly through the central energy management system, which aim is to remain within the GTO bandwidth based on a first come first served principle (Pannenweg-A, personal communication, 2025). Moreover, energy hub Pannenweg has a functioning energy trading platform where energy can be traded peer to peer. If there is not sufficient energy, a contract with a windmill is in place. If that contract's electricity is exhausted, a partnership with aggregator OM Nieuwe Energie is in place to buy energy from the market, as well as selling it if there is a surplus on the Pannenweg (Pannenweg, personal communication, 2025).

The hub's neighbor to neighbor energy scheme works according to the following principles:

> *…the person who has power first uses his own power, because then he does not pay energy tax. He supplies what he has left to the group. He gets 8.5 cents per kWh for that.*
>
> *And the group buys for 8.5 cents per kWh plus the costs of the group. That is actually a very firm, steady on overall agreement.*
>
> (Pannenweg-A, personal communication, 2025).

This cooperation with the market simultaneously imposes an incentive to use energy locally as much as possible because the arranged price is usually higher than the market price. Moreover, it is an interference with the commons system by market prices. This is something that has been observed as a potential destabilizing factor in commons arrangements (Cox et al., 2010; Bauwens et al., 2024).

9.2.4. Monitoring

To assess the state of the commons resource and the behavior of participants regarding appropriation and provision, energy management systems are installed. These energy management systems utilize data input from high frequency electricity meters, that have been fitted at participating companies to measure energy generation and consumption (ECAH-B, personal communication, 2025; Lage Weide-A, personal communication, 2025; Pannenweg-A, personal communication, 2025).

The data is fed into a collective dashboard where energy hub members are able to see their individual energy consumption and production patterns and the aggregated patterns, in relation to the bandwidth that was arranged in the contract with DSOs (ECAH-B, personal communication, 2025; Lage Weide-A, personal communication, 2025; Pannenweg-A, personal communication, 2025). To enable this monitoring system, privacy agreements are signed (ECAH-A, personal communication, 2025; Lage Weide-A, personal communication, 2025; Pannenweg-A, personal communication, 2025).

Participants are not able to see company specific data, since this is not legally allowed and would not be beneficial for trust in the cooperation (ECAH-B, personal communication, 2025). The boards and ESCos can see individual data points, mirroring Namujju's observation of 'elected monitors' (Namujju, 2024, p.5). The energy management systems and dashboards are in all cases designed by external technical consultants, in coordination with input from the DSO and the energy hub (ECAH-B, personal communication, 2025; Lage Weide-A, personal communication, 2025; Pannenweg-A, personal communication, 2025).

9.2.5. Internal Sanctions and Conflict Resolution Mechanisms

ECAH's statutes foresee internal conflict resolution. Until now, contracts within ECAH have always been between ECAH and various companies, with conflicts handled through ECAH's mediation. However, if ECAH begins operating GTO's, companies will enter into mutual contracts.

…the contracts that we will be receiving soon, once there is such a GTO — a group transport agreement, where multiple companies collaborate — will state that the companies must adhere to the collective agreements.

If not, there is a conflict. That conflict is essentially between the companies, but it is addressed in the relationship between the company and the energy cooperative.

ECAH-B, personal communication, 2025

ECAH contracts entail gradual consequences in times of infringement. The board of ECAH, based on the statutes, has the mandate to knock out parties out of the energy cooperation. This is however a last resort solution (ECAH-B, personal communication, 2025). These examples illustrate how this energy hub has established graduated sanction a local conflict resolution arena within the hub, aligning with the findings of Cox et al. (2010)

Conflicts and sanctioning mechanisms are worked out less clearly at the energy hub Lage Weide. This is partially because of the technically complex character of keeping the energy hub running. As well as the physical boundaries of this common pool resource:

"You're there with five super large companies that have been around for a long time, some since 1960, […]. So, there's always been something built, and something torn down and something added and something. "

(Lage Weide-A, personal communication, 2025)

This has affected the consistency of electricity circuits within the companies:

"…, sometimes things go wrong because something isn't set up properly. […] There are like 20 converters and coincidentally one of the converters is for some reason connected to another circuit breaker, […] which means it's just outside of the control, you know, you're only just finding out about that now."

(Lage Weide-A, personal communication, 2025)

This example accentuates the pioneering position of energy hubs. Due to the hubs pioneering character and the uncrystallized distribution mechanism, hard sanctions have not been established at Lage Weide thus far (Lage Weide-A, personal communication, 2025). Any errors are taken on by the collective, in line with the 'Naoberschap' principle:

"What happens if you exceed the limit? You can say in advance that you are liable for that. But for which part are you liable? Do you have to divide by five or not? So, we have also left that a bit in the middle. To make the right agreement. And in the cooperative, […] we actually take everything together. We divide the benefits as well as the burdens with each other. That is the idea of it."

(Lage Weide-A, personal communication, 2025)

There is, however, a conflict resolution arena in the form of an open conversation with the participants, and possible exceedances of the contract are monitored and discussed together monthly (Lage Weide-A, personal communication, 2025). This aligns with Namujju's (2024) description of group meetings as conflict resolution arena in an energy community context

For the hubs Lage Weide and Pannenweg, accountability formed a significant juridical obstacle. Collective responsibility for damages on grid infrastructure is unprecedented in this form (Lage Weide-A, personal communication, 2025; Pannenweg-A, personal communication, 2025). Insurance companies initially lacked knowledge to find a fitting solution to this novel responsibility (Lage Weide-A, personal communication, 2025; Pannenweg-A, personal communication, 2025).

9.2.5 Sub Conclusions

The sub conclusions of this research question are presented in relation to the discussed design principles:

DP 1: social boundaries. A Relationship exists between quantity of participators per contract and the activities they do in relation to the possibilities of the energy hub. More involved parties from diverse sectors could imply that there is more flexibility. But it will also add more complexity to the hub. The number of participators is limited to the physical boundaries of the hub.

The surveyed energy hubs are struggling to relate themselves to possible new participants, partly because of the fear of freeriding in relation to the hub's initiation costs, and partly because of insecurities with regards to the operational sustainability of the hub with added participants and complexity. This uncovers tension between the idea of addressing commons in a group such as an energy hub and including outsiders to address the same issue, a paradox also identified by Bauwens et al (2024).

DP 2. In line with the adaptive character of self-governing entities that address commons issues (Carlisle & Gruby, 2017), not all arrangements and principles have been worked out yet. In particular design principle 2: harmony of appropriation and provision has not been operationalized fully. The modus operandi seems to be 'learning by doing' and has thus far not hindered the effectiveness of addressing the commons issue in these hubs. This also demonstrates the adaptive character of energy hubs, which theoretically is a marker for success of self-governing entities and is an assumed benefit of polycentric governance (Huitema et al., 2019).

DP 4, 5 and 6. All energy hubs have agreements on data sharing to facilitate energy management and monitoring. The internal monitoring shows a lot of similarities across cases, pointing at the strength of this design principle with regards to managing energy commons. However, cases show differences in the way sanctions are established. The case of Lage Weide illustrates an adaptive 'way of doing' and demonstrates that social capital (Naoberschap) can substitute strict sanctions, corresponding to the findings of Cox et al. (2010).

9.3 How do energy hubs interact with supralocal actors within a polycentric governance

This research question examines the external decision-making centers, monitoring, sanctioning and conflict resolution arenas in the polycentric governance of energy hubs. Within the scope of this question are principle 2: congruence (time and quantity of appropriation and provision), principle 4b external monitoring, principle 5b external sanctions, principle 6b external conflict resolution arenas, principle 7 rights and recognition and principle 8 polycentric governance.

To structure this analysis, the chapter follows the operationalization of polycentric governance as provided in chapter 5.5, being: Location action, mutual adjustments, experimentation, trust and overarching rules. A sub conclusion is presented at the end of the chapter.

9.3.1. Local Action

To understand what shape local action takes in different cases, this section discusses the grid usage agreements that have been arranged between energy hubs and system operators.

Grid usage agreements

Grid congestion issues are time and place specific. Determinants of grid congestion are the capacities of components and networks (chapter 9.2), the energy usage and production profile (chapter 9,3), and the possibility to make energy consumption more flexible (Netbeheer Nederland, 2023), for example by shifting heavy demand to times with less grid congestion or capturing energy production overshoots with energy storage (TenneT-A, personal communication, 2025).

To make use of times without congestion, and essentially spatial-temporally alleviating the commons problem of grid congestion, new contractual agreements are being developed. These agreements are developed by DSOs, united in the overarching entity Netbeheer Nederland and in coordination with - among others - energy hubs. The proposal this coalition develops is presented to ACM (ACM, personal communication, 2025). The authority's task is to check the legal foundations of the proposal and make sure it does not disrupt the market (ACM-A, personal communication, 2025; Gerritsen et al., 2023). In this phase, the proposal is discussed with DSOs and market parties to scrutinize the feasibility of the proposal (ACM-A, personal communication). Furthermore, the proposal is made available for public review, after which the final construction will be published (ACM-A, personal communication, 2025). At the time of writing this thesis, the GTO-proposal period of public review has just closed, meaning the final version of the GTO will be published in the near future (ACM-B, 2025). The studied cases are already operational because of their approved status to experiment with grid management, which was granted by ACM (ACM-A, personal communication, 2025).

In the case of the electricity grid, ACM primarily governs the grid operators' responsibility towards connected parties and not vice versa. In the context of commons management theory, ACM is the external monitoring and sanctioning body.

Contractual practices in the studied cases

The hubs reviewed in this thesis make use of two types of contracts: a “collectief capaciteitsbeperkend contract” translated to collective capacity limiting contract, hereafter referred to as C-CBC. The other agreement is dubbed: groepstransportovereenkomst or group transport agreement (GTO).

Energy hub Lage Weide and grid operator Stedin have collaboratively developed a groepstransportovereenkomst or group transport agreement (GTO) (Stedin-A, personal communication, 2025; Lage Weide-A, personal communication, 2025).

A GTO agreement replaces the individual contracted power (GTV) that companies have with the grid operator. Instead, a single entity of companies is now responsible for the participants to stay within a collective bandwidth of contracted power (Netbeheer Nederland, 2024). This collective limit is based on historical use of grid capacity and considers local grid congestion and simultaneity (Netbeheer Nederland, 2024). The collective limit is lower than the aggregated sum of GTV’s is. Otherwise, it would not reduce local congestion (Stedin-A, personal communication, 2025; Netbeheer Nederland, 2024). An important note regarding a GTO contract is that it increases grid tariffs for the participants (RVO-B, 2025). The precise cost increase is still being determined (Pannenweg-A, personal communication, 2025).

The C-CBC was developed through collaboration between ECAH and Liander (ECAH-A, personal communication, 2025; Liander-B, personal communication, 2025). Individual CBCs are contracts that ask for a service from connected parties towards the DSO: a temporary reduction of power used by the connected party, in return for a fee. The fee depends on the severity of grid congestion and the amount of average overshooting power among other factors (Netbeheer Nederland, 2024). This call for grid space is given by the DSO (Netbeheer Nederland, 2024; ECAH-A, personal communication, 2025). CBCs vary from seasonal agreements, anytime (mentioned one day ahead) or a call to feed in power in case of a large-scale battery (ECAH-A, personal communication, 2025). A C-CBC maintains the individual CBC and GTV but now a central party is responsible and permitted to orchestrate how this temporary capacity reduction is realized by the involved parties of the C-CBC (ECAH-A., personal communication, 2025).

Table 7 provides a comparison of the aspects of the C-CBC and GTO (adapted from ACM, 2025 and ACM, 2022)

Contract	GTO	C-CBC
Terms and conditions	Grid space allocation to be handled by legal entity (energy cooperation). Can exist parallelly to grid congestion measures.	Grid space allocation to be handled by a congestion service provider (CSP). The CSP is appointed by the energy hub, alternatively, the energy hub has a status of CSP.
Grid usage	Individual users are allowed to maximize the full group capacity, provided that the technical limit of own connections allows it. The sum of individual connections is less than the bandwidth in a GTO to ensure alleviation of local grid congestion	Call for capacity limitation can be seasonal, day ahead or meant for generation or consumption. Maximum transport capacity is arranged as well as the price per MW for reduction.
Responsibilities	Service from DSO to connected parties	Service from connected parties to DSO via congestion service provider
Time	Three years transitional period or shorter *	Agreements made per case. Some contracts end when the grid is sufficiently upgraded
Costs and benefits allocation	Peak demand (KW) settled on a group netto (energy generation minus consumption) basis. Energy use over a certain time period (KWh) is not settled on a group basis. ** This promotes coordination between energy generation and consumption but can cause disproportional cost reductions for contract users over others	The price for congestion services is mutually agreed and is based on the: • Size of the service area, which is tied to a fixed amount of 'congestion funds' • The amount of flexibility (in KW) • The type of flexibility (energy generation/consumption) • Duration of activation • Frequency of activation • Notice period • Time between activations
Opting in	Opt-in is voluntary and must be approved by current contract parties. In case of a new entry, DSO starts new research into the effects of added power to the stability of this contract.	CBC is required to participate in collective CBC. Opt-in in accordance with the congestion service provider.
Opting out	Opting out results in restoring the GTV, in a way that the GTV< individual contributed power to GTO. In case a member opts out, the GTOs capacity is reduced.	CBC underlies the collective agreement to ensure technical stability in case of parties opting out.

