ODILE NIERS

STIMULATING ENERGY-HUBS ON DUTCH BUSINESS PARKS

A SYSTEMIC DESIGN APPROACH

November 2023 - June 2024
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PREFACE

Dear reader,

I am very excited to share the result of the last monts of my educational journey. Before we start delving into the contents, I would first to take you along in a short background of the forthcoming of this master thesis.

I started my studies at the TU Delft in 2017, where I obtained the BSc. Industrial Design Engineering (IDE). I have always loved the diverse scope of this program, merging principles of engineering with design methodologies, focussing on product and service development that prioritises user experience, functionality and aesthetic appeal.

What I learned most here was delving into a problem, and systematically work towards innovative, creative and effective solutions.

The older I got, the more I understood the large amount of problems exist in the world around us, especially in the field of sustainability. Intrigued by their impact and complexity, after finishing my BSc. I started the MSc. Industrial Ecology (IE) at the TU Delft and University of Leiden (joint degree). IE is a field of science in which ecological principles are applied to industrial systems, aiming to create more sustainable and efficient processes. It views industrial systems as interconnected networks, similar to ecosystems, where waste from one process can become a resource for another.

One of the concepts within IE is Industrial Symbiosis. This aims to create mutually beneficial relationships where one organisation's waste or by-product becomes another organisation's resource. After a lecture by Paola Ibarra Gonzalez, my fascination on this topic was immediately ignited

*I would like to sincerely thank **Paola Ibarra Gonzalez**, for inspiring me throughout my MSc. and master thesis project. Her encouragement, guidance and enthusiasm have powered me through the thesis project, and make me look back on our discussions and conversations with a smile.*

While being intrigued by the way in which IE taught me to analyse complex problems and pinpoint places for improvement, my background in IDE made me long for not only analysing complex systems, but also designing solutions. In my opinion, all solutions for complex sustainability problems need to include a social element, as human decision-making forms the basis of sustainability transitions. In order to understand and design for this human behaviour, the decision-maker should be central in the research and design.

*I would like to express my heartfelt gratitude to **Abhigyan Singh**, who introduced and guided me through the field of Ethnography. His mentorship, recommendations and profound insights have shaped the way I understand, research and design for problems during my thesis project, which will leave a lasting impact on my professional life.*

Wanting to combine the analysis of complex systems with designing interventions in creating symbiotic relationships between different organisations, I was pointed towards the direction of energy-hubs. Senja Boom offered me not only a cup of tea in her backyard in the middle of renovating her house, but also an introduction to energy hubs. Together we formulated and shaped the start of my research project.

*I am truly appreciative of **Senja Boom**, who supported me and cheered me on from the beginning to the end, always clearing up time in her overly packed agenda, introduced me to all stakeholders, patiently explained me everything about e-hubs and inspiring me on how much one person can change within a big company like Stedin.*

I have really enjoyed my time at Stedin, offering me much more than just a deks. Being part of multiple teams (Proposition Management, Market Intelligence and Innovation) I had the chance to meet inspiring and motivated people, who are all putting their shoulders under the energy transition.

*I would like to thank **Gerbrand Klein Hoving, Stijn Rutgers** and **Arjan Woertman** for their guidance, support and the nice conversations we shared throughout the research project.*
*Thank you **Timothy Alders** for helping me find the most interesting thesis topic I could wish for and all taemmembers of PMI for making me feel at home at Stedin.*

I could never have reached the results of this master thesis witout the support of the countless people I interviewed and met at the events I attended, nor would I have enjoyed the research project as much without them.

*I am grateful of **Maya van der Steenhoven** of the Energy Scale-Up Foundation for giving me the opportunity to speak at multiple events and supporting me throughout and after the research project, the bright and ambitious women of the **PowerVrouwen Whatsapp-group** who kept me up to date with the developments of e-hubs, and all interviewees and participants of this thesis research project.*

I have really enjoyed my master thesis project, I hope you do too.

ODILE NIERS

SUMMARY

The energy transition is an essential shift towards sustainable and renewable sources, mitigating climate change. However, a large bottleneck arises in this transition as the electricity grid struggles to transport all this renewable energy, resulting in grid congestion. Energy hubs (e-hubs) are local collaborations between stakeholders, where energy supply and demand are locally coordinated. This thesis focuses on the development of e-hubs on business parks.

However, the development of e-hubs faces challenges. Many emerging e-hubs are stuck in the initial orientation phase, where groups and collaborations need to be formed, and the possibilities for configurations are explored. There is a low level of organisation on business parks, and a limited support capacity of supporting roles.

Research and design towards e-hubs is complicated due to their socio-technical multi-actor complex systems nature. Existing literature lacks usable and actionable methods and tools to stimulate the orientation phase of e-hubs.

This thesis addresses this gap by adopting a systemic design approach, consisting of two phases. The first phase, 'Solving the Right Problem', focuses on systems thinking and ethnography in order to pinpoint the most effective point for intervention. The second phase, 'Solving the Problem Right', focuses on design thinking, open and participatory innovation to effectively design interventions to stimulate the orientation phase of e-hub development on business parks in the Netherlands in 2024.

By first investigating the paradigm of e-hubs, their societal context, challenges, gaps in current practices and academic context is explored. Consequently, the system is framed; system boundaries are defined and assumptions are stated. The roles involved in the system are defined and their engagement into the development of e-hubs is analysed. Consequently, a key role is defined.

Next, focus is put on understanding the system, including understanding the thoughts and experiences of the key role, underlying drivers and barriers, and the causal relationships between as well as the rootedness of these drivers and barriers are researched. This leads to the identification of leverage points, places within the system to intervene.

By means of weighing the multiple leverage points based on multiple criteria the key leverage point is defined, representing the Opportunity for intervention within the system. Intervening in this Opportunity will result in cascading effects that will affect the system's behaviour at large and thus stimulate the orientation phase of e-hub development. The Opportunity is translated into a Design Statement. This marks the end of the first phase of this thesis ('Solving the Right Problem'), and the beginning of the second phase ('Solving the Problem Right').

In order to design an efficient and effective intervention, first the possibility space is explored by learning from success factors in e-hub pilots and Industrial Symbiosis, a system with similar characteristics and a similar scope as to e-hub development. Lessons learned are translated into Design Cues, that are used for participatory innovation by including the key role, stakeholders and experts into the design process.

This results in the design of a new Proposition that will stimulate the orientation phase of e-hub development by focussing on its organisational dimension. The Proposition comprises four interventions in this orientation phase:

1. Energy Knowledge Hub
2. Participant Procurement Protocol
3. Energy Coalition Building Workshops
4. E-hub Facilitator Forum

Implementing these four interventions will have cascading effects on the stimulation of drivers and mitigation of barriers experienced by the key role, which results in cascading effects within the multi-actor system, which results in cascading effects within the socio-technical system of e-hub development. Therefore, the Proposition will jumpstart systemic change towards the integration of e-hubs in a decentralised energy system.

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READERS GUIDE

Hi! This is me, Odile, the researcher and designer of this thesis project. Every time you see me throughout the report, please pay extra attention as an important (sub)conclusion is drawn!

INTRODUCTION

Energy systems form the backbone of modern society, ensuring the continuous supply and transportation of electricity to homes, businesses and industries. However, the rise in electricity consumption and production has led to grid congestion - a condition where the electricity grid is overloaded, leading to inefficiencies and potential blackouts. Energy hubs (e-hubs) are one of the solutions to circumvent grid congestion. E-hubs are decentralised networks of participants in which production, conversion, storage and consumption of energy are coordinated on a local level, decreasing the dependency on the grid.

This master thesis focuses on stimulating the formation of energy hubs (e-hubs) on business parks in the Netherlands in 2024.

This research is presented for the MSc. Industrial Ecology at Delft University of Technology and the University of Leiden (joint degree), integrating influences from Industrial Design Engineering.

A systemic design approach is integrated throughout the research and report, integrating principles from systems thinking and design thinking. This approach combines a systematic localisation of the right problem to solve, discovering an opportunity for improvement, with a iterative user-centric strategy to solve this problem right, resulting in the design of a new proposition that stimulates the formation of e-hubs.

The research approach structures the report into seven following chapters (figure 1)

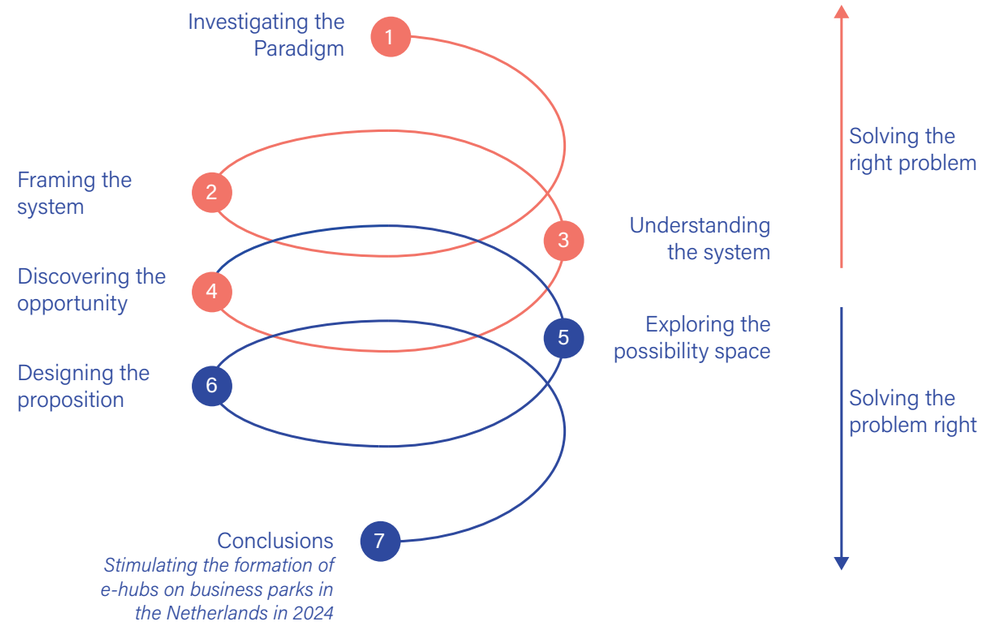


Figure 1: Report structure

INVESTIGATING THE PARADIGM

The aim of this chapter is to investigate the e-hub paradigm. This paradigm features the following aspects:

The **societal context**, **current scope** and **functioning**, experienced **challenges** and the current **solutions** in the industry addressing these challenges. Additionally, the remaining gap between these challenges and existing solutions is identified. This **gap in current practices** represents the **research direction** for this master thesis and is outlined in the **research scope**.

The **theoretical background** of e-hubs as socio-technical multi-actor complex systems, including an explanation on how such systems should be understood and researched.

The **academic context** of the gap in current practices, including a comparison between this gap and the **knowledge** produced in academic research. Additionally, a comparison is made between the theoretical background of how e-hub should be researched and the **research methods** currently used in academic studies. This analysis concludes with the identification of both a **knowledge gap** and a **methodological gap**.

A system comparable to e-hubs, which will be used as an example later in this master thesis, being **Industrial Symbiosis**. This socio-technical multi-actor complex system shares a similar scope with e-hubs.

Consequently, a **thesis goal** and **research questions** are defined.

This chapter concludes with an explanation on the **approach** taken and **research methods** used in this master thesis in order to fill the knowledge and methodological gaps.

THE SOCIETAL CONTEXT

THE GOOD: THE ENERGY TRANSITION

Human activities have unquestionably caused climate change (IPCC, 2023). Results include extreme weather, biodiversity loss, risk of water and food scarcity, massive migratory flows and conflicts around the globe. Energy-related activities are responsible for over two thirds of global greenhouse gas (GHG) emissions causing climate change (IPCC, 2020). These emissions are mainly caused by the combustion of fossil fuels in power generation, underscoring the need of replacing these fossil fuels with green energy in the **energy transition**.

The energy transition causes an increase of both the demand and supply of green electricity. The demand of electricity increases due to electrification of processes previously fuelled by fossil fuels, such as cars, heating systems, production systems and industrial processes (European Commission, 2022; Ministerie van EZK, 2022; Ministerie van IW, 2021; Scheres, 2023). The supply of electricity increases due to a rise in **renewable energy resources** (RES) to answer the demand in (green) energy. In the current outlook wind and solar energy will make up 95% of the Dutch energy mix in 2050 (cbs, 2022; TNO, 2022).

The rise in RES causes energy production to become more and more decentralised. In the old energy system most electricity is produced in a few coal and gas plants, while in the new energy system anyone can become a producer of energy by for example installing solar panels on roofs. This causes a shift in the centrally managed energy system towards a more decentrally managed energy system, existing out of a large amount of **distributed energy resources** (DER).

The growing amount of green electricity demand, RES and DER is great for reducing GHG emissions. However, it imposes large problems for the electricity grid.

THE BAD: GRID CONGESTION

The electricity grid forms the backbone of modern society, ensuring the continuous transportation of electricity to homes, businesses and industries. However, due to the increasing demand and decentralised supply of electricity this grid becomes overloaded, resulting in inefficiencies and potential disruptions like power outages. This phenomenon is called **grid congestion** (Ministerie van EZK, 2022).

In order to explain grid congestion, it is important to sketch the functioning of the electricity grid. The shape of the electricity grid can be compared to the shape of a tree (figure 2). Coal and gas plants supply a large amount of electricity, that is transported for long distances through thick high-voltage cables, the stem of the tree. This electricity is transformed to medium-voltage, transported over regional distances, the branches of the tree. Lastly, the electricity is transformed into low-voltage, transported over local distances towards houses and businesses, the leaves of the tree (Liander, 2021).

The increasing amount of demand and supply causes an increase in electricity that needs to be transported over these same cables. On top of this, the increasing amount of DER changes the direction in which the energy needs to be transported, a task for which the traditional tree-like grid structure is not equipped (Liander, 2021). In other words; **the current electricity grid is not designed to allow for the energy transition** (figure 3)**.**

Grid congestion is currently a large problem (figure 4), and will only grow in the near future due to the fast pace of the energy transition to meet the European net-zero objectives towards 2050 (European Commission, 2022). In the coming two decades the electricity that needs to be transported will grow up to seven times the current capacity (TKI Urban Energy, 2023). This increase cannot be matched with just expanding the old frame of the system due to a lack of materials and manpower. This is amplified by the fact that the growing amount of RES will result in large and unpredictable peaks of electricity that needs to be transported. RES do not cause a constant supply of electricity like coal and gas plants do, but generate peaks of supply when the sun shines or the wind blows.

A direct consequence of net congestion is power outages, in a time where society is more and more dependent on energy. Current measures to circumvent this direct consequence lead to indirect consequences, such as a hindered pace of the energy transition, increased waiting times for new connections to the grid for e.g. new businesses and neighbourhoods, limited access to reinforced grid connections for businesses who for example want to install solar panels or electric transportation systems.

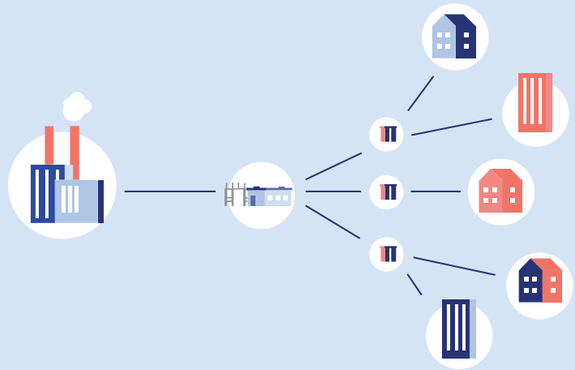


Figure 2: The tree-like shape of the electricity grid (author's image, inspired on Liander (2021))

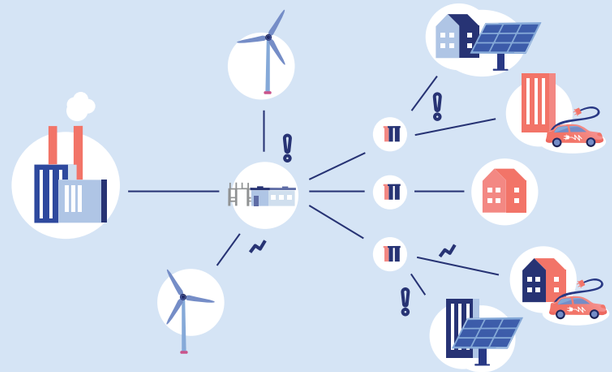


Figure 3: An increase in decentralised supply and demand causing grid contestion (author's image, inspired on Liander (2021))

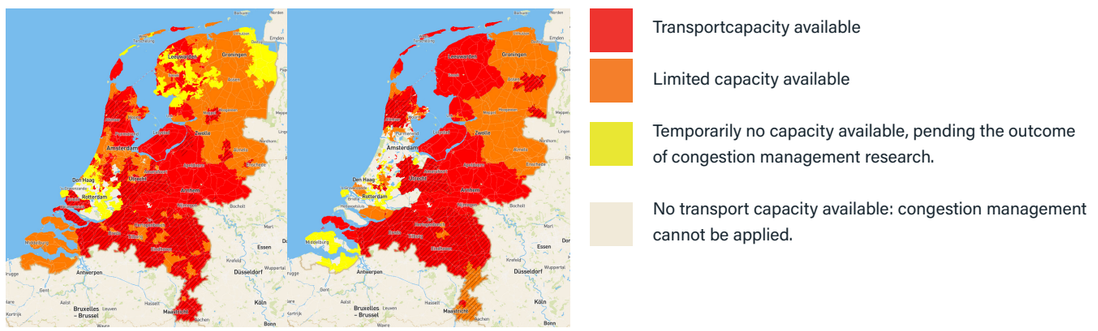


Figure 4: State of grid congestion in the Netherlands on 15-05-2024 (Netbeheer Nederland, 2024)

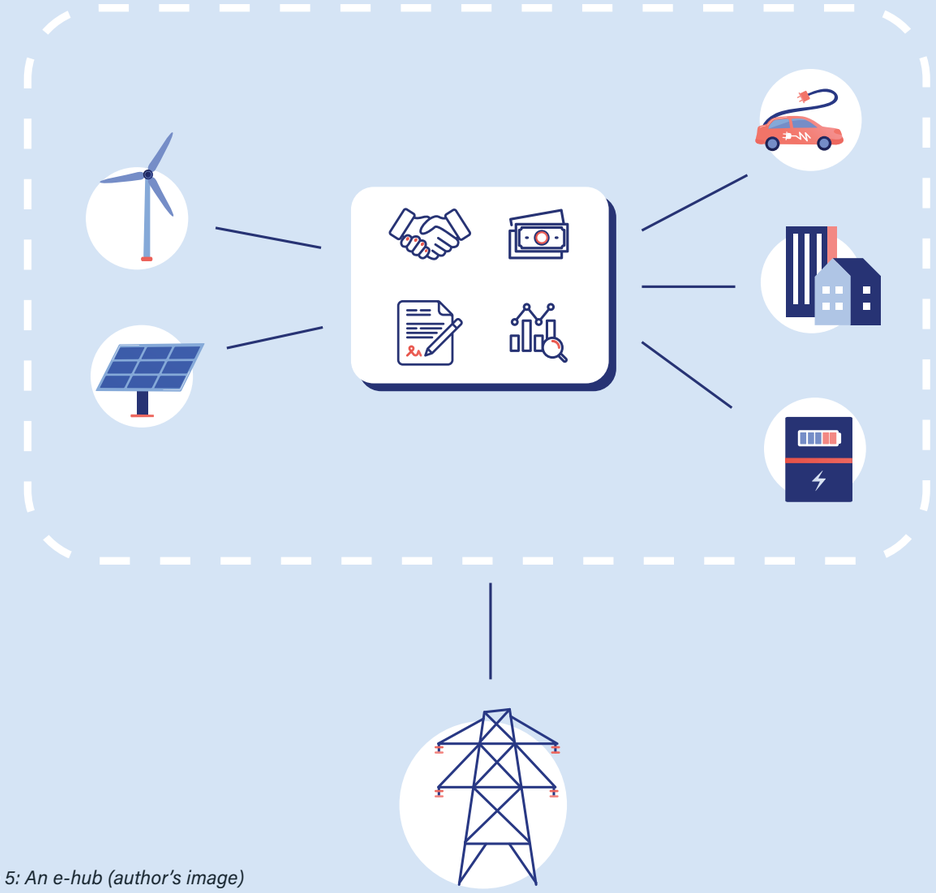


Figure 5: An e-hub (author's image)

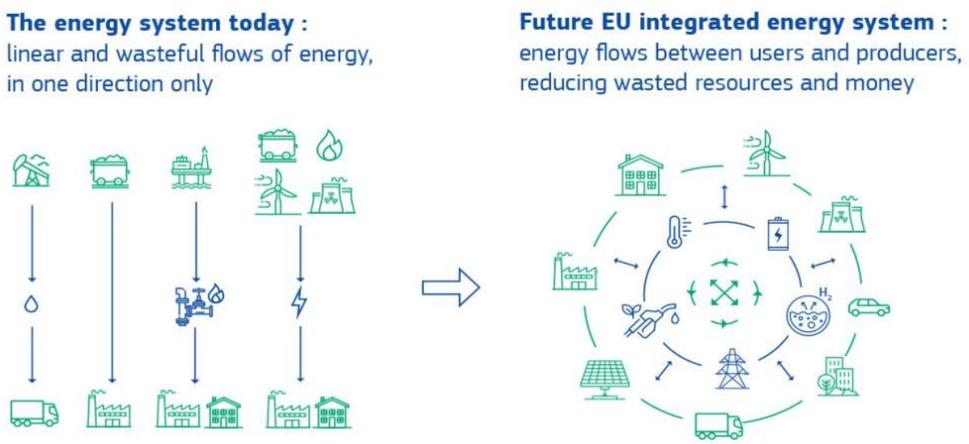


Figure 6: The future EU integrated energy system (European Commission, n.d.)

PREVENTING GRID CONGESTION WITH ENERGY HUBS

Various innovation strategies are presently in development to prevent and circumvent grid congestion. One of these efforts includes of locally exchanging electricity by means of forming an **energy hub (e-hub)**. **E-hubs are decentralised networks of participants in which production, conversion, storage and consumption of energy are coordinated on a local level** (Eladl et al., 2023; LAN, 2022; Mohammadi et al., 2017).

This definition can be split into multiple parts in order to facilitate a better understanding.

1. As depicted in figure 5, e-hubs involve the **coordination of physical assets**, including energy producers (e.g. solar panels or wind turbines), energy consumers (e.g. electric cars and buildings), and storage of energy (e.g. batteries). This production and consumption of energy, supported by storage of energy that can e.g. function as a buffer.
2. By coordinating these assets **on a local level**, the impact on the grid is decreased, as depicted in figure 5. This means grid congestion is prevented and/or mitigated.
3. This is not only beneficial for the **District System Operators (DSOs)** who manage and are responsible for the functioning of the grid, but is also benefitial of the **participants** of the e-hub, being the owners of the energy producing, consuming or storage assets. These participants experience multiple benefits, such as:
    - **Mitigation of grid congestion**; due to existing grid congestion, a vast amount of suppliers and consumers of energy are placed in a waiting line for a new or bigger connection to the grid by the DSO, who could not allow for more energy going through the grid as this would cause grid failure. By means of establishing an e-hub, these suppliers and consumers can mitigate this grid congestion and are now able to still expand their company, electrify their processes and/or settle a new company or neighbourhood (Stedin, 2023).
    - **Self-sufficiency**; participants of e-hubs gain greater control over their energy supply and costs (Firan, 2023), making them less dependent on external energy market influences like the rapidly increasing energy prices for Russian gas after the start of the war in Ukraine in 2022-2023. This autonomy ensures participants of e-hubs to be in control of sufficient and affordable energy (Firan, 2021).
    - A **financial benefit**; as participants of e-hubs can collectively acquire expertise and flexible assets, such as batteries, are able to share costs. These collectively-owned flexible assets can also facilitate trading on energy markets, making the e-hub a possibly profitable solution (Firan, 2021).

The European Commission views decentralised and interactive energy systems, like e-hubs, as an essential part of the energy transition and shifting the energy system (figure 6) (European Commission, n.d.)

THE STRUCTURAL COMPOSITION OF E-HUBS

E-hubs are not just networks that connect multple physical assets, such as different buildings, solar panels, windmills and batteries. Next to this physical dimension of e-hub exists a social dimension of different stakeholders, both inside and surrounding the hub. This social dimension influences the technical dimension of physical asset, as the stakeholders decide on what assets to install and how to utilise them. Vice versa, the technical dimension influences the social dimension in the reliability, accessibility and affordability of energy, as well as wider societal impacts such as decreased environmental impacts, increased community well-being and economic development. **This makes e-hubs socio-technical systems** (Baxter & Sommerville, 2011).