Table 7: *Grid usage agreements within the studied energy hubs (author, adapted from ACM, 2025 and ACM, 2022)*

** Currently debated in GTO proposal (ACM, 2025)*

*** ACM proposes a more balanced situation since the risks are that netted settlements can cause unequal tariffs for remaining grid users in some cases (ACM, 2025).*

The cases of ECAH and Lage Weide exemplify institutional fit (Carlisle & Gruby, 2017), gained through local action, specifically the co-development of the contracts. Energy hub Pannenweg did not develop a contract with their DSO. Furthermore, the hub and Enexis have not reached an agreement on the GTO contract terms yet (Pannenweg-A personal communication, 2025; Enexis-A, personal communication, 2025).

Because the response of the commons issue did not occur at most local level (when referring to grid usage agreements), institutional fit at de Pannenweg appears weaker compared to the local action outcomes of the other cases.

9.3.2. Mutual Adjustment

To describe the adaptation of actors in the polycentric governance system to physical, social and legal developments, the actors are classified by scale, jurisdiction, function and possible overlaps within these facets. For each energy hub a table is drafted which portrays polycentric overlap between actors (table 8; table 9; table 10). Due to its role as market regulator and lawmaker, special highlight is given to ACM. The information in these charts is obtained from interviews with the actors as mentioned in the column 'Actor'.

ECAH

The table portraying the polycentric governance network of ECAH can be found on the next page.

Mutual adjustment ECAH

ECAH, together with Liander, have developed a collective limited capacity contract. The contract was then generalized to be available for Liander's service area (ECAH-B, personal communication, 2025.

Energy hub ECAH, 7 decision-making centers, indicated by: ■					
Actor	**Geographic scope**	**Jurisdiction**	**Functional overlap**	**Joint decision making**	**Vertical overlap**
ACM ■	The Netherlands	Ensuring stable and fair markets	Policy design, rules and codes regulation in cooperation with DSOs and market parties.	Policy design and rules and codes regulation	EU guidelines
TSO Tennet* ■	The Netherlands and parts of Germany	Ensuring transmission and transport grid stability	Grid management. In coordination with DSOs, individual customers with strong connections	Extra assessment of grid stability in coordination with DSO	Legal requirements of grid stability and serving customers. Tariffs are set by ACM
DSO Liander* ■	North Holland, Parts of South Holland, Flevoland, Friesland and Gelderland	Ensuring regional and local grid stability	Grid management in coordination with TSOs, individual customers with strong connections. Cooperation with other DSOs in Netbeheer Nederland.	Foundational role in the establishment of energy hubs. Represented in provincial energy board	Legal requirements of grid stability and serving customers. Tariffs are set by ACM
Province	Province of North Holland	Governing North Holland	In the case of energy hubs, input in the energy board to select new pilot locations	Member of provincial energy board	Coordination between state and municipalities
Municipality	Municipality of Amsterdam	Governing Amsterdam. Permits and zoning a.o.	Indirect participant in the energy cooperation board and 100% shareholder of PoA.	Indirect participant in energy cooperation board and 100% shareholder of PoA.	Coordination with Province and all citizens, organization companies, etc.
PoA ■	Port of Amsterdam, Zaanhavens, North Sea Canal	Managing port and infrastructure. Implementing green strategy	Cooperates with CES large industrial clusters cooperating on the theme of energy and co2 reduction).	Municipality of Amsterdam.	Municipality is 100% Shareholder. Right to vote in ECAH
EIGEN	The Netherlands	Consortium	ECAH learning how EMS works	Knowledge institutes, grid service, ESCO	Scala of problem owners and end users
ESCo Firan	Grid area Liander	Energy management services.	Developing ECAH EMS with EIGEN partners (EIGEN, 2025)	Facilitating monitoring in energy hub	Subsidiary of Liander
ECAH ■	Port of Amsterdam	Operating Energy Hub	Coordinating grid usage agreements between the C-CBCs and DSO. Developing EMS with Firan	Tight cooperation with DSO and ESCo	PoA is represented in board. Room for subgroups is built i statutes.
C-CBCs on ECAH ■**	Substations Ruigoord IJpolder Westhaven	Contract between companies and ECAH and ECAH and DSO	Energy hub. Grid management. Load shifting	Coordinated by ECAH board	Coordination with ECAH. Sub group meeting with rights.

Table 8: *Polycentric governance of ECAH*

** Focus on the electricity grid.*

*** Subgroups per contract can be established according to statutes.*

**** For the rows concerning 'ESCo' and 'competent authorities', data was obtained from interviews with the energy hub representatives. ESCo's and competent authorities were not directly interviewed in this thesis.*

Lage Weide, 4 decision making centers					
Actor	**Geographic scope***	**Jurisdiction**	**Functional overlap**	**Joint decision making**	**Vertical overlap**
ACM ■	The Netherlands	Ensuring stable and fair markets	Policy design, rules and codes regulation in cooperation with DSOs and market parties.	Policy design and rules and codes regulation	EU guidelines
TSO Tennet ■	The Netherlands and parts of Germany	Ensuring transmission and transport grid stability	Grid management. In coordination with DSOs, individual customers with strong connections	Extra assessment of grid stability in coordination with DSO	Legal requirements of grid stability and serving customers Tariffs are set by ACM
DSO Stedin* ■	Zeeland, South Holland, Utrecht	Ensuring regional and local grid stability	Grid management in coordination with TSOs, individual customers with strong connections. And Energy Hubs Cooperation with other DSOs in Netbeheer Nederland.	Foundational role in the establishment of energy hubs. Represented in provincial energy board	Legal requirements of grid stability and serving customers Tariffs are set by ACM
Province	Province of Utrecht	Governing Utrecht (province)	In case of energy hubs, input in the energy board to select new pilot locations	Member of provincial energy board	Coordination between state and municipalities. Supporting Energy Hubs in initiation phase. Energy hub knowledge center to inform policy and regional practice. Partly based on Lage Weide's experience.
Municipality	Municipality of Utrecht	Governing Utrecht (municipality. Permits and zoning a.o.).	Governing Utrecht	n/a	Coordination with province
ESCo Groendus	The Netherlands	Energy management services.	Developing EMS	Facilitating monitoring in energy hub	Appointed by EMCU
EMCU ■	Grid field 19 on industrial site Lage Weide	Operating Energy Hub	Coordinating grid usage agreements (GTO) between the companies and DSO. Developing EMS with Groendus	Tight cooperation with DSO and ESCo	Sharing knowledge with Province of Utrecht energy hub strategist. Tight cooperation with DSO.

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Table 9: *Polycentric governance of Lage Weide*

** Focus on the electricity grid.*

Mutual adjustment Lage Weide

When Stedin and energy hub Lage Weide were in an advanced stage of researching the GTO agreement, this cooperation was temporarily held back by TenneT. Due to the interactions between Stedin and Tennet's grid and the severity of grid congestion in the FGU pocket, additional coordination was required to ensure that all grids in this area would remain stable (TenneT-A, personal communication). This was necessary because Stedin's 'dips' were not always the same as TenneT's 'dips' (Stedin-A, personal communication, 2025). Hence, on top of the GTO between Lage Weide and Stedin, a static collective capacity limiting contract between Lage Weide and TenneT is arranged which reduces the general capacity of the hub during certain periods of the year (TenneT-A, personal communication, 2025). Because of the dissimilarities between DSO and TSO stations profiles. Optimization within own capacity and mandate was required. For DSO this means setting up arrangements with end users and developing and testing new congestion management propositions (Stedin-A, personal communication, 2025). For TenneT it means adding additional flexible fossil capacity to balance peaks and dips (TenneT-A, personal communication, Stedin-A, personal communication, 2025).

Mutual adjustments Pannenweg

The Pannenweg had already been cooperating closely with the municipality Nederweert on a broader sustainable development agenda (Pannenweg-A, personal communication, 2025). Due to provincial regulations and resistance to agricultural land being used for solar-PV, the municipality requested Pannenweg to utilize roofs for solar energy (Pannenweg-A, personal communication, 2025; Provincie Limburg, 2024). However, Enexis interfered with this plan due to local grid congestion (Pannenweg-A, personal communication, 2025). This marked the starting point for Pannenweg to investigate the possibility of supplying energy and grid space among members of the cooperation (Pannenweg-A, personal communication, 2025). However, such contract did not exist yet:

Enexis made it clear from the very beginning: (…) There is no contract that gives you permission to supply solar energy to each other and then simply source the remaining energy from the EPEX market or the imbalance market. That's when we started looking into how we could structure something like that ourselves.

(Pannenweg-A, personal communication, 2025).

To research this Pannenweg appointed technical consultants.

This example illustrates how mutual adjustments within a polycentric governance system work in practice. Provincial policies start a chain of policy plans, which trajectory is in turn altered by interference of another decision-making center, in this case DSO Enexis. The polycentric governance system of Energy Hub Pannenweg is mapped on the next page.

Pannenweg, 5 decision making centers					
Actor	**Geographic scope***	**Jurisdiction**	**Functional overlap**	**Joint decision-making**	**Vertical overla**
ACM ■	The Netherlands	Ensuring stable and fair markets	Policy design, rules and codes regulation in cooperation with DSOs and market parties.	Policy design and rules and codes regulation	EU guidelines
TSO Tennet*	The Netherlands and parts of Germany	Ensuring transmission and transport grid stability	Grid management. In coordination with DSOs, individual customers with strong connections	Extra assessment of grid stability in coordination with DSO	Legal requirements o grid stability and serving customers (ACM and law?
DSO Enexis* ■	Noord Brabant, Limburg, Overijssel, Drenthe and Groningen	Ensuring regional and local grid stability	Grid management in coordination with TSOs, individual customers with strong connections. And Energy Hubs Cooperation with other DSOs in Netbeheer Nederland.	Foundational role in the establishment of energy hubs. Represented in provincial energy board.	Legal requirements o grid stability and serving customers (ACM and law?). Tariffs are set by ACM
Province	Province of Limburg	Governing Limburg (province)	In case of energy hubs, input in the energy board to select new pilot locations	Member of provincial energy board	Coordination between state and municipalities. Coordination with RES Noord en Midden Limburg and RES Zuid Limburg to indicate pilot locations.
Municipality ■	Municipality Nederweert	Governing Nederweert, Permits and zoning	Coordination with the province of Limburg	Board of business park Pannenweg	Coordination with province Formal participant of Business park Pannenweg
ESCos: **LYV Energy Management** **Rethink Zero**	The Netherlands	Energy management services.	Developing EMS Technical advice ESCos	Facilitating monitoring in energy hub	Appointed by Pannenweg
Aggregator: OM Nieuwe Energie	The Netherlands	Aggregator	Selling and acquiring energy for Pannenweg	Facilitating market access	Appointed by Pannenweg
Cooperative Pannenweg ■	Business park Pannenweg	Operating Energy Hub	Coordinating grid usage agreements (GTO) between the companies and DSO.	Tight cooperation with DSO and ESCo	Positioned above EHP-P; and the formal contractual

Table 10: *Polycentric governance of Pannenweg*
** Focus on the electricity grid.*

Polycentric energy governance synthesis

The empirical reflections of mutual adjustments have been synthetized in figure x which outlines the different types of overlaps in the polycentric governance setting of energy hubs. Blue overlaps indicate functional and jurisdictional overlaps, which can be seen between competent authorities (as government) and the system operators. Orange shapes indicate vertical cross scale overlap (vertical overlap) between decision making centers that exist in different scales such as the tight cooperation between energy hubs and the system operators. Green areas illustrate horizontal overlaps between actors operating on the same scale such as subsidiaries of the energy hub and the appointed energy service companies.

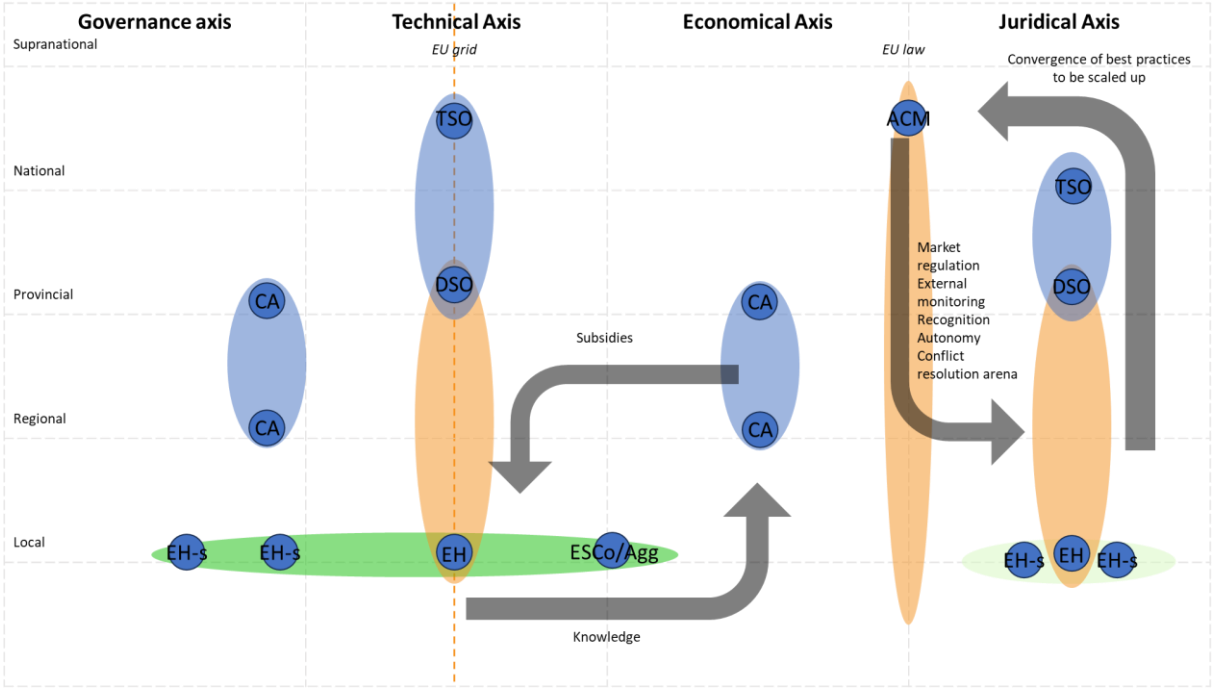

Figure 6: *The polycentric governance system of industrial energy hubs in the Netherlands (author)*

Furthermore, exchanges between subsidies and knowledge as well as external autonomous monitoring and upscaling best practices are indicated by two feedback loops. The arrows particularly highlight the polycentric system's functioning in addressing energy commons problems.