The social dimension of e-hubs is essential to include in research and design of e-hubs. As shown in figure 5, at the centre of each e-hub are agreements between stakeholders, captured in contractual agreements, resulting in flows of money and data between all stakeholders and physical assets (Topsector Energie, 2021).

In order to understand the current state and challenges of e-hubs in the Netherlands and consequently formulate a research direction, both the **technical and social dimension** are explained in the following sections. **The social dimension is split in two parts:**

1. **The legal and institutional dimension**, which encompasses current legal and institutional constructions that underline the organisational dimension;
2. **The organisational dimension**, which includes the network of stakeholders and their decision-making processes and internal dynamics that influence both the interactions between the stakeholder of e-hubs as well as their influence on the technical dimension.

THE THREE DIMENSIONS OF E-HUBS EXPLAINED

Three dimensions of e-hubs will be explained: the technical dimension, the organisational dimension and the legal dimension (figure 7). These three dimensions are interconnected and intertwined.

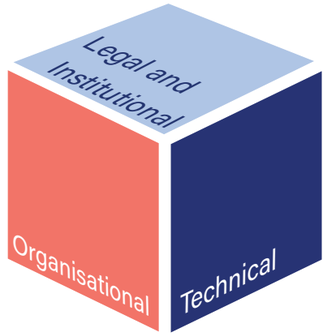


Figure 7: Three dimensions of e-hubs (Author's image)

TECHNICAL DIMENSION

The techncial dimension of e-hubs refers to the infrastructure and technology involved in generating, distributing, storing and managing energy. This includes physical assets like batteries, solar panels and wind turbines, as well as monitoring and control systems such as smart grid management software to optimise energy flows within the hub.

The technical dimension of e-hubs typically falls in one of two main configurations: a **Closed Distribution System** (CDS) or a **Virtual Power Plant** (VPP).

- CDSs are also referred to as microgrids. These systems entail installing their own infrastructure, and therefore being able to operate independently from the grid. This involves peer-to-peer energy trading, where for example energy can be bought or sold to your neighbour. However, this independency from the grid is not inherent to CDSs, they can also function as locally controlled energy systems that operate in conjunction with the larger electricity grid (Shahgholian, 2021). CDS can, but do not always function as smart grids, which are modern energy networks incorporating digital communication technology to detect and coordinate local fluctuations in usage and supply.
- Opposed to CDS, VPP do not have their own physical infrastructure. VPP are networks of interconnected DER, controlled by advanced software and control systems to optimise their collective performance. A VPP acts as a unified, decentralised flexible energy generation and consumption system. A VPP often operates within the larger grid context, offering flexibility to the grid to prevent grid congestion, as well as including flexibility to trade on energy markets (figure 8).

In the current scope of e-hubs in the Netherlands, the emphasis is primarily on e-hubs functioning as VPP. More about this will be explained in the legal dimension of e-hubs.

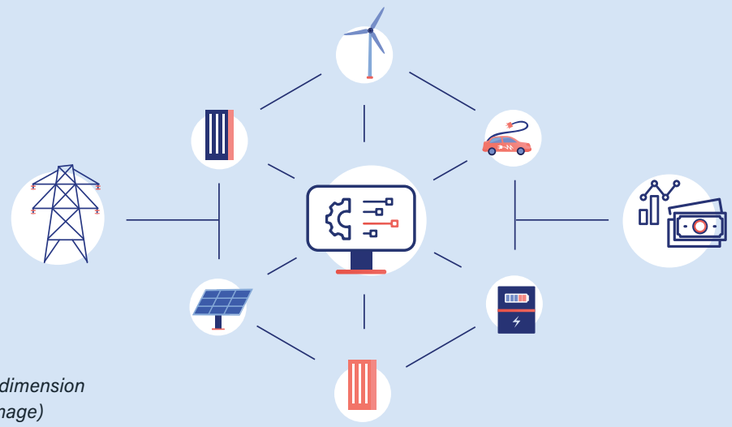


Figure 8: The technical dimension of an e-hub (Author's image)

LEGAL AND INSTITUTIONAL DIMENSION

The legal and institutional dimension of e-hubs includes entering into new contractual agreements between the participants of the e-hub, as well as between the collective and the DSO. **The current institutional main scope of governmental institutions and DSOs in the Netherlands in 2024 is focussed on establishing e-hubs on business parks, where the companies on the park become the participants of the e-hub.**

Establishing an e-hub includes engaging in new contractual agreements with the DSO, who is responsible for the management and functioning of the grid. As of may 2024, standardised contractual agreements between the group of participants and the DSO are currently in development.

There are two main developing contractual agreements between the e-hub and the DSO: a **Collectief Capaciteits Beperkend Contract (C-CBC)** (translation: Collective Capacity-Limiting Contract), and a **Groeps Transport Overeenkomst (GTO)** (translation: Group Transport Agreement) (Netbeheer Nederland, 2023; RVO, 2024). These two will shortly be explained below and in figure 9.

- The C-CLC is a legal contract in which the energy hub receives a collective power limit. This is a contractual agreement that exists next to the individual **Aansluit en Transport Overeenkomst, (ATO)** (translation: Connect and Transport Agreement) that participants already have with the DSO (figure 9). With the collective power limit, the group is asked to refrain from using a certain amount of energy during peak moments, when grid congestion is approaching (RVO, 2024). How the e-hub allocates this power limit over the different participants is up to the group to determine amongst the participants.
- The GTO replaces the individual ATO that participants already have with the DSO (RVO, 2024). This means the group of participants receives a shared grid capacity, opposed to all participants having an individual capacity (figure 9). This shared capacity is not the sum of the individually contracted capacities, as this would not help preventing grid congestion. Instead, the collective historical load is considered. This means the aggregated collective historical peak is considered to be the new shared grid capacity (figure 10). Participants can optimise their utilisation of this shared grid capacity through mutual agreements, such as coordinating rotations and specific timeslots for energy demand or supply.

While contractual agreements between the DSO and the group of participants are in development, there are **no standardised formats for the mutual agreements of the participants within the e-hub** (highlighted in pink in figure 9). **This increases pressure on the organisational dimension of e-hubs**, which will be explained next.

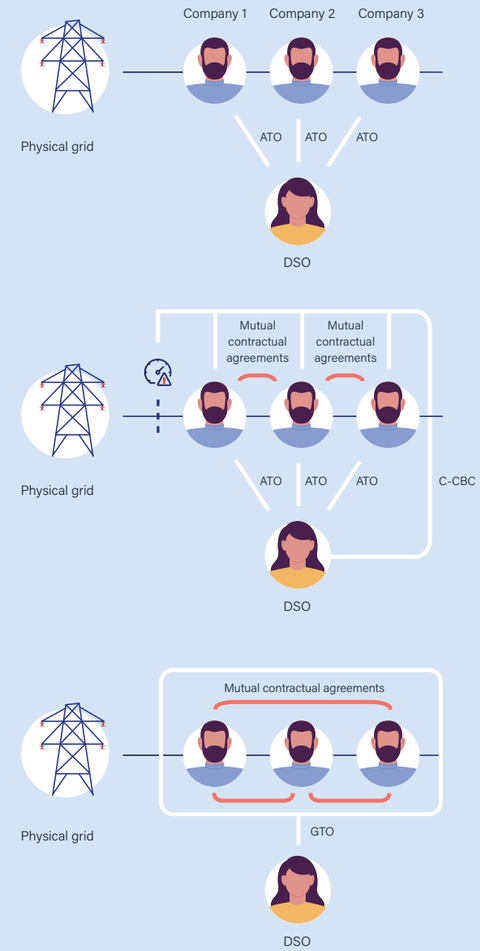


Figure 9: Different contractual agreements. Top: business-as-usual scenario. Middle: C-CBC. Bottom: GTO (Author's image)

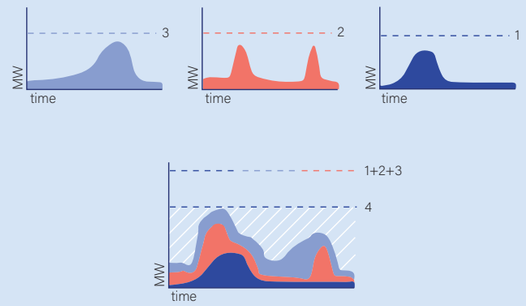


Figure 10: the new shared grid capacity is not the sum of all previous capacities, but the aggregated historical peak is considered (Author's image)

Figure 11: The organisational dimension of e-hubs (Author's image)

ORGANISATIONAL DIMENSION

The organisational dimension of energy hubs entail the agreements of the participants within the e-hub. E-hubs are community-level energy initiatives, where a community collectively participates in, owns, and/or benefits from local renewable energy projects (Bauwens et al., 2022; van der Schoor & Scholtens, 2019). As specified in the legal dimension, the e-hub retreives a certain capacity to the electricity grid, that the participants of the e-hub can optimise through mutual agreements.

To sketch an image of such agreements, let's consider an example (Figure 11). Company X is a production company, and company Y is a logistics company. They are both part of an e-hub, meaning they have to make mutual agreements on who can use the capacity and when. Company X shifts the planning towards earlier in the morning, when the electric buses of company Y are on the road. Company Y can then use the capacity that is freed by company X in the evening, when the employees of company X have gone home and company Y can charge its electric buses. This way, the peak usage of both company X and company Y remain inside the collective capacity agreed on with the DSO in the GTO.

This is a very simple example. However, the complexity of these mutual agreements increases when more companies enter the e-hub. An increased e-hub size can be favourable for various reasons (economy of scale, higher resilience, greater resource pooling, enhanced flexibility and reliability, regulatory and policy benefits, economic development, etc.), however this makes the organisation of such hubs increasingly difficult. As more companies join an e-hub, the complexity of the multi-actor system increases. More about this will be explained later in the theoretical background.

Organisation efforts needed from participants are fundamentally different from the previous energy system, in which companies sign a contract with the DSO and do not have to worry about their energy capacity. E-hubs inherently entail an increase in **energy democracy**, involving the decision-making power is distributed amongst the participants of the e-hub, requiring all participants to actively participate in, influence, and benefit from the collective (Debizet, Pappalardo & Wurts, 2023; van Veelen & van der Horst, 2018). This is related to e-hubs being **grassroot innovations**, referring to locally-driven processes that lead to the creation of novel solutions and inventions by individuals or communities that are close to the problem (Raj et al., 2022; UNDP, 2023). This tailors designs and benefits of e-hubs to meet the needs of the participants, but this also means that a one-size-fits-all organisational structure for e-hubs is not feasible. As a result, in each e-hub active participation is required, including e.g. sharing of data, exploring possible collaborations and as a result implementing adjustments to company processes. Next to this, active collaboration is required, jointly investigating opportunities, considering each other when making future company plans growth strategies, sharing costs for assets and expertise, etc.

Once established, an e-hub mostly collaborates with a **Congestion Service Provider (CSP)**, who installs hard- and software to automatically manage the agreements made on the allocation of capacity at certain amounts of time (see the technical dimension of e-hubs). However, reaching these agreements and establishing a new e-hub is the main organisational focus of e-hubs. Reaching such agreements is a challenge still barely overcome by the first e-hub pilots as explained further in the next sections.

In conclusion, the technical and legal dimensions of e-hubs are trending towards becoming standardised products, whereas the organisational dimension is falling behind in this regard.

CHALLENGES IN THE DEVELOPMENT OF E-HUBS

The conclusion of the three dimensions is confirmed by CE Delft (2023), which argues that the biggest problem in realising sustainability transitions within business parks, like e-hubs, is a low organisational level and complex stakeholder process (figure 12) **90% of business park in the Netherlands are currently inadequately organised for the realisation of e-hubs** (CE Delft, 2023). Only 20% of business parks in the Netherlands even have some organisational structure, like a park manager or business association (RLI, 2024), meaning **80% of business parks have to start from scratch in the organisational dimension when developing an e-hub**.

Increasing this organisational capacity for the establishment of e-hubs is complicated by the multitude of systemic characteristics of e-hubs. Not only are e-hubs **socio-technical systems**, they also have a **multi-actor** nature and can be classified as **complex systems**. This will be further explained in the theoretical background in next sections.

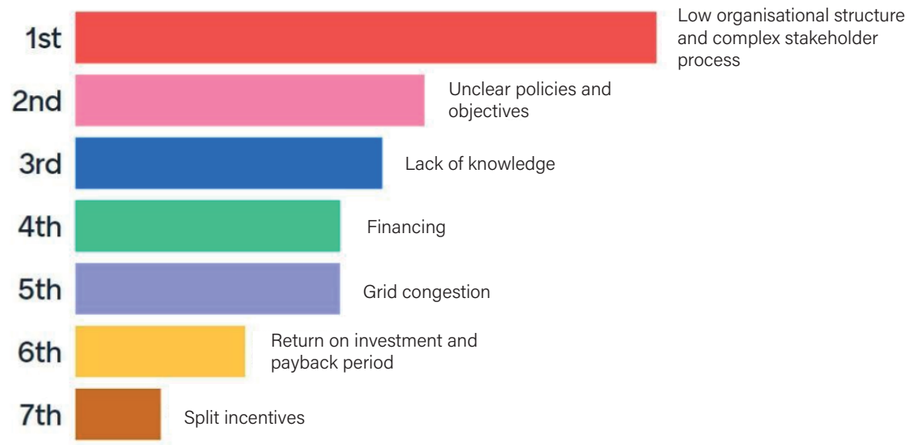


Figure 12: The biggest bottlenecks in sustainability transitions on business parks in the Netherlands (translated from CE Delft, 2023)

CONCLUSION OF THE SOCIETAL CONTEXT:

E-hubs are an essential part of the solution for preventing and mitigating the effects of grid congestion, and thereby allow for the energy transition in the Netherlands. E-hubs provide multiple benefits for different stakeholders. Therefore, the development of e-hubs on business parks should be stimulated.

However, e-hubs require a fundamentally different design opposed to the traditional energy system, requiring active participation and collaboration of actors that produce, consume and/or store energy.

E-hubs are socio-technical systems. While the technical, legal and institutional dimensions of e-hubs are moving towards becoming standardised products, the organisational dimension shows bottlenecks. With 90% of business parks being currently inadequately organised and 80% not being organised at all, the organisational dimension of e-hubs should be researched and stimulated.

CAUSES OF THE CHALLENGES: THEORETICAL BACKGROUND

UNDERSTANDING COMPLEXITY IN RESEARCHING E-HUBS: SOCIO-TECHNICAL MULTI-ACTOR COMPLEX SYSTEMS

As explained in the last sections, e-hubs are **socio-technical systems**, where social (including organisational and legal) and technical elements are intertwined and mutually influence each other. While the technical and legal dimensions of e-hubs are currently developing into standardised products, mainly the organisational dimension which eventually leads to mutual agreements between stakeholders and the technical composition of the e-hub, appears complex. This complexity can be explained by the **multi-actor** characteristics of e-hubs, and their nature of being **complex systems**. These terms as well as their impact on e-hub development will be explained in this section.

UNDERSTANDING COMPLEXITY: MULTI-ACTOR SYSTEMS

Multi-actor systems systems involve three main principles (Enserink et al., 2022; Sander & Nijhof, 2021):

1. Multi-actor systems involve **multiple entities or actors**, each with its **own goals, behaviours and interactions**. These actors can be individuals, organisations or even automated systems.
2. These actors interact with each other to achieve a certain **purpose of the system**. Behaviour of the system are influenced not by the actions of a single actor, but by the **interactions and interdependencies among all the actors** involved. These interactions can be cooperative, competitive, or a combination of both. Outcomes of these interactions result in **emergent properties** that may not be predictable from the actions of individual actors alone.
3. However working on the same purpose, all actors have their own interests. They are **self-serving**.

For e-hubs, this means that the development of each e-hub is dependent on the actors both within the hub and surrounding the hub. Figure 13 shows an example of these actors. More research on the multi-actor nature of e-hubs will be explained in Chapter 2: Framing the System.

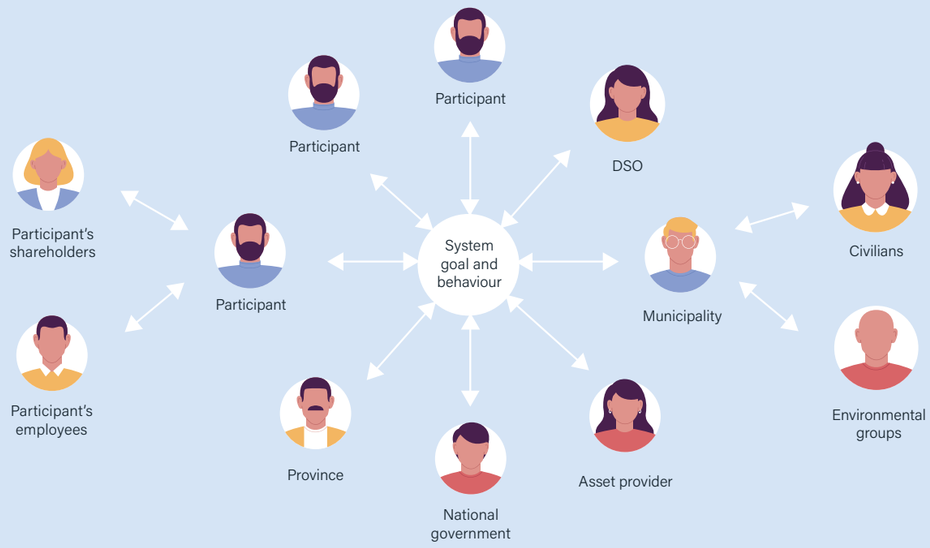


Figure 13: A visualised example of the multi-actor nature of e-hubs

UNDERSTANDING COMPLEXITY: COMPLEX SYSTEMS

E-hubs can be defined as **Complex Systems.** A complex system is a dynamic network of interconnected elements that exhibit emergent behaviours, self-organisation and adaptation in response to changes in their environment. Changes or disruptions in one part of the system can have cascading effects on other connected components within the system purpose (Ahmed et al, 2005; Meadows, 2008; Simons & Nijhof, 2021)

More specifically, a complex system exists out of:

- **Multiple agents or components**: a complex system consists of various individual entities or components, often referred to as agents. These agents may be individual humans, physical assets, software agents, or other entities capable of interacting with each other and the environment.
- **Interactions and dependencies:** Agents in a complex system interact with each other and their environment, forming a network of interdependencies. These interactions can be direct or indirect and may involve feedback loops, where the actions of one agent affect the behaviour of others.
- **Emergent behaviour:** a complex system exhibits emergent properties or behaviours that arise from the interactions between individual agents, rather than being dictated by a central controller or authority. This relates closely to the current emergence of e-hubs, which are formed bottom-up instead of top-down.
- **Adaptation and evolution**: agents within a complex have the ability to adapt to changes in their environment over time. This adaptation may involve learning, innovation, or evolution, allowing the system to better survive and thrive in a dynamic and uncertain environment.
- **Self-organisation:** complex have the capacity for self-organisation, meaning they can spontaneously restructure or adapt their organisation or behaviour in response to changes in their environment or internal dynamics. For e-hubs self-organisation is also happening, as new e-hubs form themselves but get stuck. The challenge for this master thesis is to inject a small change in the internal dynamics of the system, which overcomes barriers and stimulates drivers experienced by agents of the system, which allows for smoother self-organisation.

Figure 14 shows an example of possible multiple components of e-hubs, interacting and depending on each other, and showing emergent behaviour, adaptation and evolution and self-organisation over time. This makes e-hubs complex systems and makes their development unpredictable.

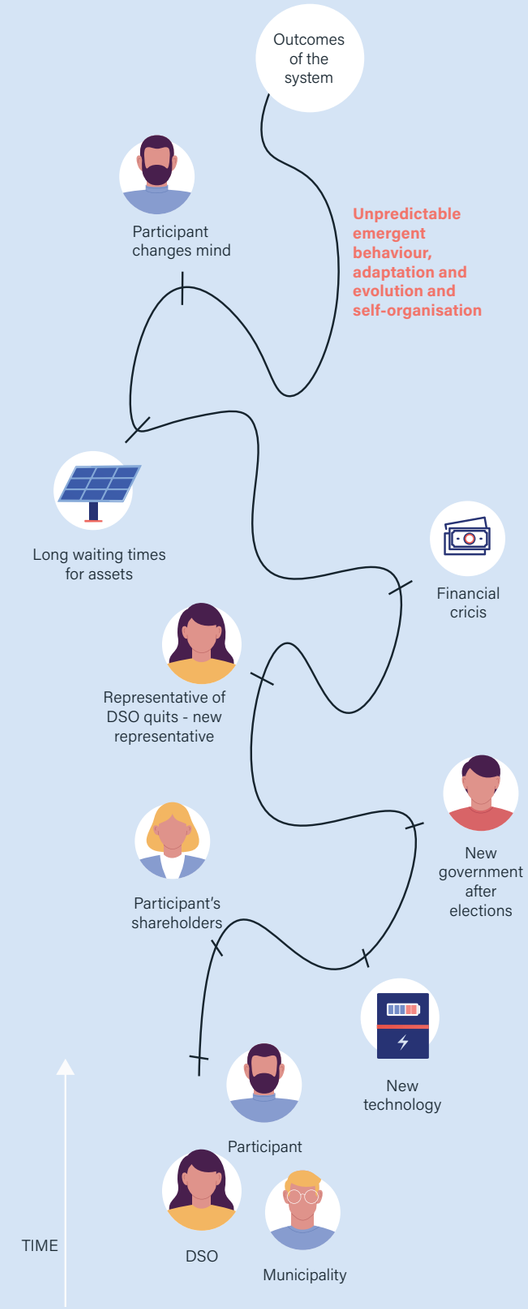


Figure 14: A visualised example of e-hubs as complex systems

DEFINING A GAP IN CURRENT PRACTICES

CURRENT EFFORTS IN OVERCOMING THE CHALLENGES OF E-HUBS

The organisational challenges of developing new e-hubs are currently mainly mitigated by assigning facilitators and process managers for e-hubs with government funding, and by generating knowledge on development processes of e-hubs.

Knowledge is mainly acquired by taking lessons learned from e-hub pilost and drafting roadmaps in which organisational, financial and legal obstacles are translated into actions to collectively and systematically accelerate the development of e-hubs. Smaller developments, tools and methods that are currently evolving and aim to stimulate e-hub development are discussed in appendix E. In this section, overarching frameworks, highlights and conclusions will be discussed. The developments and tools discussed in appendix E mainly focus on the technical and legal dimensions, **leaving a gap in current practices on stimulating the organisational dimension of e-hub development**

Currently there are three main frameworks that do stimulate the organisational dimension of e-hub development (figures 15, 16, 17) (EIGEN, 2023; Energyscale-up, n.d.; Provincie Utrecht, 2024, Firan, 2023a, RVO, 2023). Most of these initiatives are funded by the Dutch government.

The structure of these three roadmaps is similar, distinguishing four main phases within the development of emerging e-hubs:

1. **The orientation or initiation phase** focuses on seeking and exploring new coalitions. Existing frameworks describe different steps that need to be taken in this phase, including a research of which local conditions need to be taken into account and whether sufficient momentum can be generated among companies to serve as pioneers for a new e-hub. A problem is defined for the specific location of the e-hub, the potential for flexibility is determined (meaning to what extent the timing and size of demand and supply can be altered), and the socioeconomic impact is investigated. This phase is concluded with the establishment of a legal cooperative (EIGEN, 2023; Provincie Utrecht, 2023, Firan, 2023a).
2. **The preparation phase** focuses on researching the technical possibilities of the e-hub and achieving the most feasible and viable technical design for the hub. This phase includes taking the steps of developing multiple possible designs for the hub, and determining a strategy to outsource the technical development of the e-hub. This phase is concluded with a go / no go decision of all participants to join the e-hub (EIGEN, 2023; Provincie Utrecht, 2023, Firan, 2023a).
3. **The realisation phase** focuses on the establishment of the hub. According to current roadmaps, this includes installing assets and software, establishing a legal entity, and proceed with testing and refining the technical design of the e-hub (EIGEN, 2023; Provincie Utrecht, 2023, Firan, 2023a).
4. **The exploitation phase** focuses on assetmanagement and operations. Current roadmaps describe this phase as overseeing the e-hub's functioning to ensure business continuity, managing administration and maintenance of assets and software (EIGEN, 2023; Provincie Utrecht, 2023, Firan, 2023a).