9.3.3. Experimentation

Financial

Lage Weide has received subsidies by the Province of Utrecht, a condition of subsidies was knowledge sharing between Lage Weide and an account manager of the province (Lage Weide-A, personal communication, 2025). This arrangement has shaped the steps-to-follow for novel energy hubs. First, the prospected hub contacts the province to learn what procedures to take to initiate an energy hub. Second, an entity is established. Third, the potential hub contacts Stedin for further technical assessment and contractual agreements (Stedin-A, personal communication, 2025). The knowledge sharing of this subsidy provincial is specifically targeted at actors within the Province of Utrecht.

At ECAH, the monitoring aspect is funded by MOOI subsidies (EIGEN, 2025). The management systems blueprint will be available open source for other users, within and outside of the hub (ECAH-B, personal communication, 2025; EIGEN, 2025).

Similarly, to set up the energy management system of energy hub Pannenweg, a HER+ subsidy was granted. The condition of this subsidy is explicitly to generate open-source knowledge (RVO, 2023).

Regulatory support

The current contract forms require energy hubs to be organized in a formal entity, a status that is relatively easy to obtain (ECAH-A, personal communication, 2025). When energy hubs initiate experiments that cross the legal boundaries of the energy law or codes, an exemption must be requested at the Authority of Consumers and Market (ACM-A, personal communication, 2025). The request, usually submitted by both the DSO and the energy hub, entails the juridical articles obstructing operations, requests the duration of exemptions and how exemptions should work, and it illustrates the situation on the hub. After approving this request, the ACM encourages monitoring of the experiment (ACM-A, personal communication, 2025). “If it turns out to work, we want to converge it to a general proposition. For this you must codify this process.” (ACM, personal communication, 2025).

This demonstrates how the legal space for experimentation results in the convergence of best practices for higher scale roll out.

Knowledge sharing

All energy hubs engage with (semi)governmental bodies to exchange knowledge, partially in return for subsidies, where knowledge sharing is often a prerequisite (Stedin-A, personal communication, 2025; Lage Weide, personal communication, 2025). However, all energy hubs indicate that the knowledge sharing is very one directional given their frontrunner’s position compared to other energy hub initiatives (ECAH-B, personal communication, 2025; Lage Weide-A, personal communication, 2025; Pannenweg-A, personal communication, 2025)

In relation to polycentric governance, subsidies can be seen as port of policy experimentation and adaptation. From increased connectivity and collective learning, best practices emerge that can be adopted by other initiatives (Jordan & Huitema, 2023; Gillard et al., 2017). However, Voß and Schroth (2018) warn that a polycentric arena has the risk of consolidating the ideas of powerful parties that are ‘at the table’. Being among the front runners or attracting subsidies, facilitates this position at the table.

Voß and Schroth (2018) recommend that polycentric experiments must “make sure that experimental politics receive public scrutiny and t give it a solid democratic constitution” (Voß & Schroth, 2018, p.112). This is what the ACM’s theoretically addresses. The code development procedure is organized in such a way that during the design and review of the proposal, stakeholders can send formal opinions and feedback (ACM-A, personal communication, 2025). However, stakeholders are defined narrowly in the sense of representative bodies and branch organizations (ACM-A, personal communication, 2025). ACM’s role is also to enforce the grid codes and electricity law and settle disputes between connected parties and the system operators (ACM- personal communication).

9.3.4. Trust

The cases studied underline the importance of trust in setting up an energy hub:

"So, it's very much about creating trust, giving trust and showing that a certain system, for example an energy hub that we have a pilot of that controls everything, shows that control works, that it really works."

ECAH-A, personal communication, 2025

One of the most important things in the Energy Hub is finding each other. Trusting each other. That really takes a lot of time.

TenneT-A, personal communication, 2025

We found each other, we trust each other, we speak to each other directly […] That way you can arrange this well. And if you had everything fixed in advance in contracts, then you can't get started. So, we just do it based on experience, insight and trust.

(Lage Weide-A, personal communication, 2025).

Standing from this quote by the representative of Lage Weide is that trust has resulted in building a conflict resolution mechanism, which will be discussed further in Chapter 9.3.5.

In all cases, grid operators monitor the grid behavior of the energy hubs. This is to test calculations of bandwidths and maintain grid stability in case of emergency (Liander-A, personal communication, 2025; Stedin-A, personal communication, 2025; Enexis-A, personal communication, 2025). This aligns with findings by (El Afifi et al., 2024).

9.3.5. Overarching Rules

This section discusses the overarching rules between actors in the polycentric governance network.

Recognition

In relation to overarching rules, ACM naturally takes on the key role as central market regulator and monitoring agency. As mentioned before, ACM monitors experiments closely to see if the propositions of these experiments can be codified or generalized and thereby leveled up to higher scales (ACM-A, personal communication, 2025). This process implies that during the experiment certain self-organizations can have 'more rights than others.' However, later this is adjusted again when general contracts and codes are available. The most direct mission for ACM is to ensure a fair and working market. ACM has to weigh the interests of a fair market for both the supply and demand side during the development of new grid codes. ACM also has to ensure that new grid codes are in line with European regulation. A crucial article is the European and national rule that similar cases of grid requests have to be treated as such by system operators. The contracts and grid management propositions that are being developed might interfere with this principle (ACM-B, 2025).

Within this polycentric governance network, and even the common pool management of the grid, ACM clearly takes on the role of autonomous authority on conflict resolution. ACM is independent from any ministry or administration (ACM-A, personal communication, 2025). Although the ACM operates on a national scale, local parties still have access to this arena. This is because the ACM monitors the behavior of grid operators vis-à-vis connected parties ACM monitors qualitatively and quantitatively if needed, to settle dispute (ACM- personal communication, 2025). Moreover, ACM enforces the grid codes and electricity law (ACM- personal communication, 2025; Gerritsen et al., 2023).

The system operator – energy hub Nexus

For energy hubs to start operating, they must obtain a status as congestion service provider (CSP) or appoint a CSP in the case of a C-CBC (ECAH-B, personal communication, 2025). This means meeting requirements by the DSO such as physical characteristics and being organized in an entity. No other actors - except for the TSO if the grid situation calls for it - have any veto over this recognition. For a GTO to be effectuated, the energy hub must provide an operational startup protocol, which will be assessed by the DSO (Enexis-A, personal communication, 2025).

DSOs monitor both individual companies as well as the group contracts (both GTO and C-CBC) and serve as the external monitoring mechanism over the state of this commons pool resource, which Namujju (2024) highlighted as an important marker of design principle 4.

DSOs impose sanctions in case of grid exceedances (Liander-A, personal communication, 2025; Stedin-A, personal communication, 2025; Enexis-A, personal communication, 2025). DSOs treat collectives the same as individual GTVs, meaning a letter is automatically sent and after a certain amount of transgressions contacts are started (Liander-A, personal communication, 2025; Stedin-A, personal communication, 2025; Enexis-A, personal communication, 2025). In case of emergency the DSO shuts down the station to make sure the regional grid does not get affected (Enexis-A, personal communication, 2025).

However, collective responsibility is a tedious point since operating a hub might be difficult due to the physical complexity (DP1) and the organizational complexity (DP2) of the energy hub. Additionally, trust in possible new companies may be diminished, since they have not been part of the collective process of setting up the hub from start to finish.

Furthermore, pioneering means taking risks and since the technical risk is also carried by a group, a serious yet accidental transgression of the contract could be fatal for the energy hub. The debate about collective responsibility is now happening in the public consultation of de code proposal (Pannenweg-A, personal communication, 2025).

Competent authorities

In the cases studied, apart from the Pannenweg, competent authorities have no formal (planning) role unless physical assets need to be placed that require environmental permits such as batteries. Instead, competent authorities' predominant role is to facilitate subsidies, support organization building and networking, and sharing learned lessons. This limited formal role allows the hubs to retain some autonomy from state actors. However, subsidies are tied to state actors.

9.3.6 Sub Conclusions

The following conclusions can be drafted regarding the sub question: *How do energy hubs interact with supralocal actors within a polycentric governance.*

Energy hubs strongly interact with other decision-making centers through a chain of mutual adjustments and collective experiments, demonstrating institutional, functional and geographical overlap (Carlisle & Gruby, 2017). Local action takes place through the collective development of new grid management contracts and flexibility propositions by energy hubs, system operators and ESCos. These experiments are closely monitored by system operators to assess technical stability and the ACM to ensure balanced policy outcomes. Furthermore, other financing or subsidizing organizations valorize the generated knowledge, supporting scalable – sometimes open source - models for upscaling energy hubs, empirically demonstrating the benefits of polycentric governance (Kellner et al., 2024; Jordan et al., 2018).

Autonomy within overarching rules proves to be crucial in this 'success' of polycentric governance. Importantly, the governance system that 'led' to grid congestion already consisted of a - more hegemonic (Wolsink, 2020) - yet polycentric structure with multiple overlapping decision-making centers; being ACM, TSOs and DSOs. This system was 'fully regulated', with system operators responding reactively to incentives set by the regulator (Duma et al., 2024, p.9). However, the roles of system operators are shifting (Duma et al., 2024; Winkel et al., 2025). As the energy system decentralizes, system operators are expected to be more proactive and to facilitate flexibility. This shift entails giving responsibility to collectives or non-central actors to manage subsets of the grid collectively. For example, by granting a congestion service provide (CSP) status. Also, the ACM is adopting a different approach:

We have to regulate more proactively, because it's relatively new. So, you set a framework in which you say: within these boundaries, we believe the market should develop. At the same time, we recognize that based on the experience we will gain, we will have to make adjustments here and there…

(ACM-A, personal communication, 2025)

These developments show that autonomy is a deciding factor in effective polycentric governance and hence a decisive factor in the local response to grid congestion by energy hubs. This transition marks a broader shift in energy governance hierarchy. Essentially, the recognition of new roles by supra local actors and the autonomy of collectives to self-govern the grid has been allowed for local responses to higher scale problems (Huitema et al., 2019).

The practice of upscaling and converging best practices uncovers a conceptual weakness of polycentric governance theory. The theory simultaneously promotes experimentation and upscaling of local knowledge (Voß & Schroth 2018) and on the other side, institutional fit (Carlisle & Gruby, 2017). The practice of energy hubs uncovers the discrepancies between these propositions. Although the GTO at de Pannenweg was eventually proposed through the polycentric system, the resulting version is a diluted form of earlier GTO proposals by DSOs and does not fit institutionally as a result.

Finally, in relation to Bauwens et al., (2024) call for research on the interaction between scales in energy commons management: the intra spatial dimension of the commons problem does not get alleviated by the current energy hubs. This limitation stems from the following reasons:

1. The power on which contracts are based is too little to make a supra local impact. Meaning, grid congestion still affects parties on the waiting list in the region (TenneT-A, personal communication, 2025)
2. Grid extensions are still needed and due to interlinkages of stations and higher grids, hubs depend on DSOs and TSOs for structural upgrades, as is the main task of grid operators (Pannenweg-A, 2025).
3. However, if flexibility and collectives get upscaled it could potentially lead to a situation where fewer upgrades are needed, significantly impacting the space that is required to implement new stations and connections (TenneT-A, personal communication, 2025).

9.4 What is the effect of Ostrom's design principles on commons management in Energy Hubs?

This research question examines the individual contributions of Ostrom's design principles on sustainable management of common pool resources to practices on Dutch Energy Hubs. The impact of each principle is assessed by building on the empirical results of sub questions 1, 2 and 3 which have discussed operational, governance and polycentric components of energy hubs.

This analysis assesses the significance of each principle for common management as well as cross principle interactions. The analysis is contrasted to the theoretical framework - specifically chapter 5.4 - and with a meta-analysis by Cox (et al., 2010), to compare electricity grid common management with broader commons contexts. This allows for a micro level comparison of energy hubs in relation to macro level data on commons management. Moreover, this research question addresses the theoretical gap in defining indicators for successful commons governance, as identified in chapter 2.2. Finally, an adaptation of Ostrom's design principles will be made to fit the case of energy hubs, in line with one of the key research goals of this thesis.