The challenges in the organisational dimension of e-hubs, as described in last section, are mainly focussed on the first two phases of e-hub development. In these phases, coalitions are established, and opportunities for collaborations are explored. Mainly the first phase, the orientation phase, influences the complexity of the multi-actor complex systems, as the combinations of actors, their interdependencies, and the system goal are not yet explored, causing the most flexibility and uncertaincy of stimulating the organisational dimension e-hub development. In other words, in order to start playing the game of negotiations in the preparation phase, first the board, pins and dice should be designed in the orientation phase.
The orientation phase is therefore essential to resaerch in order to stimulate e-hub development, as this phase shows the most complexity and forms the basis for both the multi-actor and complex system characteristics of e-hubs.

As of may 2024, most companies are stuck in their orientation phase (Energyscale-Up, 2024), as shown in figure 18.

Figure 15: Four phases of the e-hub blueprint by MOOI EIGEN (2023)

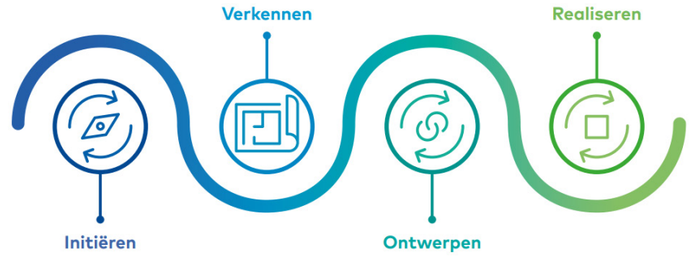


Figure 16: E-hub development roadmap including four phases by FIran (2023a)

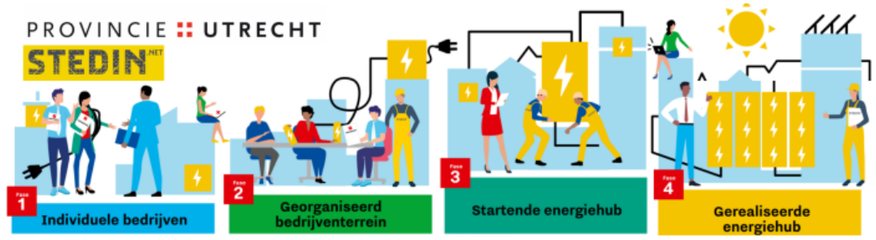


Figure 17: Four phases of the e-hub development process by Provincie Utrecht (2023)

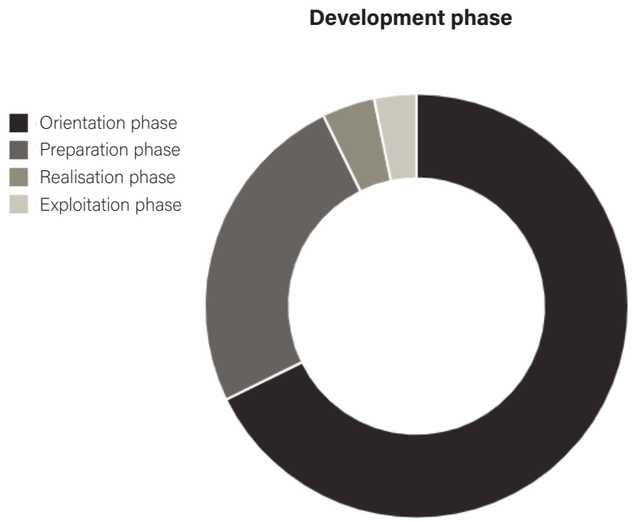


Figure 18: Current state of e-hubs in the Netherlands (translated from: Energy Scale-Up, 2024)

However, **a common pattern across all current roadmaps is teir top-down approach**. The frameworks assuming that a facilitator approaches a business park instead of vice versa, as illustrated in figure 19. Due to the complex systems nature of e-hubs, they can however not be designed from top-down. On top of that, facilitators lack the legal authority to design e-hubs; businesses retain autonomy over sharing their data and deciding whether joining an e-hub is a viable option for them.

This top-down approach in current practices shows two main discrepancies to the multi-actor complex nature of e-hubs:

1. There is no liniar and/or one-size-fits-all solution possible for the multi-actor complex nature of e-hubs
2. Approaching a multi-actor complex system from top down shows practical inefficiencies, including inefficiency and a limited availability of facilitators.

These two discrepancies are explained below.

"Step 1A. Identify the relevant stakeholders and the problem definition and provide comfort and trust towards the companies.

The already present or to be appointed (process) coordinator will ascertain the ambitions and bottlenecks concerning sustainability, electricity connections, and E-mobility from the companies, the objectives, ambitions, and wishes from the (regional) government, and the bottlenecks and expansion plans of the grid operator and document this. A CRM-like environment can help to map contact details and specifics, but this can also be done through MS OneNote or a similar tool. Additionally, a registry with publicly available data can help to get an initial understanding of the issues locally at hand."

Figure 19; Quote from the blueprint by MOOI EIGEN (MOOI EIGEN, 2023)

NO ONE-SIZE-FITS-ALL SOLUTION IS POSSIBLE IN THE DEVELOPMENT OF E-HUBS

While existing frameworks and roadmaps provide a good example of the development process of e-hubs, a linear approach, nor complete one-size-fits-all solution is not possible for multi-actor complex systems like e-hubs, as explained in the theoretical background. Existing frameworks provide a good backbone to the development process, however they are not able to stimulate the development of e-hubs regarding emergent behaviour, adaptation, evolution and self-organisation.

INEFFICIENCIES IN APPROACHING E-HUBS FROM TOP-DOWN

A top-down approach in establishing e-hubs on business parks entail that facilitators have to actively stimulate momentum on the business park, including continuous efforts to encourage business participation. In practice, **this approach is not efficient in fostering grassroot innovation and energy democracy**, and may even lead to resistance in the development of e-hubs.

Practitioners explain these statements by the quotes in figure 20.

Next to this, the **demand to e-hubs exceeds the available support by facilitators**, 84 business parks are stuck in their orientation phase as of may 2024, partly due to the limited amount of available support by facilitators (Energy-Scale Up, 2024). This amount will quickly increase; as explained in the contextual problems grid congestion is a rapidly growing problem, resulting in a surge of business parks that could benefit from an e-hub but lack the organisation and support to progress beyond the orientation phase.

"Especially in the beginning, we spent a lot of time keeping all companies on board. You have to keep them constantly engaged."

- An independent process manager of an e-hub pilot on a business park in the Netherlands, 2024

"We were fortunate that the park manager had good connections with all the companies on the park, otherwise they wouldn't have readily accepted a 'stranger' telling them what to do."

- A process manager of an e-hub pilot on a business park in the Netherlands, 2024

"When I arrive at an business park, the first few meetings are truly moments where everyone vents their frustrations and tells me that the DSO and I need to solve them. They do not feel yet that they need or want to actively participate in finding these solutions."

- A facilitator of e-hubs on business parks in the Province of Utrecht, 2024

Figure 20: Practitioners explaining inefficiencies in a top-down approach

CONCLUSION OF THE BACKGROUND OF THE CHALLENGES IN THE ORGANISATIONAL DIMENSION OF E-HUBS AND HOW CURRENT PRACTICES SHOW A GAP IN ADDRESSING THESE CHALLENGES:

In conclusion, **it is preferable to stimulate e-hubs from bottom-up insead of top-down** in order to overcome two main challenges in e-hub development:

1. To allow for emergent behaviour, adaptation and evolution, as e-hubs are multi-actor and complex systems
2. Because of the inefficient development processes in a top-down approach, combined with the limited availability of facilitators to be involved in the entire development process.

It is therefore desirable for e-hubs to have a self-organising character, which needs to be stimulated in the orientation phase of e-hub development.

While existing frameworks provide a good backbone for the development of e-hubs, they are **limited in addressing the two challenges and stimulating a self-organising character** of e-hub development.

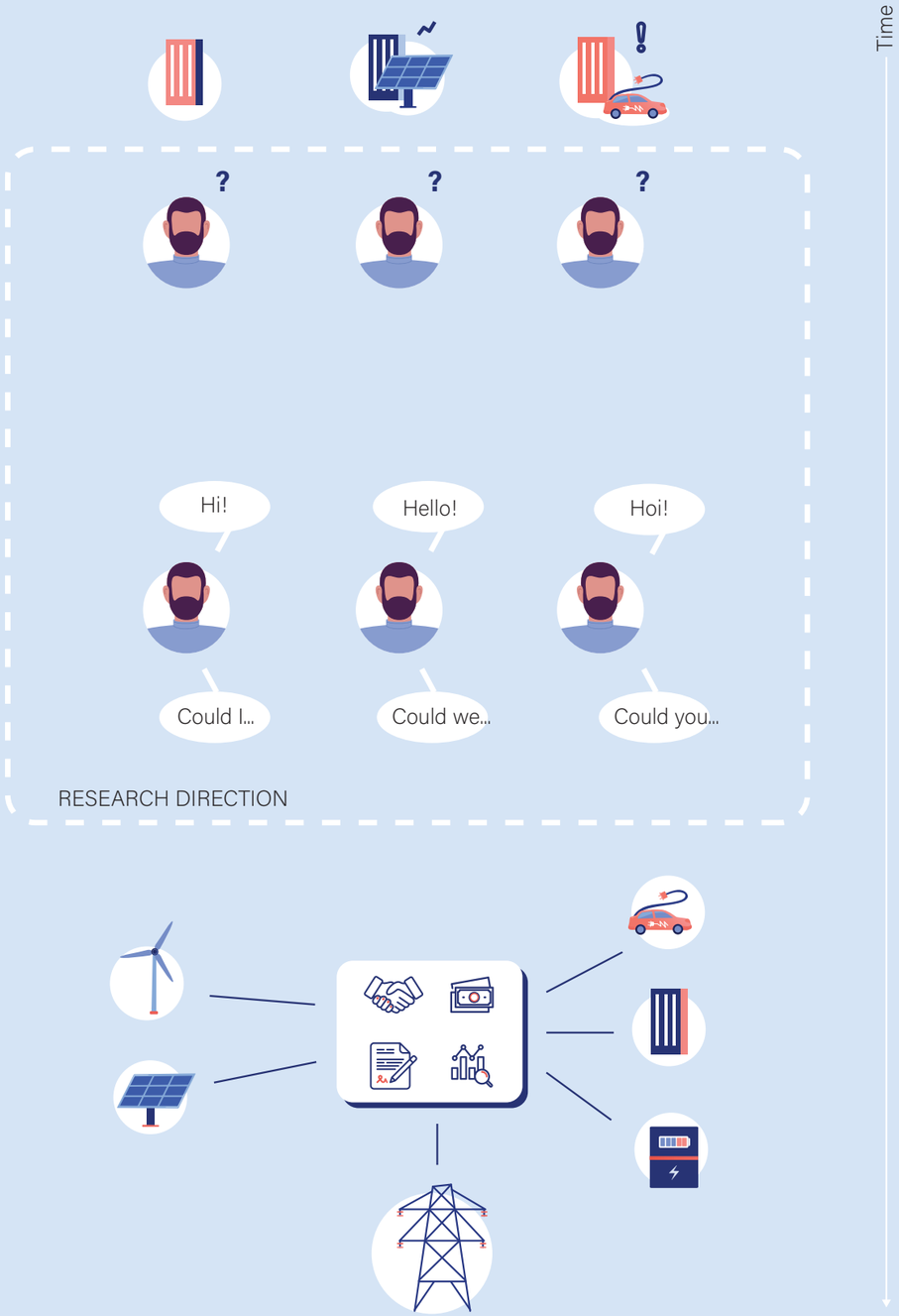


Figure 21: The research direction (Author's image)

CONCLUSION OF THE SOCIETAL CONTEXT: GAPS IN CURRENT PRACTICES AND RESEARCH DIRECTION

In conclusion, e-hubs on business parks are an important solution to grid congestion, and thus an essential part of the energy transition in the Netherlands. The technical and legal dimentions of e-hubs are trending towards becoming standardised products, whereas the organisational dimension is falling behind in this regard. Currently 90% of business parks are not sufficiently organised to start an e-hub, and 80% are not organised at all. Current solutions to this problem involve a top-down approach, where facilitators initiate new e-hubs. However, this creates resistance in grassroot innovation and energy democracy, and due to a lack in (human) resources of facilitating roles it is desirable for e-hubs to have a self-organising character. Current frameworks on the organisational dimension of e-hubs focus on a top-down approach, however this approach is inefficient and unfeasible on the larger scale. There are however no existing frameworks or tools that stimulate this self-organising character and/or provide guidance to participants of potential e-hubs to organise themselves into successful e-hubs.