9.4.1. The Effects of Ostrom's Design Principles on Commons Management

To allow for comparison between quantitative (Cox et al., 2010) and the qualitative data of this thesis, the meta analysis effect size (Phi-statistic) by Cox et al. (2010) is categorized into 3 strata:

- $\phi > 0.6$, strong effect
- ϕ 0.4-0.6 medium effect
- $\phi < 0.4$, weak effect.

Standard phi coefficent interpretation benchmarks are explicitly not utilized, as these would typically render all but two design principles as 'medium' or 'strong'. In table 11, the design principles as collected by cox will be presented, accompaned by an indiciation of their observed effect within the scope of this study. In table 11, a comparison is made between Cox et al., 2010, and the empircal data from this study. Additional content is provided by referring to the theoretical framework (chapter 5).

Ostrom's design principle	Operationalization	ECAH	Lage Weide	Pannenweg	Synthesis	Cox et al. (2010) ϕ	Effect cat.	Empiry EH
1. Clearly defined boundaries	a) Physical boundaries	3 hubs operating on 3 OS, power mostly gets into the PoA by one TSO station	Field 19 is clearly defined however the hub is very dependant of upstream developments due to FGU pocket not being comparted	Clear boundary, 1 ring, 2 fields	Clearly defined boundaries are not the key factor in energy hubs addressing the commons dilemma. The grid's complexity stems from interconnectedness and upstream interdependencies, requiring integration into supralocal governance structures (chapter 9.3). Instead, it could be argued that the unclarity of boundaries or the lack of compartmentation of the general electricity system has created a need for local management and thus boundaries	0.313	Weak	≈
	b) Social boundaries	40 in hub. Energy cooperation. Possibility to start sub entities	5 in hub Energy cooperation	45 in peer-2-peer, 15 to 17 prospective GTO participants	The amount and type of participators is limited to the physical, technical and legal boundaries of the hub. A Relationship exists between quantity of participators per contract and the sectors they are in relation to the possibilities of the energy hub	0.692	Medium	≈
2. Congruence	a) Harmony of appropriation and prov	Contracts between companies and ECAH. In turn, C-CBC contract between ECAH and Alliander	GTO with Stedin. CBC with TenneT	GTO: first come first served. P2P fixed price and connection to markets via aggregator	More involved parties from diverse sectors could imply that there is more flexibility. But it will also add more complexity to the hub. The size of participating companies can affect the advantages on congruence. Distinction between members and non members results in unclarity regarding the 'contritbution' to opt in	0.737	Strong	≈
	b) Proportional cost/benefit allocatio	Allocation systematics to be determined	'Naoberschap'	P2P price agreements	Some arrangements are still being developed, illustrating the adaptive 'learning-by-doing' character of energy hubs	0.632	Strong	**>X**
3. Collective action agreements	a) Data sharing agreement	Individual data shared in collective dashboard. Aggregated group data visible for all.	Individual data shared in collective dashboard. Aggregated group data visible for all.	Individual data shared in collective dashboard. Aggregated group data visible for all.	Similarities in data sharing agreements	0.466	Medium	≈
	b) Collective ownership	No collective investment or ownership of assets; however, individual assets are used collectively.	No collective investment or ownership of assets; however, individual assets are used collectively.	Collective ownership of batteries. Legal structure (bv) facilitates collective ownership and investments	Variation between cases			
	c) Collective investments	Statutory opt-out term. Opting in comes entails handing over DSO-user responsibilities to parent organization	Statutory opt-out clause. Opting in mechanism under development	All companies on IP already member of the cooperation. Not all parties can partake in GTO due to the technical requierements of having a	Depends on legal arrangement and choices based on a.o. risk averseness or subsidiy availability			
	d) Opting in and out	Cooperation. General members meeting and board. Statutes allow sub groups to be formed based on sub stations	Cooperation. General members meeting and board.	Park cooperation with general members meeting and a Limited organization (B.V). Which allows for shared investments (battery).	Opting out comes with a opt out term of a fixed period. Opting in arrangements not fully developed. Opting in also demands additional research by the grid operator to ensure grid staibility.			
	e) Collective choice agreements				All studied cases carry out multiple long-term collective action agreements. This forms the core of hub operations. The legal form is decided by the wish to do collective investments in physical infrastructure such as batteries or renewable energy sources.			
4. Monitoring	a) Internal monitoring	Energy management system. All users see own and collective energy and grid metrics.	Energy management system. All users see own and collective energy and grid metrics.	Energy management system. All users see own and collective energy and grid metrics.	Energy flows are monitored transparenly and near real-time, enabling swift responses to potential exceedances. This is a key strength of internal monitoring in energy hubs. However, the effectiveness of monitoring can be constrained by the physical boundaries of technical installations and depends on collective agreements on data sharing, which in turn require trust. The state of the commons (grid) is monitored by the DSO, who also compares this to data from the hub's energy management system	0.792	Strong	≈
	b) External monitoring	DSO has access to monitoring and monitors the grid bandwidth.	DSO has access to monitoring and monitors the grid bandwidth.	DSO has access to monitoring and monitors the grid bandwidth.		0.587	Medium	**X>**
5. Sanctions	a) Internal sanctions	Accounted for in cooperation statutes. Sanctions are graduated. Board holds the mandate to expel parties from hub	To be determined. Setbacks are carried collectively (Naoberschap)	To be determined	All hubs have established graduated sanctions. Also outsider parties like the DSO, TSO or ACM are enforcing graduated (and automated) sanctions. There is however tension on the point of accountability. EHs indicate experimentation can come with technical exceedances. The system operators have to ensure no (supra) regional blackouts happen (grid stability) or infrastructure gets damaged.	0.398	Weak	≈
	b) External sanctions	Standard sanctions from DSO. Collective is accountable for exceedances	Standard sanctions from DSO. Collective is accountable for exceedances	Standard sanctions from DSO. Collective is accountable for exceedances				
6. Conflicts resolution arenas	a) Internal conflict resolution arena	General members meeting. Statutes	Trust, close contact and honesty	General members meeting. Frequent briefing by key figures to participants	Conflict resolution within the energy hubs is handled internally, based on a foundation of trust. This trust has been established through the process of establishing a hub, which requieres transparency among other values. Since creating an energy hub is resource-intensive, participants are motivated to continue due to the collective investment already made.	0.429	Strong	≈
	b) External conflict resolution arena	ACM overarching and external, independent supervisor on conflicts	ACM overarching and external, independent supervisor on conflicts	ACM overarching and external, independent supervisor on conflicts	The external, independent agent that settles disputes is ACM. ACM is taking this role currently in the case of the GTO proposal. The DSO enforces external monitoring and hence sanctions by the energy hub. The ACM investigates if DSOs operate within legal mandate vis-á-vis energy hubs and individual consumers.			
7. Rights and recognition	Rights and recognition	CSP status. Grid check completed by the DSO, but no grid check has been executed by the TSO. Hub initiation took place before transport grid	Grid check by DSO and TSO. Fiats by DSO, TSO and ACM.	Initially no fiat given by DSO. Started a search for alternatives. Now grid check by DSO. No grid check by TSO due to the relatively limited capacity.	The regulatory recognizing party is ACM, which gives exemptions on grid codes and the electricity law. For the operation of energy management contracts, fiats are given by DSO and in case of severe congestion and complex interaction between grid levels (DP1 physical boundaries) the TSOs do so tool.	0.311	Weak	**X>**
8. Polycentric governance	Polycentric governance	7 decision making centers. Horizontal en vertical overlap. Autonomy and recognition from ACM and DSO	4 decision making centers. Horizontal en vertical overlap. Autonomy and recognition from ACM, DSO and TSO	5 decision making centers. Horizontal and vertical overlap. Autonomy and recognition from ACM and DSO	All energy hubs demonstrate strong characteristics of polycentricity with various types of overlap. The key to unlocking the benefits of the polycentricity is in this case autonomy, the room and recognition to experiment and hence the changing roles from the system operators as well as energy users (now prosumers) and the possibility of them to form a collective. Upstream grid issues are not enlightened by energy hubs. Vice versa, hubs and surrounding areas still depend on grid upgrades for more grid capacity.	0.262	Weak	**X>**

Table 11: *Synthesis and comparison of empirical results with meta-analysis on Ostrom's design principles by Cox et al. (2010)*

Explanation of individual effects of each design principle on energy commons management,

1. Cox et al. (2010) argue that social boundaries have a stronger role than physical boundaries in commons management. This was also identified in this study. The electricity grid spans geographical and jurisdictional scales and is meshed. The regional grid can be affected and limited by higher grid levels. Alternatively, disruptions on lower components can cascade into disbalances on higher grids. The physical 'boundary' in the strict sense of the word does not exist due to the interlinkages with other scales. However, in the case of energy hubs, the properties of the physical boundary (grid topology) and resource inputs and outputs (renewable energy sources and batteries) strongly constrain the possible groups that can be formed to manage the common.

   Establishing an energy hub requires a lengthy process. It involves creating juridical entities, intensive research regarding energy flows and flexibility potential and sharing data. Therefore, social boundaries are crucial for commons management and are shaped throughout the foundational process of energy hubs (Bauwens et al., 2024). Furthermore, energy hubs form a coalition, implying a set of mutual responsibilities and dependencies. This can directly impact business activities, which underscores the importance of relying on the commons group. In short, trust is essential to establish and maintain. Moreover, the grid operators must also trust the hub in managing the grid. A role that was previously exclusive to them (Duma et al., 2024). To conclude this means that the social boundaries of an energy hub and trust are significant for successful commons management. However, the process of defining the social boundaries potentially results in exclusion of non-participants (Bauwens et al., 2024).

2. Congruence on times of use, and the question of who uses which amounts are the core of grid usage contracts with the DSOs. The 'times of use' are clear and are settled in these contracts. In the case of a C-CBC, the time and quantity can be determined up until one day ahead. The GTO sets bandwidth for feed-in and appropriation in a clear manner. The contracts are therefore tailored to local circumstances, in line with empirical review by Cox et al. (2010).

   However, it is the responsibility of energy hubs to figure out how to make an equitable distribution of times-of-use, amounts of use and by whom. This raises two main questions: how are parties compensated for giving or taking grid capacity? And how do we value this grid capacity? The investigated energy hubs are still exploring these topics. This also ties into the rather awkward position energy hubs have vis-á-vis nonmembers. Energy hubs are currently researching how new parties can opt-in and compensate fairly for the already made efforts, and how the stability of the contracts can be ensured. Finally, cost-benefits allocation can be unequal between parties relative to their energetic contribution. The question is whether inequality is undesired in the case of collectively solving commons problems, or if hubs are to embrace the value of 'naoberschap': looking after each other.

3. Cox et al. (2010) find that local knowledge and the possibility to steer the energy hub bottom-up through collective agreements can benefit common pool resource management. However, this can be undermined by a weak organizational structure, disproportionately strong local powers, or external bureaucratic interference (Cox et al., 2010). The energy hubs are all established in sound legal entities with general member meetings and experience limited external decision-making pressure. Furthermore, the hubs are supported by ESCos on techno-economical matters.

   For participants in the energy hub, energy is not always a core business. Therefore, these entrepreneurs prefer to be unburdened instead of having to be involved in every aspect of the energy hub. Concludingly, Cox et al.'s (2010), finding of the moderate effect of design principle 3 is also resonated by the practices on Dutch energy hubs.

4. The meta-analysis by Cox et al. (2010) illustrates the strong effect of both internal and external monitoring on managing commons. This is also found in the case of energy hubs, where monitoring is constant and often near real time. Appropriators, the energy hub as an organization and external partners such as system operators can see individual and collective usage of the common through an energy management system. Due to the immediate and possibly dangerous effects of any exceedances on the energy grid, these systems have the potential to manage unwanted energy flows or even shut down systems. Without monitoring, especially in this very advanced manner, energy hubs would not have been feasible and energy hubs would possibly not have been trusted enough by both participants and DSOs to be allowed to manage energy flows and be collectively responsible. This underscores the strong effect of monitoring on energy commons management.

5. Cox et al. (2010) found moderate support for role of graduated sanctions in effective commons management. The case of energy hubs shows similar patterns although cross case differences exist in the way sanctions are handled. For example, ECAH makes use of relatively standard statutory arrangements, whilst Lage Weide operates with limited fixed sanctioning clauses. Either way, having graduated sanctions is not necessarily the strongest indicator for successful commons management. Due to the repeated interactions in the hub and with external actors, trust is fostered (Ostrom, 1990). Cox et al., describe that strong social capital can replace the need for graduated sanctions. The sanctions by system operators in case of exceedances are also standardized and no different from individual connections. However, the collective accountability is something that potentially nerves cooperations and insurance agencies.

6. Energy hubs have access to both local arenas as well as an external independent authority (ACM). This aligns with earlier studies on commons management (Cox et al., 2010). Frequent meetings and evaluations could be seen as a conflict resolution arena (Namujju, 2024). The energy management systems also help with resolution due to the detailed reporting they can generate.

7. Even though Cox et al. (2010) assess this principle as relatively weak, empirical findings of this thesis suggest that rights and recognition are vital in governing energy commons. In the Netherlands, energy and electricity are heavily regulated by the allocation of distinct roles (Gerritsen et al., 2023). These roles impose the unbundling of generation from transmission, distribution and retail (Bauwens et al., 2024, p.1) and are not fit for handling a complex

system of co-prosumers (Bauwens et al., 2024). There have been advancements in grid codes and laws (Dieperink & Bos, 2025), yet without fiats from system operators, for example to become a congestion service provider (ECAH), self-governing parts of the grid is very restricted. In absence of legal instruments, energy hubs have to find alternative avenues. Pannenweg has succeeded in this by sharing solar energy. However, the hub is not sharing grid capacity yet.

8. Due to the cross regional character of the grid, energy hubs need to operate in a polycentric manner and exhibit strong characteristics of such systems (see chapter 9.3). This finding is not aligned with Cox et al.'s (2010) description of principle 8 being *moderately supported*. In the case of energy hubs, polycentric governance is arguably the strongest contributor to enabling commons management. Before grid congestion, polycentricity did exist but with little to no autonomy for local scale actors.

With the rapid advances in distributed renewable energy sources came a question for regulators and system operators to redefine their role and adapt to a new reality where local grid consumers simultaneously become suppliers to the grid (Duma et al., 2024). In this new reality of decentralized systems, grid operators can no longer be regarded as the sole monopolists in grid management. On a local scale, energy hubs have the responsibility and autonomy to ensure that as a collective, the grid's limits are respected.

9.4.2. Towards Indicators of Successful Commons Management

As identified in the scientific relevance section (chapter 2.2), commons theory struggles to define successful outputs of commons management and rather focuses on identifying the institutional principles necessary for self-governance (Araral, 2014; Cox et al., 2010*)*. This thesis proposes two directions for consideration:

1. Financial independence

A successful output could be financial independence. Energy hubs are pioneering with shared responsibility and governance over fundamental infrastructure that was previously organized in a top-down manner. To achieve this, new legislation and contracts had to be developed, technology had to be tailored from case to case and participants had to build a general shared understanding of the purpose of an energy hub. Naturally, this is a time and cost-intensive process. Subsidies - that also aim to unlock the built-up knowledge for the greater good - can help with this process. However, commons management systems running autonomously from subsidies or funding would prove self-sufficiency of the self-governing entity, and build resilience against co-optation (Bauwens et al., 2024).

2. Scaling upwards and scaling out

Due to the physical properties of energy commons and the shared investment costs and fears of freeriding, an insider-outsider dichotomy between members and non-members not only exists but also implies the energy commons issue persists on a regional scale. When new members can participate or make use of the tools that were developed in an energy hub, such as the open-source energy management system (ECAH) or standard contracts (Smart Energy Hubs OOST Nederland, N.D.; Invest-NL, Kennedy van der Laan, 2024) the commons problem might be alleviated locally. However, due to upstream interdependencies, the commons problem of grid congestion is only holistically addressed once upscaling happens. This calls for energy management pools, not

necessarily in the form of an energy hub, but with the properties of a dense network of local energy generation, production and flexibility (in technical, behavioral and economic sense).

Another positive spillover effect of a commons pool management system could be that cooperating on one theme can inspire collectives to cooperate on different environmental challenges such as water, as ECAH is currently exploring. Social capital is already built through the process of organizing an energy hub and can form a solid base for expanding towards different themes.

9.4.3. Adaptation of Ostrom's Design Principles

This thesis identifies three alterations to Ostrom's design principles.

Trust should be regarded as design **principle 0**, before the physical and social boundaries. It forms the basis of a collective, uncertain process in which data and investment plans might be brought forward transparently, possibly with direct competitors. Parties should trust each other enough to remain in a bandwidth and be collectively responsible. Hence, initiation requires trust. Through repeated interactions, trust is built upon further. This is strengthened by having key individuals that are familiar with prospective participants and form a central point of communication for all stakeholders.

Principle 2, specifically the division of costs and benefits in combination with **principle 5** sanctions and **6** conflict resolution mechanism, could be enhanced by the organizational trait to look after each other (Naoberschap). While formal sanctions and mechanisms can be in place, the energy hubs operate based on social relationships, trust and collective accountability. By the time an energy hub is operating, mutual trust has been cultivated through the repeated interactions by participants. An enabling factor for this could be design principle 4: monitoring. Since the monitoring system is exceptionally precise and highly frequent.

10. Conclusion and Discussion

10.1 Research Goals and Questions

This research aimed to make an approach to an adaptation of Elinor Ostrom's Design Principles applied to energy commons. Furthermore, it tried to understand the interlinkages between energy hubs and higher scales focused on the electricity grid and polycentric governance (Bauwens et al., 2024), specifically taking into account a transforming institutional framework (Agrawal et al., 2023). The conclusion is drafted in a synthesizing manner, in which Ostrom's principles are related and merged rather than discussed separately like in chapter 9.4.

In conclusion, this thesis uncovered the complexity of grid interactions, showcasing the dependency of grid stability on upstream and downstream activities. An insight into the potential to locally alleviate grid congestion was given by analyzing three cases. However, this also uncovered tensions between insiders and outsiders of energy hubs, echoing earlier findings by Bauwens et al. (2024). The process of initiating an energy hub is resource intensive. As a result, energy hubs are still researching and trialing how to distribute costs, grid space, value grid capacity and creating a fair opt-in arrangement for new entrants. While energy hubs partially enlighten grid congestion for members, their magnitude is not sufficient yet to free up grid space locally. For this, a network of energy commons organizations is necessary.

Principle 2: congruence forms an interesting principle in the case of energy hubs. Questions such as how grid capacity is valued, by whom, at what time and in relation to reciprocity are not crystallized yet by the studied hubs. So far this does not result in 'failures. This element of congruence, in combination with the principles regarding sanctions and conflicts, are partially captured by the 'Naoberschap' value.

Energy commons management principles generally align with that of ´traditionally studied´ commons (Agrawal et al., 2023; Cox et al., 2010). The differences are that monitoring is automated, transparent, highly frequent and precise. Other common pool systems and energy pools (Namujju, 2024) describe how monitoring is practiced through human action, which can result into bias and error. This could lead to inadequate outcomes or even failing of the self-organization (Cox et al., 2010). However, it must be noted that while the energy management system automates and orchestrates energy flows, its underlying principles are shaped by human design and are therefore subject to potential disbalances.

All in all, energy management and monitoring play a significant role in the functioning of energy hubs. In-hub monitoring supports overall grid management while the energy management system and transparent dashboards serve as tools that can help leverage mutual trust between participants.

Another key difference between 'general commons' (Cox et al., 2010) and energy commons is the importance of principles 7: rights and recognition, and principle 8: polycentric governance. Autonomy turns out to be a vital characteristic of operational energy hubs, stressing the importance of principle 7 and 8.

Foundational to the establishment of energy hubs is the institutional shift of the energy regime. Polycentric governance was present 'before' the emergence of energy hubs. However, this system was reactive which resulted in a delayed response to the swift electrification of society.

Now, the shifting institutional roles of the regulator and system operators who also influence each other have paved way for more autonomy for smaller actors (like energy cooperatives) and governance decentralization, responding to the energy system at large that is becoming increasingly decentralized. This is also described as a 'distributed energy system' (Duma et al., 2024; Wolsink, 2020). This demonstrates that polycentric governance systems should be studied considering the adaptivity or instability of institutional factors. Thereby responding to Agrawal's (2023) call to research commons problems from an institutional dynamic perspective. This thesis uncovered a theoretical inconsistency of polycentric governance between the experimentation – upscaling process and the institutional fit, as earlier identified by Voß & Schroth, 2018.

Finally, the studied energy hubs are – in varying ways - collectively managing the energy grid, generation, consumption, flexibility and storage. However, energy hubs are still in a startup phase, supported by subsidies, funding and a pioneering spirit. Whether these energy hubs will evolve into self-sustaining, independent entities is something that future developments will determine. Moreover, the hubs currently cause an insider-outsider distinction (Bauwens et al., 2024). Addressing the commons in a commons organization is not accessible for all, as indicated by Wolsink (2020).

10.2 Limitations and Scientific Recommendations

This thesis did not include a critical assessment of sustainability aspects of the energy hub concepts hubs with regards to system optimization. Although the goal of energy hubs is to free up grid capacity, it is not always critically assessed if this space is meant for scaling up production or for decarbonizing industrial processes. It could be argued that growing within the current 'growth-based paradigm' is inherently not sustainable and undermines Paris 2015 goals (Bauwens et al., 2024, p.12).

Optimizing the usage of grid efficient is resource efficient, if referring to the resources needed for grid cables and convertors. However, the broader environmental impact - the 'scope 2 and 3' of energy hubs – is not necessarily sustainable, as stressed by Bauwens et al. (2024). Future research could be aimed at developing an assessment framework for a more comprehensive analysis of the sustainability of energy and grid optimizations.

A methodological limitation of this study is the small number of cases that were included, limiting the generalizability of findings. To overcome this limitation, future research using large-N statistical analyses could be valuable to validate and generalize the proposed adaptations of Ostrom's design principles made in this thesis.

Another key limitation is the reproducibility of the research because of the cross-case synthesizing method that has been chosen. The researcher's background can affect the interpretation of data and the design of a coding scheme. In response to this, a detailed code book is provided as well as reflexivity on the researchers' position and the abductive process of this research.

Sampling-wise, this thesis was limited by a timeframe. This resulted in the exclusion of energy hubs that operate with a closed distribution system (gesloten distributiesysteem or GDS). Such a system operates more autonomous than the hubs studied in this thesis and are – however not fully – less dependent on higher grid scales and could therefore generate valuable insights regarding autonomy and upstream dependencies. Furthermore, a GDS would provide analytical value because of the role of system operator is effectively taken on by an entity within the GDS. Future research could benefit from comparing GDS models to other self-governance systems, like the ones studied in this thesis.

This thesis focused primarily on the governance of energy commons from a polycentric point of view. Combined with time constraints, this focus meant that actual participants of energy hubs, such as representants of companies, were not interviewed. Future research could include a more in-depth exploration of participants and thereby potentially uncover power dynamics within polycentric governance. Voß and Schroth (2018) have signaled that this is a blind spot of contemporary polycentric governance theory. Researching the micro aspects of energy commons could also offer interesting insights into participants' engagement with energy monitoring, which can reflect Foucauldian notions of discipline and normalization in the context of the panopticon (Foucault, 1977).

Other directions for future research include:

Close examination of the implementation of GTOs and C-CBCs. Surveying the long-term stability and success of energy commons. The potential for synergies with other sectors or areas of society like neighborhoods or horti- and agriculture. The potential of other contractual arrangements and their suitability for different types of hubs (scale and sector wise) beyond this thesis scope of GTOs and C-CBCs.

Exploration of the complex interactions between time, technical properties, supply, demand, legal frames, business operations and reciprocity in determining the value or willingness to pay for grid space within grid usage agreements. This could be researched through an interdisciplinary collaboration including but not limited to economics, commons research and mathematical modelling, among other disciplines.

In addition, an attempt could be made to calculate grid flexibility tipping points. These points indicate thresholds where flexible capacity is densely concentrated and well meshed. This allows for a potential reduction of the need for additional infrastructure, which could eventually lower the costs that are passed on to citizens through socialization and higher grid tariffs (Wolsink, 2020).

10.3 Practical Recommendations

The current energy hub stimulation program is aimed at supporting hubs-in development. With an expectation of realizing of 60 to 70 promising initiatives (Jetten, 2024). From the conclusions of this thesis, it can be argued that the energy hub should not be considered as an end in themselves but seen as an instrument to stimulate local flexibility and cooperation. This does not always imply establishing an energy hub or cooperation or signing contracts with DSOs.

As demonstrated by the case studies, getting an energy hub to the operational phase takes significant effort and can be highly complex. Furthermore, for true impact, a dense network of flexibility and local coordination between generation and consumption has to be developed. This network does not necessarily have to follow the energy hub format, considering the long procedure and current legal limitations to certain contracts. The energy hub model is not the most optimal solution for each case.

Despite efforts to scale up contracts, tools and organizational structures, as also embedded in the program (Jetten, 2024; RVO-A, 2025), energy hubs create a division between members and non-members. Not all actors can participate yet. Therefore, critical examination is required to see if the energy hub concept can be simplified, for example by forming smaller coalitions or by looking at solutions that rely less on external fiats and more on entrepreneurial initiative.

A lot of propositions and contracts are currently being developed. While it is encouraging to see that DSOs and other parties are evolving in their new role within a distributed energy system, the growing

number of propositions increase the complexity of the playing field, which could lead to paralysis or slower the implementation of measures. A recommendation could be to focus on ‘what we have now’ and ensure that these propositions function and are being adopted, rather than constantly introducing new propositions.

10.4 Reflection

Research process

In 2024, I started working within the energy transition sector. For me this meant I had to shift from the academically driven, scientific approach I learned at university to a practice-oriented approach which asks for different methods and reporting. From the first semester of this academic year both work and study ran parallel, which allowed me to practice with both ways of working. This work experience has built a somewhat pragmatic approach in me, which is also the rationale of this thesis. The setup of this thesis is in line with pragmatist thinking, in the sense that it is oriented towards problem solving. The thesis aims to contribute to practical implications of principles within energy hubs and is not bound to single techniques or scientific methods (Cresswell, 2007).