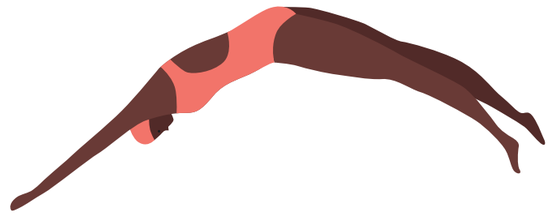
A new proposition is needed to stimulate and guide potential participants to organise themselves into new e-hubs, focussing on the orientation phase of their development process (figure 21). This proposition is not a replacement of, but an addition to the current frameworks, overcoming their limitations by adding a bottom-up and self-organising approach. In the research and design of this new proposition, it is essential to recognize that e-hubs are socio-technical, multi-actor complex systems. This will be explained further in the following sections.

RESEARCH SCOPE

The scope of this research can be divided into different domains:

- Subject matter scope: E-hubs; being socio-technical multi-actor complex systems
- Geographical scope: the Netherlands, with a focus on (but not limited to) e-hubs within the geographical area in which Stedin operates, being the provinces of Zuid-Holland, Utrecht and Zeeland.
- Spatial scope: business parks
- User-centric scope: businesses that are interested in starting an e-hub (hereinafter referred to as 'the participant.'
- Temporal scope: 2024
- Legal scope: the laws and regulations of act in 2024 in the Netherlands.
- Process scope: the orientation phase of e-hub emergence

This master thesis is conducted in collaboration with Stedin, a Dutch DSO. Stedin wants to stimulate the emergence of e-hubs in order to decrease net congestion.



Now that a research direction and scope have been defined, let's dive deeper into researching, understanding and stimulating the orientation phase of e-hub development. The remainder of this chapter will focus on the following aspects:

- Theoretical background on research methods for socio-technical, multi-actor complex systems
- A deep-dive in to current academic context, focussing on both the knowledge generated on the stimulation of e-hub development, as well as the research methods used in academic literature.
- This results into the definition of two gaps in current literature:
    1. A knowledge gap (**what** is researched)
    2. A methodological gap (**how** is it researched).
- Following the knowledge gap, research questions are drafted.
- Following the methodological gap, the research approach, methodologies and methods for this master thesis are designed.

THEORETICAL BACKGROUND OF RESEARCH METHODS

OF SOCIO-TECHNICAL, MULTI-ACTOR COMPLEX SYSTEMS

RESEARCH AND DESIGN WITHIN SOCIO-TECHNICAL, MULTI-ACTOR COMPLEX SYSTEMS: SYSTEMS THINKING

In order to research and design socio-technical, multi-actor complex systems, systems thinking is essential (Meadows, 2008). Systems thinking differs significantly from linear thinking, which is often used in today's problem-solving techniques. In linear thinking, the symptoms of the problem are determined, and solutions are designed towards solving these symptoms. On the other hand, systems thinking not only examines the symptoms of problems but traces them back to their origins within underlying systematic structures and seeks solutions here (figure 22).

Linear thinking and applying simple solutions to complex problems not only fails to solve the problem, but it often makes the problem worse due to unintended and unforeseen consequences and the dependencies it creates (Simons & Nijhof, 2021). A good example for this is the Rat Effect, concerning a linear thinking solution to a rat outbreak in Hanoi, Vietnam. The local government offered a bounty for every rat killed, a simple solution at first glance; more rats killed meant a lower population of rats. However, citizens started to breed rats, in order to capitalise on the bounty, stimulating the rat outbreak (The Sydney Morning Herald, 2016). This simple solution aggravated the problem because it did not factor in the motivations of the actors involved in the system. Actors focused on their self-interest in the short term (earning money) rather than on achieving a common goal (dealing with the outbreak of rats).

THE GOAL OF SYSTEMS THINKING: PUSHING LEVERAGE POINTS

For solving problems in complex adaptive systems, we must start looking at what is driving the problems and how we can change them. This starts with looking at the problem in a different way: the problems we face are not necessarily the problems we need to solve. The problems we face can only be the symptoms, results or outcomes of other deeper underlying elements, structures, behaviour and human choices. Therefore, deeper levels of the problem need to be explored before coming up with a solution. Through a systems thinking perspective, which involves understanding interconnectedness, feedback loops, and dynamics within a system, leverage points can be identified. Leverage points refer to specific areas within a complex system where small changes can lead to significant shifts in behaviour or outcomes, due to **cascading effects** within the system (Meadows, 2008). These points represent strategic opportunities for intervention or influence, allowing individuals or organizations to efficiently manage or transform the system (figure 23).

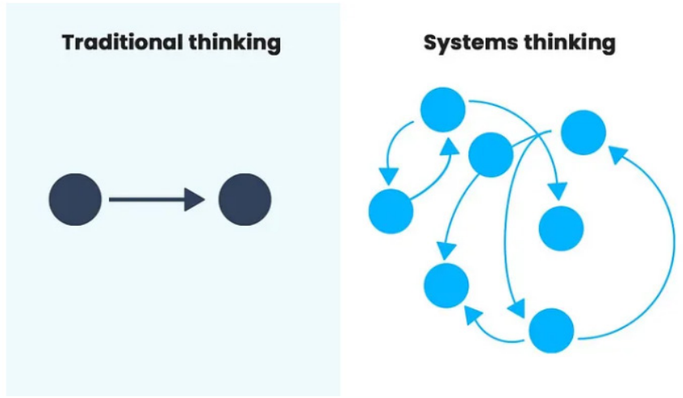


Figure 22: Traditional thinking versus systems thinking (Gandhi, 2022)

Figure 23: Pushing leverage points causes cascading effects (Author's image)

FINDING LEVERAGE POINTS: MAPPING COMPLEX SYSTEMS

There are many different ways to map complex systems and discover leverage points. For this master thesis, two main theories are researched: the **Causal Loop Diagram (CLD)** and the **Iceberg Model (IM)**.

CLDs, also called System Thinking diagrams or Influence diagrams, serve as powerful tools for mapping complex systems as they visualise multiple agents or components, interactions and dependencies causing feedback loops, giving insight into the emergent behaviour of the system (Morecroft, 2015). In a CLD, causal links depict how changes in one variable influence others, either positively (through reinforcing loops) or negatively (balancing loops). This is a simple way of showing how elements in a system interrelate. These diagrams help to identify feedback loops within a system, uncovering dynamic behaviours and potential leverage points for intervention or improvement.
When drawing a causal loop diagram, the following steps should be taken:

1. **Identify the key variables:** begin by identifying the key variables or factors that are relevant to the system of study. In the context of e-hubs, these are drivers and barriers in any form (e.g. law and regulation, certain beliefs, certain roles that are missing or abundant, certain technologies that are missing or abundant, etc.), that stimulate or withhold the emergence of e-hubs.
2. **Determine causal relationships**: analyse how the variables of last step interact with each other. Causal relationships should be identified between variables, considering both direct and indirect influences. This shows whether changes in one variable lead to changes in another variable, either positively (an increase in value A causes an increase in value B, or more leads to more and less leads to less, indicated with a '+') or negatively (an increase in value A causes a decrease in value B, or more leads to less and less leads to more, indicated with a '-') (figure 24)
3. **Identify feedback loops:** Analyse the structure of the CLD to identify feedback loops. Feedback loops are patterns of causal relationships where changes in variables loop around, affecting each other repeatedly. These loops can either strengthen (positive feedback) or stabilize (negative feedback) the system.
4. **Identify leverage points**: to locate the leverage points, feedback loops that are causing the problem (in the case of e-hubs: inertia in the orientation phase of their development), or hindering the goal of the system should be investigated. Additionally, the feedback loops that are supporting the goal or resolving the issue should be investigated. Feedback loops that are hindering the goal of the system should be solved, and feedback loops that are supporting the goal of the system should be stimulated.

Symbol	Interpretation	Mathematics	Examples
X →(+) Y	All else equal, if X increases (decreases), then Y increases (decreases) above (below) what it would have been. In the case of accumulations, X adds to Y.	$\partial Y/\partial X > 0$ In the case of accumulations, $Y = \int_{t_0}^{t}(X + \ldots)ds + Y_{t_0}$	Product Quality →(+) Sales Effort →(+) Results Births →(+) Population
X →(-) Y	All else equal, if X increases (decreases), then Y decreases (increases) below (above) what it would have been. In the case of accumulations, X subtracts from Y.	$\partial Y/\partial X < 0$ In the case of accumulations, $Y = \int_{t_0}^{t}(-X + \ldots)ds + Y_{t_0}$	Product Price →(-) Sales Frustration →(-) Results Deaths →(-) Population

Figure 24: Cause and effect relationships in CLD. (Sterman, 2000)

Positive feedback loops are called Reinforcing loops (R), indicating a loop is exponentially increasing or decreasing (figure 25). Reinforcing loops cause dramatic growth or collapse, amplify change and have a snowballing effect, make something greater or less, and accelerate growth or decline by being vicious or virtuous cycles. They are composed of all positive polarities in the same direction and/or an even number of negative polarities in the opposite direction.

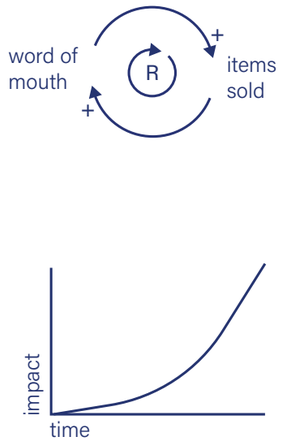


Figure 25: Reinforcing loops (Author's image)

Negative feedback loops are called Balancing loops (B), indicating the loop seeks balance and equilibrium (figure 26). Balancing loops keep things under control and limit dramatic growth. They are composed of a series of variables that are connected in a loop that has an odd number of negative polarities.

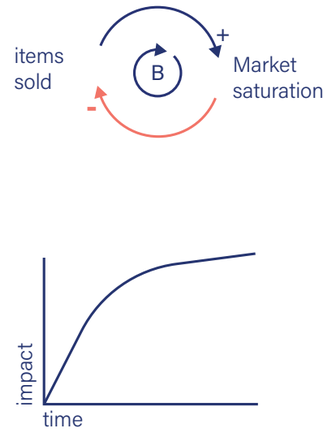


Figure 26: Balancing loops (Author's image)

Reinforcing (R) and balancing (B) loops can also affect each other (figure 27).

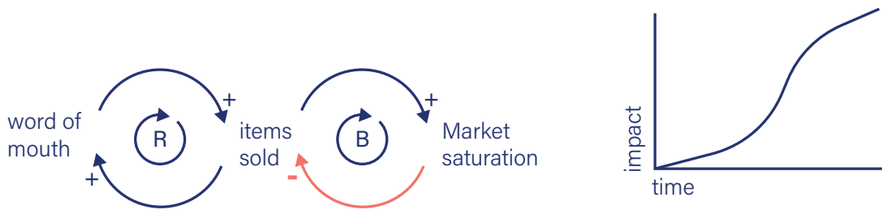


Figure 27: Reinforcing and balancing loops effecting each other (Author's image)

Where CLD's focus on causality between elements of the system, the **Iceberg Model** (**IM**) focusses on adding depth of understanding and identifying root causes. The iceberg serves as a metaphorical representation of the visible and hidden aspects of a complex system (figure 28).

The visible problems, or symptoms, form the tip of the iceberg, while the biggest part of the iceberg is hidden under the water. All levels are interconnected and together they create a system. In order to change the system and innovate towards more sustainable systems, the deeper levels of the iceberg must be researched. This starts with researching the way we behave and the decisions we make. A question to ask for this level is 'What are the incentives to behave like this? Next, underlying structures need to be researched. What are the underlying power structures? How are the incentives institutionalised in policies, rules, taxes, infrastructure, education? Lastly, insights into our collective beliefs, culture and values offers knowledge on what we value as a society.

Four simple questions to ask for a complete picture of the system are (Simons & Nijhof, 2021):

1. What behaviour is creating the problem?
2. What incentives do people have to behave like that?
3. Where or how are these incentives fixed in the underlying structures?
4. Who has the power to uphold this regime and what do we value and believe in maintaining those power structures?