The most challenging part of this thesis was to develop a conceptual model that integrates both commons theory and polycentric governance, in the context of a relatively novel phenomenon like energy hubs. This took some iterations and eventually also influenced the abductive methodological approach of this thesis. Both theories, however, proved to be an effective lenses to work with in this research topic and helped to elucidate specific information. Something that was necessary since this thesis spans diverse topics including technology, law, economics and governance. The vastness of this thesis is also something I was challenged by. I made a conscious effort to focus and demarcate the research topic, however, as often the case with GPE problems, a lot of branches are integrated.

Data collection

Given the limited time frame between developing a sound interview guide and the writing down results, I tried to plan interviews proactively. Unintentionally, I arranged the interview with ACM relatively early. For my understanding of the concepts I was studying and the relationships between actors, specifically DSOs and energy hubs, it would have been better to plan this interview after the interviews with other respondents. In general, I noticed there were moments where additional probes could have uncovered even more links and aspects of energy commons governance. However, interviewing, critically listening and acting simultaneously can sometimes be challenging.

Abductive approach

The abductive approach contributed to the possibility to redraft Ostrom’s design principles. After the collection of data and initial rounds of coding, I realized I had operationalized polycentric governance inadequately to be integrated in commons theory. Hence, additional operationalization was conducted after which the data was revisited, in line with abductive coding practice (Vila-Henninger et al., 2024).

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Appendix I: Interview Guides

This appendix contains the interview guides used to collect data in this thesis. The guides were developed based on the theoretical and conceptual framework. Since all interviewees were Dutch, interviews were conducted in Dutch. Hence, the interview guide is presented in Dutch to ensure content integrity of the conducted interviews and English to facilitate reproducibility and validation by the second reader.

Interview Guide Energy Hubs

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Inleiding

U heeft een uitnodiging gekregen voor een wetenschappelijk onderzoek van de Radboud Universiteit. U krijgt eerst uitleg over het onderzoek. Lees deze informatie rustig door. Daarna kunt u aangeven of u mee wilt doen.

Waarover gaat het onderzoek?

Dit onderzoek richt zich op de governance structuren die worden gehanteerd in energiehubs om het lokale energienet optimaal te benutten, en om energie uit te wisselen. Dit gebeurt vanuit de theoretische invalshoek van *Commons management,* gemunt door Elinor Ostrom. Onderwerpen die aan bod komen zijn netcongestie, samenwerking op een bedrijventerrein en samenwerking tussen een bedrijventerrein en externe (overheids)partijen.

Mijn thesis gaat over hoe zogeheten energy hubs op Nederlandse bedrijventerreinen gezamenlijk het lokale energienet beheren. Ik bekijk dit vanuit het idee van commons – gedeelde hulpbronnen die door meerdere partijen worden gebruikt én beheerd, zoals lokaal opgewekte energie of netcapaciteit.

Om dit te analyseren gebruik ik de Design Principles van Elinor Ostrom. Zij heeft onderzocht waarom sommige gemeenschappen in staat zijn om gedeelde middelen (zoals water of bossen) duurzaam te beheren. Haar principes geven richtlijnen voor succesvol collectief beheer; zoals bijvoorbeeld duidelijke regels, inspraak van deelnemers, en goede afspraken over toezicht en conflictoplossing.

Ik pas deze principes toe op energy hubs, omdat het elektriciteitsnet op bedrijventerreinen steeds vaker een gedeelde, schaarse hulpbron wordt. Door netcongestie moeten bedrijven samenwerken om het beschikbare net slim te gebruiken. Met mijn onderzoek wil ik beter begrijpen hoe die samenwerking in de praktijk werkt, welke governance-structuren er zijn, hoe ze omgaan met andere partijen zoals netbeheerders en overheden, en hoe de principes van Ostrom hierbij helpen of juist ontbreken.

Wat wordt er van u verwacht?

In dit onderzoek wordt u geïnterviewd door Ward Boots, bachelor student Geografie Planologie en Milieu. Als u toestemming geeft, wordt er een geluidsopname van deze interviews/observaties gemaakt om de nauwkeurigheid van het onderzoek te waarborgen. De opname wordt gebruikt voor het onderzoek. Een interview duurt ongeveer één uur. U wordt misschien gevraagd om meer dan één interview.

In het interview stel ik u vragen over de werking van energyhubs vanuit technisch, economisch, governance and juridisch perspectief. Voorbeelden van vragen zijn: "Hoe wordt bepaald wie op welk moment toegang heeft tot welke middelen (eenheden van energie of netruimte)?" en “Wat is de rol van de netbeheerder in het oprichten van de energy hub?”

Anonimiteit

Het opgenomen interview wordt gebruikt om onderzoeksvragen te beantwoorden. Dit interview is volledig anoniem, de resultaten zullen geanonimiseerd opgeschreven worden. Wanneer er resultaten beschikbaar zijn zullen deze eerst met de respondenten worden gedeeld. Mocht u zich niet langer comfortabel voelen, dan is er de mogelijkheid om dit aan te geven. De data zal dan niet langer voor het onderzoek worden gebruikt.

Vrijwilligheid

Als u tijdens het interview besluit dat u niet meer wil verder gaan dan zullen we direct stoppen met het interview. U bepaalt zelf of u meedoet aan dit onderzoek. Dat is vrijwillig. U mag altijd nee zeggen. U hoeft geen vragen te beantwoorden waar u liever geen antwoord op geeft. U mag op elk moment tijdens het onderzoek stoppen en uw toestemming intrekken.

Praktische zaken:

- Hoe zitten we met tijd, heeft u aansluitend afspraken of is er ruimte voor uitloop?
- Deelname aan het interview is vrijwillig. U bent vrij om elk moment te stoppen.
- Alles wat we bespreken is vertrouwelijk en alleen bestemd voor dit onderzoek. Ik zal niet in de andere interviews aanhalen wat we hier bespreken.
- Zijn er voor de rest nog vragen?
- Dan zal ik nu beginnen met het afnemen van het interview.

A. Introductie vragen

1. Wat is uw functie?
2. In welke rol bent u betrokken bij de energy hub?
3. Voor hoe lang bent u betrokken bij de energy hub?
4. Wat voor type bedrijven zijn er gevestigd op het bedrijventerrein?
5. Welke bedrijven nemen deel aan de energy hub (EH)?
6. Welk type overeenkomst is er met de TSO/DSO?

7. Hoe is de energie hub aangesloten op het hoog/midden/laagspanningsenergienetwerk? Of op (onbalans)markten?

B. Eigenschappen van de energiehub

Design principe (DP) 1 **Duidelijk afgebakende grenzen**	Beschrijving van het bedrijventerrein (BT)	8. Hoe hebben bedrijven op het BT samengewerkt voor de initiering van EH? 9. Wie zijn de stakeholders in de energiehub en wat zijn hun verantwoordelijkheden? 10. Hoeveel partijen doen er mee?
	Beschrijving van EH	11. Wat waren de drijfveren (economisch, productie-uitbreiding, elektrificatie, betrouwbaarheid, milieu) voor de start van de EH? 12.Wat waren de redenen om deel te nemen voor bedrijven 13 Wat waren redenen voor bedrijven om niet deel te nemen a) externe barrieres (buiten macht bedrijf) b) intrinsieke motivatie 14 Zijn er gevallen dat partijen worden uitgesloten voor deelname? Waarom? 15. Wie nemen er deel aan de EH (overheidsinstanties, ESCo)? > Waarom nemen deze partijen (niet) deel?

C. Commons management in de energiehub

DP2 **Overeenstemming regels en lokale omstandigheden**	Harmonie van toe-eigening en verdeling	16. Hoe wordt bepaald wie op welk moment toegang heeft tot welke bronnen (energie-eenheden of netruimte)? 17. Hoe worden kosten verdeeld in EH?
DP3 **Collectieve afspraken**	Afspraken binnen EH	18. Is er een parkmanager/sleutelfiguur A. Wat is hun mandaat? B Hoe faciliteert de parkmanager/sleutelfiguur samenwerking en afstemming in de energy hub? 19. Is de EH georganiseerd in een juridische entiteit? A. Wat voor juridische entiteit? B. Wat waren redenen om te kiezen voor deze juridische entiteit 20. Hoe worden gegevens gedeeld in de energiehub? A. Onder welke voorwaarden 21. Hoe worden gezamelijke investeringen gemaakt? 22. Hoe is het eigendom van assets (zoals: batterijen, energiebeheersystemen, laadpunten, zonnepanelen, kabels) georganiseerd? 23. Hoe kunnen partijen zich in- en uitschrijven voor energiehub? 24. Hoe komen afspraken over energiegebruik tot stand?
DP 4 monitoring	Intern	25. Hoe wordt de naleving van energieverbruiksafspraken gecontroleerd? En door wie?
	Extern	26. Hoe monitoren de TSO/DSO de energieactiviteiten op de EH?
DP 5 sancties	Interne sancties	27. Wat voor sanctioneringen zijn er voor overtreders?
	Externe sancties	28. Wat voor sanctioneringen zijn er vanuit de TSO/DSO richting de EH in het geval van overtredingen?
DP 6 **Conflict resolutie mechanismen**	Conflict resolutie arenas	29.Hoe worden conflicten binnen de EH opgelost? 30. Is er een centrale externe partij die het gebruik van de *commons* bewaakt? > Hoe kan deze partij ingrijpen?
DP 7 **Erkenning en recht tot organiseren**	Erkenning	31. Worden de afspraken binnen de Energy Hub erkend door overheidsinstanties, de ACM of DSO/TSO? Op welke wijze?
	Recht op organisatie	32. Welke juridische procedures moesten de initiatiefnemers van Energy Hub doorlopen om de EH op te richten? En welke vergunningsprocedures?

		33. Wat was de rol/het mandaat van de TSO/DSO om de EH in werking te laten treden? A Heeft de TSO/DSO een grid stress-check uitgevoerd?
DP 8 Polycentric Governance	Besluitvormingscentra	34.Welke andere partijen hebben een formele beslissingsrol in de Energy Hub, inclusief het recht om voor of tegen voorstellen te stemmen? A) Initiatiefase B) Operationele fase 35. Hoe ziet de afstemming eruit met andere andere supralokale (net)ontwikkelingen? 36. Hoe werkt de EH samen met bevoegd gezag? 37. Wordt EH gesubsidieerd door de (overheidspartijen)? Of andere externe partijen? Op welke wijze? Waarom wel/niet?

38. Welke andere eigenschappen of factoren dragen bij aan het functioneren van de energiehub?

39. Heeft u verder nog toevoegingen of vragen?

Interview Guide DSOs

A. Inleidende vragen

1. Wat is uw functie?
2. In welke rol bent u betrokken bij de energiehub?
3. Hoe lang bent u al betrokken bij de energiehub?
4. Wat is de huidge status van het net in het deelgebied waarin de energiehub gelegen is?

B. Colmonts management in Energy Hub

5. Kun je beschrijven wat het proces is om [energiehub] op te starten vanuit de rol van [netbeheerder]?

6. Zijn er gevallen dat partijen worden uitgesloten voor deelname? Waarom

DP2 **Congruence: rules and local conditions**	Harmony of appropriation and distribution.	7. Hoe wordt bepaald wie op welk tijdstip toegang heeft tot welke bronnen (energie-eenheden of netwerkruimte)? Wat is de rol van Enexis hierin? 8. Hoe worden de kosten verdeeld in die nodig zijn om energie hub op te richten? 9. Hoe wordt gecommuniceerd met EH over toekomstige ontwikkelingen/huidig beheer? Extra aansluitingen aanleggen? 10. Welke vormen van congestiemanagement worden verder toegepast? (Indien van toepassing).
DP 4 monitoring	Internal monitoring	11. Hoe wordt de naleving van energieverbruiksafspraken gecontroleerd?
	External monitoring	12. Hoe monitoren de TSO/DSO de energieactiviteiten op de EH?
DP 5 Sanctions	Internal sanctions	13. Wat voor sanctionering zijn er voor overtreders?
	External sanction	14. Wat voor sanctioneringen zijn er vanuit de DSO richting de EH in het geval van overtredingen?
DP 6 Conflict resolution mechanisms	Conflict resolvance arenas	15. Neemt de DSO deel aan conflictresolutie in EH? Bijvoorbeeld door meetdata te delen? 16. Hoe worden conflicten tussen EH en DSO geadresseerd?
DP 7 Recognition and rights to organize	Rights to organize	17 Wat was de rol/het mandaat van DSO om de EH in staat te stellen te gaan werken? A Heeft DSO een grid stress check uitgevoerd? 18. Hoe verloopt samenwerking met ACM?

		19. Hoe verloopt samenwerking met andere netbeheerders? 20. Hoe ziet de afstemming met TenneT eruit (indien van toepassing)? 21. Wat zijn de eisen vanuit de netbeheerder voor het afsluiten van een GTO?/C-CBC > Wettelijk en technisch? 22. Wat zijn de eisen vanuit de netbeheerder voor het oprichten van een EH? 23. Hoe kunnen expliciete afspraken met netbeheerders over vermogensgrenzen en flexibiliteit bijdragen aan een betrouwbare en efficiënte netinfrastructuur, en hoe moeten afwijkingen van deze afspraken worden beheerd?
DP 8	Centers of decision-making	24.Welke andere partijen hebben een formele beslissingsrol in de Energy Hub, inclusief het recht om voor of tegen voorstellen te stemmen? A) Initiatiefase B) Operationele fase 25. Was er coördinatie met andere supralokale (net)ontwikkelingen? 26> Hoe werkt de netbeheerder samen met andere DSOs 27 Hoe werkt de netbeheerder samen met de TSO. 28. Hoe werkt de netbeheerder samen met bevoegd gezag? 29. Hoe werkt de netbeheerder samen met ESCo? 30. Hoe werkt de netbeheerder samen met ACM?