The iceberg model highlights the importance of understanding both the visible and hidden aspects of a system to gain a comprehensive understanding of its behaviour dynamics. Leverage points can be found often in the deeper levels of the iceberg model, although elements on deeper layers of the iceberg model might be harder to address than on the surface-level.

More information on the combination of CLD and IM will be provided in the methods section of this master thesis research.

A discussion on the power of these research methods in systemic design of socio-technical multi-actor complex systems is provided in Chapter 7: Conclusions.

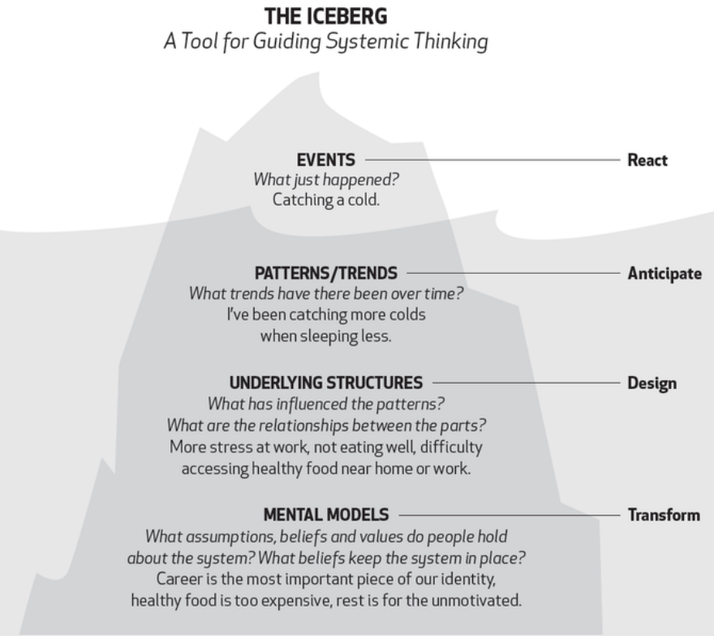
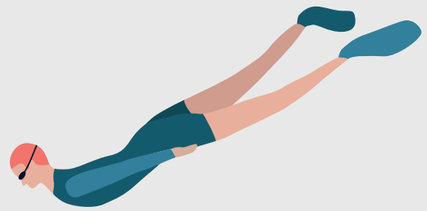


Figure 28: The iceberg model (Ecochallenge, n.d.)



ACADEMIC CONTEXT

AIM AND FOCUS OF THE LITERATURE REVIEW

As stated in the **research direction**, a new proposition is needed to stimulate and guide potential participants to organise themselves into new e-hubs, focusing on the orientation phase of their development process.

The gap in current practices described in last sections is compared to the academic literature. The **aim of this literature review is twofold**:

1. To discover what academic research output or **knowledge produced** contribute to the stimulation and guidance of potential participants into new e-hubs, focussnig on the orientation phase of their development process. This **allows to** build on previous work, identify a gap in current knowledge causing need for further research, and compare the research outcomes produced in this master thesis to existing knowledge in order to identify differences.
2. To examine how this academic knowledge is produced, by identifying the **research methods used** in current academic studies. As discussed in the theoretical background, e-hubs are socio-technical, multi-actor complex systems. Understanding the research methods used to study these systems is crucial for obtaining holistic and practical insights. Examining the research methods used **allows to** design the approach taken in this master thesis by adopting successful practices, but also allows to identify gaps or limitations of current research in studying e-hubs as socio-technical, multi-actor complex systems.

This review f**ocuses on the following aspects** in the retreived literature:

- **The scope** of the research methods and the knowledge gained. Given the rapid pace of the energy transition and the varying development of e-hubs across regions, influenced by national policies and regulations, in order to design an effective proposition it is crucial to understand the state of e-hubs in the **Netherlands in 2024**.
- **The focus on the orientation phase of e-hub development** in both the research methods used and the knowledge produced: as described in the research direction, it is important to focus on the orientation phase of e-hub development while designing a proposition that stimulates e-hub development. The current focus on this phase is therefore researched in existing academic literature.
- The **actionability** of the research outcomes and of the **knowledge produced**: given the urgent and growing demand for e-hubs due to grid congestion as explained in the societal context, it is crucial that research outputs are quickly implementable. This means the produced knowledge should be usable by potential e-hub participants, rather than merely describing processes or offering policy advise. This includes assessing the extent to which research output addresses **organisational implications**, given that the organisational dimension of e-hubs is emphasised in the research direction.
- This actionable knowledge can by created by using not only research methods to describe current processes, but by also **designing interventions** to implement outcomes of this research.
- The **applicability and depth of understanding** offered by the **research methods used**. In order to design an effective proposition, it is important to understand real-world experiences, behaviours and contexts of e-hubs. Therefore, it is desirable for the research methods used in current literature to collect data firsthand from the actual environment where the phenomenon under investigation occurs.

This literature review is shown in tables 2 to 5, and concludes in both a knowledge gap and a methodological gap.

READERS MANUAL FOR THE LITERATURE REVIEW

Given the complexity of e-hubs, they can be researched from a variety of angles, each focusing on different aspects. Therefore, this literature review is divided into multiple sectios. The **structure of this literature review is as follows:**

1. Academic literature focussed on the **technical** side of e-hubs
2. Academic literature focussed on the **social** side of e-hubs
3. Academic literature that focus on **system integration** of both technical and social aspects of e-hubs
4. Academic literature that focuses on the **drivers and barriers** experienced by participants of potential e-hubs. This is crucial knowledge for this master thesis, as designing a proposition to stimulate and guide potential e-hub participants requires understanding their experiences. This enables the identification and stimulation of drivers, and mitigating experienced barriers.

In each of the four sections, a table is created to illustrate the knowledge generated, the methods employed, and the remaining knowledge and methodological gaps identified in each reviewed paper. An illustrative example is provided in table 1.

At the bottom row of each table, a section-specific conclusion is presented, consolidating and highlighting the knowledge generated, the methods used and the remaining gaps in both knowledge and methodology.

After the four sections are discussed, an overarching conclusion is drawn from the entire body of reviewed literature. This conclusion encompasses the researched topics, the methodologies employed, and underscores the remaining knowledge gap and methodological gap. of what is researched and how, and the remaining knowledge gap and methodological gap.

Table 1: Illustrative example of the tables used in the literature review

Paper	**What knowledge is generated?**	**How this researched?**	**Knowledge gaps**	**Methodological gaps**
Author, year	Research output	Methods employed	Remaining gaps in research output	Remaining gaps in methods employed
Conclusions	Conclusions on knowledge generated	Conclusions on methods used	Conclusions on remaining knowledge gaps	Conclusions of remaining methodological gaps

ACADEMIC LITERATURE WITH A FOCUS ON THE **TECHNICAL** DIMENSION OF E-HUB DEVELOPMENT

Table 2 (part 1/2): academic literature with a focus on the technical dimension of e-hubs

Paper	What knowledge is generated?	How this researched?	Knowledge gaps	Methodological gaps
Mohammadi et al. (2017)	The transition from separate energy systems towards forming an e-hub is researched. A conceptual model is presented in which various possible options for the technical composition of e-hubs are presented, like different energy sources, different energy carriers and different conversion techniques.	Conducting a literature review on the different inputs, converters, storage systems and outputs for e-hubs, analysis of dominant structures, identification of weaknesses, strengths and challenges and a discussion of the potentials of the e-hub concept.	While an overview is provided on what possible techniques can be used, actionability is missing. There is no knowledge provided of when certain sources, carriers and conversion techniques are the best option for a developing e-hub. This includes information as efficiency, costs, preferable combinations in certain scenarios, etc.	No field research was conducted, missing details and nuances of actual e-hubs. E-hubs are not researched as being multi-actor or social systems. No complexity is included.
Mansouri et al. (2022a)	A model is developed for designing e-hubs that addresses challenges of increasing energy demand and declining efficiency, integrating a demand response programme to improve efficiency and reduce CO2 emissions.	Mathematical modelling, Mixed-Integer Non-Linear Programming (MINLP), Simulation, Scenario Analysis, employing a dynamic modelling framework to account for changing conditions over time. Data used includes electrical, heating and cooling load scenarios, wind speed scenarios, electricity price scenarios, gas price and installation costs.	Improved efficiency and reduced CO2 emissions can be seen as a driver for participants to form a new e-hub, however the model researched will not stimulate the orientation phase of the e-hub formation, where focus is put on forming new coalitions and common visions amongst stakeholders instead of optimising assets.	human decisions are not taken into account. The sources, geographical or temporal scopes of the data used for modelling are not mentioned. While a dynamic framework is employed, the research does not count for complexity of the system.
Shahrabi et al. (2021)	An improved e-hub planning and scheduling tool including multiple RE-sources and storage systems to optimize operation, planning and costs of an e-hub.	System modelling of DER and electricity and heating storage systems. It uses Quantum Particle Swarm Optimisation (QPSO) to minimise total costs and reduce emissions, and compares this with other optimisation algorithms.	The developed tool will primarily help the operation and planning of already existing assets. This will not stimulate a new e-hub in their orientation phase, where new coalitions and common visions amongst stakeholders have to be created.	Data is used from secondary sources, no temporal or geographical scope is mentioned. E-hubs are not researched as being multi-actor systems, human decision-making is not discussed.
Ding et al. (2022)	A review of optimisation and control for e-hubs with multiple Multi-Energy Systems (EMS), which are integrated systems that combine multiple energy carriers, sources, and conversion technologies.	A comprehensive literature review covers e-hub modelling methods, optimisation techniques, solution algorithms and IoT-based control structures.	This review can be very useful for new e-hubs to design a combination of energy carriers, sources and conversion technologies in their preparation, realisation or exploitation phases. However, in the orientation phase, where new coalitions and common visions amongst stakeholders have to be created this tool adds little value.	Mostly secondary data sources are used, missing details and nuances of actual e-hubs. No temporal or geographical scope is mentioned, and human decision-making and complexity are not researched.
Zhang et al. (2020)	An optimisation model for the planning of e-hubs with multiple energy sources. By minimising emissions and costs, the model determines the best combination of generators and devices.	Mathematical modelling and optimisation combining different generators, energy devices and transmission lines. The e-hub is simulated and optimised using a Particle Swarm Optimisation (PSO) algorithm. The model is validated using two case studies with time durations of two and five years.	This model can be very useful for new e-hubs to design a combination of energy carriers, sources and conversion technologies in their preparation, realisation or exploitation phase. However, in the orientation phase, where new coalitions and common visions amongst stakeholders have to be created this tool adds little value.	'The Brazilian system' is mentioned as being one of the case studies, however further information on the geographical or temporal scope is not provided. No human decision-making or the multi-actor nature of e-hubs is mentioned.
Davatgaran et al. (2018)	An optimal bidding strategy for an e-hub to maximise profit by participating in day-ahead and real-time markets. The strategy tackles uncertainties like the fluctuating energy generated by RE sources. The strategy is suited for a mix of multiple energy sources.	The researchers make a model of the e-hub, and by using stochastic optimisation the model allows for decision-making under uncertainty. Mixed Integer Linear Programming (MILP) is used to optimise the model. The model is validated through numerical simulations, which involve running the model with different input parameters and scenarios to assess its performance and effectiveness in optimising bidding strategies for the e-hub.	An optimal bidding strategy on the day-ahead and real-time markets can be a large driver for participants of potential e-hubs to collaborate, as there is a financial incentive. However, this tool does not further stimulate the orientation phase of e-hub development, where new coalitions and common visions amongst stakeholders have to be created	The research focusses on the e-hub being one entity instead of being a multi-actor system. No social aspects are mentioned. No complexity of the system is mentioned. There are no implications of what this strategy will mean for e-hubs in the Netherlands in 2024.

Table 2 continues on the next page.