31. Werkt [DSO] nog aan nieuwe proposities met andere [energiehub], netbeheerders of ACM

32. Zijn er kenmerken/belangrijke factoren van EH die we nog niet besproken hebben? Kun je een beschrijving geven.

Interview Guide TSO

A. Inleidende vragen

1. Wat is uw functie?

2. In welke rol bent u betrokken bij de energiehub? (geselecteerde case in specifiek DSO-gebied)

3. In welke rol draagt u bij aan energiehubs? In DSO-servicegebied

4. Hoe lang bent u al betrokken bij de energiehub?

B. Netkenmerken

6. Wat is het type overeenkomst met de TSO/DSO?

Netkenmerken (DP1)

7. Hoe ernstig is de netcongestie in de buurt van de case? (Hoge midden- en lage spanning?)

8. Hoe is de energiehub aangesloten op het net?

9. Hoe lang duurt het voordat er netwerkuitbreidingen in dit gebied worden uitgevoerd?

DP2 **Congruence: rules and local conditions**	Harmony of appropriation and provision	10. Hoe wordt bepaald wie op welk moment toegang heeft tot welke middelen (energie-eenheden of netcapaciteit)? 11. Hoe komen afspraken over hoe om te gaan met situaties waarin er congestie op het net ontstaat, tot stand? 12. Hoe de kunnen DSO en de energiehub anticiperen op situaties met netschaarste? 13. Hoe werken eventuele vergoedingen voor diensten die de energie hub aan het net levert, zoals het bieden van flexibiliteit of noodstroom in tijden van schaarste?
DP 4 monitoring	Internal monitoring	16. Hoe wordt de naleving van energieverbruiksafspraken gecontroleerd? Op collectief niveau, per ring, per subgroep en per aansluiting.
	External monitoring	17. Hoe monitort de DSO de energieactiviteiten op de EH?

		18. Hoe monitort de TSO het net van de DSO?
DP 5 Sanctions	Internal sanctions	18. Wat voor sanctionering zijn er voor overtreders?
	External sanction	19. Wat voor sanctioneringen zijn er vanuti de TSO richting de EH in het geval van overtredingen?
DP 6 **Conflict resolution mechanisms**	Conflict resolvance arenas	20. Neemt de TSO-deel aan conflictresolutie in EH? Bijvoorbeeld door meetdata te delen? Waarom wel/niet?
DP 7 Recognition and rights to organize	Rights to organize	22. Wat was de rol/het mandaat van DSO om de EH in staat te stellen te gaan werken? A Heeft TSO een grid stress check uitgevoerd? Hoe zag dit eruit? Waarom wel/niet?
DP 8 Polycentric Governance	Centers of decision-making	20. Wat is het type overeenkomst met de TSO? 21. Hoe vindt er afstemming plaats met andere supra lokale (net)ontwikkelingen? 22. Hoe werkt TSO samen met bevoegde gezagen? 23. Kan een energiehub ruimte vrijmaken voor regionale aansluitingen? Zo ja, hoe? Zo nee, waarom niet? 24. Hoe beïnvloeden de netten van de DSO en TSO elkaar?

25. Zijn er andere belangrijke kenmerken of factoren van energiehubs die we nog niet hebben besproken? Zo ja, kunt u deze beschrijven?

Interview Guide ACM

A. Introductory questions

1. Wat is uw functie?
2. In welke rol bent u betrokken bij de energy/energiewet?
3. Voor hoe lang bent u betrokken bij de energy hub?

B. Questions regarding ACM's role in energy regulation

4. Hoe maakt ACM deze nieuwe contracten, ism overheden/netbeheerders en innitiatieven?

5. Hoe voorkomt ACM gridlock (kip-ei problem) zonder interruperen van de vrije markt?

6. Wie zijn de decision-makers bij een netcode wijziging?

7. Hoe worden netinvesteringsplannen getoetst op redelijkheid? (art 21 elektriciteitswet)

8. Wat is de rol van ACM in de energietransitie?

9. Wat is de rol van ACM bij het toestaan van een energiehub?

10. *"De maatregelen die de ACM neemt worden alleen een succes als de netbeheerders er voortvarend mee aan de slag gaan en afnemers gebruik maken van de nieuwe mogelijkheden?"*

Waarom? Wat is voortvarend aan de slag gaan. Dwingt de acm dit verder af?

11. Hoe gaat de ACM adoptie van nieuwe proposities monitoren?

12. *De ACM wil netbeheerders ruimte geven om te experimenteren om netcapaciteit efficiënter te gebruiken. Indien het experiment vooruitloopt op de Energiewet of nieuwe regels in energiecodes, kan de ACM die ruimte mogelijk geven door op verzoek te gedogen.*

Onder welke voorwaarden, en was dit ook het geval bij een van de cases?

C. Commons management in the Energy Hub

DP3 collectieve afspraken		13.Hoe werkt het opstellen van een nieuw contract? 14. Hoe werkt een netcode wijziging?
DP 4 monitoring		15. Hoe monitort ACM de naleving van contracten? 16. Hoe monitort ACM TSO/DSO
		17. Wat voor informatie is relevant om te bepalen of een codewijziging wenselijk is?
DP 5 sancties	Interne sancties	18. Wat voor sanctioneringen zijn er voor overtreders?
	Externe sancties	19. Wat voor sanctioneringen zijn er vanuit de TSO/DSO richting de EH in het geval van overtredingen?
DP 6 **Conflict resolutie mechanismen**	Conflict resolutie arenas	20.Hoe worden conflicten tussen Netbeheerder/EH opgelost 21. Is er een centrale externe partij die het gebruik van de *commons* bewaakt? 22. Hoe kan deze partij ingrijpen? Hoe kan ACM ingrijpen? 23. Hoe bewaakt de ACM de balans tussen het bevorderen van marktconcurrentie en het ondersteunen van decentrale, door de gemeenschap geleide energiesystemen?
DP 7 **Erkenning en recht tot organiseren**	Erkenning	24. Worden de afspraken binnen de Energy Hub erkend door overheidsinstanties of de ACM?
	Recht op organisatie	25. Welke juridische procedures moesten de initiatiefnemers van Energy Hub doorlopen om de EH op te richten?
DP 8 Polycentric Governance		26. Hoe wordt het prioriteringskader opgesteld? 27. Hoe verhoudt de vrijgekomen netruimte door energiehubs zich tot het prioriteringskader?

English Interview Guides
Interview guide Energy Hubs

A. Introductory questions

1. What is your function?

2. In what role are you involved in the energy hub?

3. How long have you been involved in the energy hub?

4. What types of companies are located on the industrial park?

5. Which companies are participating in the energy hub (EH)?

6. What type of agreement is there with the TSO/DSO?

7. How is the energy hub connected to the high/medium/low voltage energy network? Or to (imbalance) markets?

B. Properties of the energy hub

Design principle (DP) 1 **Clearly defined boundaries**	Description of the business park (BT)	8. How have companies at the BT collaborated to initiate EH? 9. Who are the stakeholders in the energy hub and what are their responsibilities? 10. How many parties are participating?
	Description of EH	11. What were the drivers (economic, production expansion, electrification, reliability, environment) for the start of the EH? 12.What were the reasons for companies to participate? 13 What were the reasons for companies not to participate? a) external barriers (beyond the company's control) b) intrinsic motivation 14 Are there cases where parties are excluded from participation? Why? 15. Who participates in the EH (government agencies, ESCo)? > Why do these parties (not) participate?

C. Commons management in the energy hub

DP2 **Agreement on rules and local circumstances**	Harmony of appropriation and distribution	16. How is it determined who has access to which resources (energy units or grid space) at what time? 17. How are costs divided in EH?
DP3 **Collective agreements**	Appointments within EH	18. Is there a park manager/key figure? A. What is their mandate? B How does the park manager/key figure facilitate cooperation and coordination in the energy hub? 19. Is the EH organised in a legal entity? A. What kind of legal entity? B. What were the reasons for choosing this legal entity? 20. How is data shared in the energy hub? A. Under what conditions? 21. How are joint investments made? 22. How is the ownership of assets (such as: batteries, energy management systems, charging points, solar panels, cables) organised? 23. How can parties register and deregister for energy hub? 24. How are agreements on energy use made?
DP 4 monitoring	Internal	25. How is compliance with energy consumption agreements monitored? And by whom?
	External	26. How do the TSO/DSO monitor energy activities on the EH?
DP 5 sanctions	Internal sanctions	27. What sanctions are there for offenders?
	External sanctions	28. What sanctions are there from the TSO/DSO towards the EH in the event of violations?

DP 6 **Conflict resolution mechanisms**	Conflict resolution arenas	29.How are conflicts resolved within the EH? 30. Is there a central external party that monitors the use of the *commons* ? > How can this party intervene?
DP 7 **Recognition and right to organize**	Recognition	31. Are the agreements within the Energy Hub recognised by government agencies, DSOs/TSO or the ACM? Explain how
	Right to organize	32. What legal procedures did the Energy Hub initiators have to go through to set up the EH? And what permit procedures? 3 3. What was the role/mandate of the TSO/DSO in putting the EH into effect? A Did the TSO/DSO perform a grid stress check?
DP 8 Polycentric Governance	Decision-making centers	34.Which other parties have a formal decision-making role in the Energy Hub, including the right to vote for or against proposals? A) Initiation phase B) Operational phase 35. What is the coordination like with other supra-local (network) developments? 36. How does the EH cooperate with the competent authority? 37. Is EH subsidized by (government parties)? Or other external parties? How/why not?

38. What other characteristics or factors contribute to the functioning of the energy hub?

39. Do you have any further additions or questions?

Interview guide DSOs

A. Introductory questions

1. What is your position?
2. In what role are you involved in the energy hub?
3. How long have you been involved with the energy hub?
4. What is the current status of the grid in the sub-area in which the energy hub is located?

B. Commons management in Energy Hub

5. Can you describe the process of starting up [energy hub] from the role of [grid operator]?

6. Are there cases where parties are excluded from participation? Why?

DP2 **Congruence: rules and local conditions**	Harmony of appropriation and distribution.	7. How is it determined who has access to which resources (energy units or network space) at what time? What is Enexis' role in this? 8. How are the costs allocated that are needed to set up the energy hub? 9. How is communication with EH about future developments/current management? Installing additional connections? 10. What other forms of congestion management are applied? (If applicable).
DP 4 monitoring	Internal monitoring	11. How is compliance with energy consumption agreements monitored?
	External monitoring	12. How do the TSO/DSO monitor energy activities on the EH?
DP 5 Sanctions	Internal sanctions	13. What kind of sanctions are there for offenders?
	External sanction	14. What sanctions are there from the DSO towards the EH in the event of violations?
DP 6 Conflict resolution mechanisms	Conflict resolution arenas	15. Does the DSO participate in conflict resolution in EH? For example by sharing measurement data? 16. How are conflicts between EH and DSO addressed?
DP 7 Recognition and rights to organize	Rights to organize	17 What was DSO's role/mandate in enabling the EH to start working? A Has DSO performed a grid stress check? 18. How does cooperation with ACM work? 19. How does cooperation with other grid operators work? 20. What does the coordination with TenneT look like (if applicable)?

		21. What are the requirements of the grid operator for concluding a GTO?/ C-CBC > Legal and technical? 22. What are the requirements of the grid operator for establishing an EH? 23. How can explicit agreements with grid operators on power limits and flexibility contribute to a reliable and efficient grid infrastructure, and how should deviations from these agreements be managed?
DP 8 Polycentric governance	Centers of decision-making	24.Which other parties have a formal decision-making role in the Energy Hub, including the right to vote for or against proposals? A) Initiation phase B) Operational phase 25. Was there coordination with other supra-local (network) developments? 26> How does the grid operator collaborate with other DSOs? 27 How does the grid operator work together with the TSO? 28. How does the grid operator cooperate with the competent authority? 29. How does the grid operator work together with ESCo? 30. How does the grid operator work together with ACM?

31. Is [DSO] still working on new propositions with other [energy hub], grid operators or ACM?

32. Are there any characteristics/important factors of EH that we have not yet discussed? Can you provide a description?

Interview guide TSO

A. Introductory questions

1. What is your position?

2. In what role are you involved in the energy hub? (selected case in specific DSO area)

3. In what role do you contribute to energy hubs? In DSO service area

4. How long have you been involved with the energy hub?

B. Network characteristics

6. What is the type of agreement with the TSO/DSO?

Network characteristics (DP1)

7. How severe is the grid congestion near the case? (High medium and low voltage?)

8. How is the energy hub connected to the grid?

9. How long will it take before network expansions are implemented in this area?

DP2 **Congruence : rules and local conditions**	Harmony of appropriation and provision	10. How is it determined who has access to which resources (energy units or grid capacity) at what time? 11. How are agreements made on how to deal with situations in which congestion arises on the network? 12. How can DSO and the energy hub anticipate situations with grid shortages ? 13. How do any compensation work for services that the energy hub provides to the grid, such as providing flexibility or emergency power in times of scarcity?
DP 4 monitoring	Internal monitoring	16. How is compliance with energy consumption agreements monitored? At collective level, per ring, per subgroup and per connection.

	External monitoring	17. How does the DSO monitor energy activities at the EH? 18. How does the TSO monitor the DSO network?
DP 5 Sanctions	Internal sanctions	18. What kind of sanctions are there for offenders?
	External sanction	19. What sanctions are there from the TSO towards the EH in the event of violations?
DP 6 **Conflict resolution mechanisms**	Conflict resolution arenas	20. Does the TSO participate in conflict resolution in EH? For example by sharing measurement data? Why/why not?
DP 7 Recognition and rights to organize	Rights to organize	22. What was DSO's role/mandate in enabling the EH to start working? A Did TSO perform a grid stress check? What did this look like? Why/why not?
DP 8 Polycentric Governance	Centers of decision -making	20. What is the type of agreement with the TSO? 21. How is coordination with other supra-local (network) developments taking place? 22. How does TSO cooperate with competent authorities? 23. Can an energy hub free up space for regional connections? If so, how? If not, why not? 24. How do the DSO and TSO networks influence each other?

25. Are there other important characteristics or factors of energy hubs that we have not discussed? If so, can you describe them?

Interview guide ACM

A. Introductory questions

1. What is your position?
2. In what role are you involved in the energy law?
3. How long have you been involved with the energy hub?

B. Questions regarding ACM's role in energy regulation

4. How does ACM create these new contracts, in collaboration with governments/grid operators and initiatives?

5. How does ACM prevent gridlock (chicken-egg problem) without interrupting the free market?

6. Who are the decision-makers in a network code change?

7. How are grid investment plans tested for reasonableness? (Article 21 Electricity Act)

8. What is the role of ACM in the energy transition?

9. What is the role of ACM in allowing an energy hub?

10. *"The measures that the ACM takes become only A success if the grid operators get to work on it quickly and customers usage making the new possibilities ?"*

Why? How does ACM stimulate this?

11. How does the ACM handle the adoption of new propositions monitors?

12. *The ACM wants to give grid operators room to experiment to use grid capacity more efficiently. If the experiment anticipates the Energy Act or new rules in energy codes, the ACM may be able to give that room by tolerating on request.*

Under what conditions, and was this also the case in any of the cases?

C. Commons management in the Energy Hub

DP3 collective agreements		13.How does drawing up a new contract work? 14. How does a network code change work?
DP 4 monitoring		15. How does ACM monitor compliance with contracts? 16. How does ACM monitor TSO/DSO?
		17. What information is relevant to determine whether a code change is desirable?
DP 5 sanctions	Internal sanctions	18. What sanctions are there for offenders?
	External sanctions	19. What sanctions are there from the TSO/DSO towards the EH in the event of violations?
DP 6 **Conflict resolution mechanisms**	Conflict resolution arenas	20.How are conflicts between Grid Operator/EH resolved? 21. Is there a central external party that monitors the use of the *commons*? 22. How can this party intervene? How can ACM intervene? 23. How does the ACM monitor the balance between promoting market competition and supporting decentralized, community – led energy systems?
DP 7 **Recognition and right to organize**	Recognition	24. Are the agreements within the Energy Hub recognised by government agencies or the ACM?
	Right to organize	25. What legal procedures did the Energy Hub initiators have to go through to set up the EH?
DP 8 Polycentric Governance		26. How is the prioritization framework established? 27. How does the grid capacity released by energy hubs relate to the prioritization framework?

Appendix II: Codebook

The codebook demonstrates how the theoretical and conceptual framework were operationalized. This codebook offers guidance for conducting systematic data analysis. Code groups are indicated by the format **[CODENAME]x** in bold. Codes marked in blue indicate later adaptations, in line with the abductive methodological approach of this thesis. An additional codebook with example quotations is provided exclusively to the supervisor and second reader to protect participant anonymity.

Code	Code name	Definition
Dx	**Driver (D)**	Drivers to participate in EH
D1	Grid congestion	Due to the volatilaty of RES and accelerated ET, the dutch grid is facing Grid Congestion. It cannot transport all energy at the same time and place
D2	Frontrunner	The individual or company that takes the lead in initiating an EH
D3	Expanding	Expanding company activities
D4	New companies	Addition of companies on IT
D5	Electrification of industrial processes	Electrification of industrial processes
D6	Shared problem	Electricity (Grid) considered as shared problem by park
D7	Energy is part of core business operations	Energy is a key aspect of in company proceses
D8	Electrification of logistics	Electricification of fleet
D9	Continuity	Longetivity of the company depends on energy
D10	Sustainability	
L	**Limitations**	Barriers that prevented participating in EH
L1	Unwilling to share data	Unwilling to share data
L2	No sense of urgency	No sense of urgency
L3	Hesitant towards shared investments	Hesitant towards shared investments
L4	Unknown timepath	Unknown when technique/policy/subsidies will be ready
L5	Unknown costs&benefits	Unknown costs&benefits. EH are pioneering, therefore costs/benefits are not standardized yet
L6	Insurance	Insurance not always available for technical or juridical failures
L7	Exclusion	Companies (un)willingly excluded from EH
CIP	**Cooperation on industrial park**	Themes on which the energy cooperation or IP cooperates
CIP1	Energy	Energy
CIP2	Business Investment Zone	Legal coalition of 5 years. Cooperation with municipality included
CIP3	Safety & Security	Safety & Security
CIP4	Networking	Networking
CIP5	Park association	Park association that has appointed a Park Manager
Sx	**Stakeholders DP1**	Parties/individuals involved in EH (from initation to foundation and operation)
S1	Formal participants	Participants that are legally part of EH
S2	Companies on IP	Companies on IP
S3	Competent authority	Municipality, Province, the State
S4	ESCo	Energy Service Company, providing services like measuring, managing and reporting energy flows
S5	Financial institutions	Bank/investment institutes financing EH
S6	Key person	Individual that binds the EH together, represents EH or is formally the in the board, spokesperson to s8, s9
S7	Park manager	Individual that enhances cooperation between companies on IP. Spokesperson to s3 and s8, s9
S8	DSO	Distribution System Operators

S9	TSO	Transmission System Operator
S10	ACM	Authority of consumers and market
S11	Energy cooperation	Legal entity that cooperates in generating, distributing and using energy. Optionally funds other activities with the proceeds
S12	Board Energy Cooperation	The board that governs the Energy Cooperation
IA	**Industrial Activities**	The sectors that companies on IP are active in
IA1	Logistics	Logistics
IA2	Resources	Resources
IA3	Heavy industry	Heavy industry
IA4	Medium-heavy industry	Medium-heavy industry
IA5	Light industry	Light industry
IA6	Services	Services
IA7	Food	Food
Bx	**Boundaries DP1**	
B1	Extent of electricity grid	The physical boundaries of the electricity grid that affects or is affected by the EH
B2	Connection to Regional Grid	Description of EH's connection to the regional (DSO) grid
B3	Connection to national grid	Description of EH's connection to the national (TSO) grid
B4	Measure point	Point where energy flows are measured. Usually through a device by either the measuring company of the DSO or a third party
CGCx	**Congruence DP2**	Otherwise described as the harmony of appropriation and provisioning
CGC1	Agreements on times of use	Who uses which amounts of energy *when*
CGC2	Agreements on quantity of energy	Who uses *which* amounts of energy when
CGC3	Costs-benefits allocation	Allocation of operational costs and benefits (monetary and non monetary) Includes human capital
CGC4	Collective investments	Investments that are done cooperatively. *With the whole group*
CGC5	Energy management	Steering energy flows within the energy hub
CO	**Cooperation DP3**	Set out the participation of users in decision-making processes concerning the common pool resource
CO1	Allocation of roles	Who is responsible for what activity
CO2	Contact	Communication within and outside of EH
CO3	Contract	Binding agreement between parties in EH and or parties outside of EH
CO4	Juridical entity	Juridical form in which EH is organized
CO5	Opting in and out	Joining or leaving the EH
CO6	Datasharing	Sharing company energy data within EH and with TSO/DSO
CO7	Energy usage agreements	Agreements on usage of RES or electricity grid
CO8	Ownership of assets	Legal ownership of assets related to E production, consumption, storage or distribution
CO9	Key figure	Individual that binds the EH together, represents EH or is formally the in the board, spokesperson to s8, s9
M	**Monitoring DP 4**	Monitoring of energy flows in EH
M1	Internal monitoring	Monitoring of grid/energy usage within EH
M2	External monitoring	Monitoring of grid/energy usage by TSO/DSO
SNx	**Sanctions DP 5**	Sanctions for breaching agreements within EH
SN1	Internal sanctions	Internal sanctions for breaching agreements regarding energy/grid usage
SN2	External sanctions	External sanctions for breaching agreements regarding energy/grid usage
CRMx	**Conflict resolution mechanisms DP6**	Conflict resolution
CRM1	Internal	Internal arrangements for settling conflicts
CRM2	External	External arrangements for settling conflicts

CRM3	Central authority	The central decision maker/ veto voter
Rx	**Recognition and rights to organize DP7**	This principle considers if the right to govern the common pool resource is recognized by external higher authorities authoritie
R1	Recognising authority	The authority with the mandate to recognise activities in EH
R2	Recognition	The acknowledgement of the permission to manage electricity and the grid in EH
R3	Mandate	Authority given by organization A to organization B
R4	Permits	Municipal permits for construction/environmental activities on EH
PGx	**Polycentric Governance DP8**	A combination of decision-making centers that represent various levels of authority, and that function in accordance with a set of common regulations despite being officially independent of one another
PG1	Decision makers internally	Decisionmakers within EH
PG2	Decision makers externally	Decisionmakers outside of EH
PG3	Coordination supralocal developments	Coordination with developments outside of EH that impact the grid/require grid extension
PG4	Subsidies	Subsidies
PG5	DSOs cooperating	Cooperation in the overarching Organization: Netbeheer Nederland
PG6	Government policy	Actions that are directly influenced by state policies
Otx	**Other**	
OT1	Trust	the confidence of involved parties in the EH in the actions of EH
OT2	Perseverance	Willingness to continue the collective efforts made in EH
OT3	Other	A code for other important information or statements that cannot be specifically categorized under any of the other codes
OT4	Adaptability	The ability to adapt to new developments, exogenous and endogenous
OT5	Knowledge	Knowledge that is built-up through the process of establishing an EH
OT6	Flexibility	The abality to change energy flows and behavior that results into different energy consumption patterns
DSOx	**DSO - Distribution System Operator**	Describing the roles, functions and values DSOs have in energy commons. Codegroup is also applied to TSO
DSO1	Measuring	Measuring energy flows
DSO2	Calculating	Calculating future patterns based on measure data and models
DSO3	Contract	Partaking in a contract with another entity
DSO4	Innovation	Renewing proceses and encouraging novel developments
DSO5	Product development	Developing new propositions regarding grid management, measurement and monitoring as well as contracts
DSO6	Mandate	The legal rights and plights of a system operator
DSO7	Legal boundary	Legal impossibilites for a system operator
DSO8	Infrastructure upgrade	Replacing or expanding components of the electricity grid
DSO9	Knowledge generation. Merged with OT5	Valorizing insights from pilots and product development
DSO10	Standardization	Standardizing propositions for upscaling
DSO11	Customization	Tailored solutions
DSO12	Facilitatiting	Supporting EH in coming of age processes
DSO13	Stability	Tradtionaly one of the core tasks: ensuring a stable electricity grid
ACMx	**ACM - Authority for consumer & market**	
ACM1	Developing legislation (laws)	Conforming to or adapting legal articles (state law)
ACM2	Developing regulation (codes)	Writing energy regulation
ACM3	Market supervision	Overseeing market dynamics
ACM4	Stakeholder input	Facilitating input for code/law proposals
ACM5	Role in PG	Position of ACM in regard to other actors in PG network

Appendix III: Table of Respondents

Name	Function	Duration interview (mins)
ECAH-A	Stakeholder Manager	60
ECAH B	Chair of Port Authority and ECAH	60
Lage Weide-A	Initiator Energy Hub	60
Pannenweg-A	Initiator Energy Hub	60
Liander-A	Energy Hub Coordinator	45
Liander-B	Energy Transition Consultant	45
Stedin-A	Regional Manager	30
Enexis-A	Stakeholder Manager	45
TenneT-A	Program Manager Congestion Management	30
ACM-A	Project Leader Congestion Management	30

Appendix IV: List of Tables

Appendix V: List of Figures

Appendix VI: List of Abbreviations

Abbreviation	Meaning
EH	Energy Hub
PG	Polycentric Governance
ODP	Ostrom's Design Principles
DP	Design Principle
DSO	Distribution System Operator
TSO	Transmission System Operator
ACM	Authority for Consumer and Market
ESCo	Energy Service Company
DSM	Demand Side Mangement
GTO	Groepstransportovereenkomst (Group transport agreement)
C-CBC	Collectief capaciteitsbeperkend contract (Collective capacity limiting contract)
ECAH	Energie Coöperatie Amsterdamse Haven