Table 2 (part 2/2): academic literature with a focus on the technical dimension of e-hubs

Paper	What knowledge is generated?	How this researched?	Knowledge gaps	Methodological gaps
Hemmati et al. (2018)	A sustainable framework for designing an e-hub, considering environmental and social impacts, by analysing the different possible parts of e-hubs. The size and dispatch of DER are optimised.	To determine the environmental and social impacts, Life Cycle Assessments (LCA) of different components of the e-hub are conducted, combined with the External Cost Method. Stochastic programming is used to address different uncertainties such as wind speed, solar radiation, and electricity and heat demands. The proposed framework is evaluated through simulation on a case study	While environmental and social impacts are important to consider during the development of new e-hubs, this tool will mainly be useful in the preparation, realisation and exploitation phases. However, in the orientation phase, where new coalitions and common visions amongst stakeholders have to be created this tool adds little value.	The researchers mention the limitation of assuming the decision making is centralised in this paper, "although this is not the case in reality because of various shareholders and stakeholders". In the description of the case study used, only technical components are mentioned instead of also including actors, and no geographical or temporal scope is mentioned, making it unclear what the direct implications of this study are on e-hubs in the Netherlands in 2024.
Conclusions	Academic literature focussing on technical aspects of e-hubs mainly consists out of frameworks and tools that model and design assets within e-hubs in order to increase efficiency, decrease costs and/or increase revenue and decrease social and environmental impacts.	All researches focus on mathematically modelling, simulating and optimising technical components and assets within e-hubs.	Two main topics are missing in current literature on the technical dimension when looking for a new proposition to stimulate and guide participants in the development of a new e-hub, being actionability of the research output (the organisational implications) and a focus on the orientation phase of e-hub development. ▪ **Actionability:** the knowledge generated from the researches reviewed in this section is mostly abstract and descriptive in nature, lacking practical applicability for participants of potential e-hubs. Next to this, there is no information disclosed on the *organisational implications* of the knowledge produced by the researches of this section. while technical and economic optimisation is of importance in order to attract and include participants of e-hubs, there is no information given on the organisational implications of the optimisation frameworks and tools. E-hubs are collaborations of multiple organisations, where human factors like beliefs, values and relationships play a critical role in how technical solutions are adopted and utilised within the systems. Ignoring these aspects can lead to unforeseen challenges and resistance to change. ▪ **A focus on the orientation phase**: most technical and economic frameworks and tools can be interesting to use during the technical design of the e-hub, which will be in the preparation or realisation phases, or for optimising the existing e-hub during the exploitation phase. However, in the orientation phase participants have to come together, form a coalition, and starting to explore the technical possibilities. The level of detail proposed in the technical and economic frameworks and tools researched are unnecessary will most likely only distract participants during the orientation phase of developing e-hubs.	Based on the research scope and the depth of understanding generated by the research methods used in the reviewed literature, four main methodological gaps can be recognised: ▪ The **scope**: very little geographical or temporal scopes are mentioned, making it unclear what the direct implications of the research results are on e-hubs on business parks in the Netherlands in 2024. ▪ **Depth of understanding:** ▪ The papers examined do not delve into e-hubs as **socio-technical systems**. While Hemmati et al. (2018) touch upon certain facets of the social dimension, they primarily focus on the effects of the technical dimension on social impacts, rather than inherently considering the social aspects as integral components of the socio-technical system of e-hubs. ▪ E-hubs are not researched as **multi-actor systems**. No multiple stakeholders are mentioned and no human decision-making is considered. ▪ E-hubs are not researched as being **complex systems**. While multiple (technical) components and the relationships between them is researched, no emergent behaviour, evolution, or self-organisation is mentioned.

ACADEMIC LITERATURE WITH A FOCUS ON THE **SOCIAL** DIMENSION OF E-HUB DEVELOPMENT

Table 3 (part 1/2): academic literature with a focus on the social dimension of e-hubs

Paper	What knowledge is generated?	How this researched?	Knowledge gaps	Methodological gaps
Warbroek et al. (2019)	Warbroek et al. (2019) test the social, organisational and governance factors for success in local low carbon energy initiatives. Findings include that the success of local energy initiatives depends on three dimensions; related to the initiative itself (organisational factors), related to the interaction with the local community (social factors) and the presence of supportive governance settings and linkages with local governments and intermediaries (governance factors). The study underlines the need for success factors within all three dimensions for success of the initiative. Success factors from the different factors recognised in the paper include: ▪ Organisational factors: project champions (the driving volunteers and starters of the initiative), human capital, size, availability of time, access to funds and board diversity. ▪ Social factors: alignment with local values and frames of reference, alignment with the institutional characteristics of the local community, visibility, community involvement, bonding capital and bridging capital. ▪ Governance factors: linkage to government, linkage to intermediaries, supportive governance arrangement. Lastly, the study underpins that new energy initiatives differ greatly in the approaches they take, which inevitably means that there is no one-size-fits-all approach for a successful initiative.	The study employs a Variable-Oriented Cross-Case Research Design. This involves analysing claims through both within-case and cross-case analyses. Fourteen cases are studied within their real-life context in the Dutch provinces of Friesland, to maximise variation in terms of success and geographical distribution across the province. Data is collected through semi-structured in-depth interviews, documentation review (websites, policy documents, etc.), direct observations (workshops, meetings, field visits) and examination of physical artifacts (energy installations, community centres). Interview recordings are transcribed and analysed and case descriptions are created based on empirical evidence. Values are assigned to variables using a five-point scale, supported by qualitative descriptions. The cross-case analysis involves identifying bivariate correlations between independent variables and indicators of the dependent variable. Spearman's Rho is used as a correlation measure, and qualitative insights from case studies are used to provide in-depth understanding. This analysis combines qualitative and quantitative methods, serving as a triangulation approach.	The success factors described can be applied to the **orientation phase** of e-hub development. However, while knowledge on success factors do form a basis on what should be included in the development of e-hubs, these success factors are merely descriptive and **not yet actionable**. They do not provide direct support to potential participants that want to start a new e-hub. A knowledge gap remains in the actual steps the participants should take, what decisions they should make, what relationships or assets they should invest in during the development of an e-hub. Outcomes of Warbroek et al. (2019) can be used as a foundation for policy makers, but not by participants of developing e-hubs themselves.	The research selects case studies of fourteen low carbon energy initiatives. These entail the bottom-up initiating and managing of a project, or series of projects, involving the generation, stimulation, and/or facilitation of low-carbon energy by citizens on a local scale. The **research scope seems similar to the scope of this master thesis, however** business parks are expected to show different behaviour from the civic society, due to different characteristics and interests. Also, the research is conducted in 2019, making it questionable if the research outcomes are still valid in 2024 related to the fast pace of the energy transition. While the paper includes research on the social side of e-hubs, including the multi-actor nature of energy communities (like e-hubs), **no complexity** within the system was researched including causal effects and rootedness of the success factors found.
van de Grift & Cuppen (2022)	Van de Grift & Cuppen (2022) state that the attention for actors of renewable energy technologies (RET) is limited in academic literature. Assuming that public concerns on e-hubs behave the same as public concerns on RET, this research presents new insights on different actors of RET and their relationships to controversies surrounding these technologies. The review identifies two main categories in the existing empirical social science: RET actors' perceptions of public opposition and their responses to it. Results include that inadequate public participation and having incorrect knowledge is a cause of opposition to RET. Actors respond to this opposition by: ▪ Using public engagement instrumentally to prevent and reduce opposition ▪ Taking a reactive approach to public opposition and focus on project development ▪ Making strategic choices in public engagement to prevent public opposition ▪ Educating the public to reduce opposition ▪ Using community benefits to reduce public opposition ▪ Contrasting claims to delegitimise public opposition ▪ Using regulatory and power structures to restrict public opposition ▪ Accomodating public concerns to reduce opposition	A systematic literature review is conducted by developing a list of keywords to search relevant records in academic databases such as Scopus and Web of Science. Focus was put on various actors, with a specific focus on projects characterised by public opposition. 89 full-text publications were coded inductively using Atlas.ti software. Codes and themes were validated through discussion rounds.	Assuming that e-hubs are one of the applications of RET, an understanding of the relationship between actors of e-hubs and public concerns can be relevant for the design of the proposition. In the proposition, these public concerns can and should be answered in order to stimulate potential participants to establish e-hubs. The knowledge generated by the research **is quite actionable**, as specific strategies to answer public concerns are provided. The knowledge generated **is also relevant for the orientation phase** of e-hub development, as adressing public concerns can be seen as one of the first steps that need to be taken before convincing this public to actively participate in the establishment of e-hubs. **However**, van de Grift & Cuppen mention a lack of research on the diversity of actors. For e-hubs, being multi-actor systems, it is essential to map the actors in, and surrounding the system in order to understand its dynamics. This is a remaining knowledge gap.	The research describes a descriptive nature of the publications reviewed in the research, meaning that insights are provided but no examples are given. This decreases the depth of understanding, and causes a **remaining methodological gap on used research disciplines such as anthropology and ethnography**, as van de Grift & Cuppen also describe in their recommendations. Next to this, no temporal or geographical **scope** is mentioned, however in troughout the text there are some mentions of a 'German example' and 'Brazilian example.' A gap methodological gap remains for the scope of the Netherlands in 2024. Also, while the research does include the social side and multi-actor nature of e-hubs, little research is conducted to complexity, including emergent behaviour and evolution.

Table 3 continues on the next page.

Table 3 (part 2/2): academic literature with a focus on the social dimension of e-hubs

Paper	What knowledge is generated?	How this researched?	Knowledge gaps	Methodological gaps
Rodhouse et al. (2023)	Rodhouse et al. (2023) describe societal value co-creation in e-hubs. This entails the creation of social, environmental and economic benefits for and with communities, end-users, governments, companies and other stakeholders. The research describes that societal value co-creation is not yet an established approach, and many unclarities persists, for example on what stakeholders to involve and when, how and how much to involve them. This is mainly due to differing expectations that stakeholders have of societal values offered by e-hubs. The knowledge generated in this research includes an approach on co-creating societal value, including three governance steps: 1. Timing in expectations: when and how different societal stakeholders are expected to be included in co-creation 2. Timing of expectations: when to open up for new expectations of co-creation, when to invite new and alternative expectations to explore or identify new and unknown ideas, perspectives and value opportunities 3. Actor positions: which expectations become embedded in project development	An e-hub in Emmen, the Netherlands is investigated in a longitudinal, qualitative single case study from december 2018 to october 2020. Data was gathered through observations, interviews and document analysis from 19 project meetings, 9 interviews with developers and 7 critical project documents.	Knowledge on the creation of societal value by managing conflicint expectations in co-creating e-hubs is **relevant for the orientation phase** of e-hub development. When new coalitions and groups are formed, it is essential that participants have shared expectations of the societal value of the e-hub, including social, environmental and economic value. However, the knowledge produced is quite descriptive in nature. The research focuses on providing governance advise, while l**ittle actionable knowledge** is provided on how participants of e-hubs can manage conflicting expectations and start co-creating societal value.	**The geographical scope of the research is similar** to the scope of this master thesis, focussing on an e-hub in Emmen (the Netherlands). **However**, **the temporal scope differs**, focussing on 2018-2020 meaning no insight is generated on the current state of e-hubs in 2024, which is of importance given the fast pase of the energy transition and the rapid development of e-hubs. Also, a single case study is researched. Rodhouse et al. (2023) **recommend future research of a multi-case study.** While the social aspects of e-hubs as well as their multi-actor character are researched, there is **no focus on complexity**, evolution and emergent behaviour. Research is conducted to heterogeneous co-creators (multi-actor), however **Rodhouse et al (2023) recommend future research** to creating synergies between different project parts and activities (complex), which may result in different outcomes of their research.
Conclusions	Current academic literature generates knowledge on factors that influence the success of developing e-hubs (organisational, social and governance factors), information on how actors of renewable energy projects react to public concern around these projects, and governance structures to stimulate co-creation of societal value are researched in current academic literature on social aspects of e-hubs.	The reviewed studies used systematic literature reviews, as well as real-life case studies on e-hubs in the Netherlands.	While all studies reviewed **are relevant for the orientation phase of e-hub development**, generated knowledge is mostly descriptive in nature and are **not yet actionable** for the stimulation of potential participants in the development of e-hubs. In other words, information on the 'what to do' is provided, but information on 'how to do it' is missing.	**None of the researches reviewed share the scope** of this master thesis, missing research on e-hubs on business parks in the Netherlands in 2024. Also **missing is research on the complex nature**, including interactions between not only actors but also between processes, activities and other contextual factors. No emergent behaviour and evolution e-hubs is researched.

ACADEMIC LITERATURE WITH A FOCUS ON SYSTEM INTEGRATION OF THE SOCIAL AND TECHNICAL DIMENSIONS OF E-HUBS

Table 4 (part 1/2): Academic literature with a focus on a system integration of the social and technical dimensions of e-hubs

Paper	What knowledge is generated?	How this researched?	Knowledge gaps	Methodological gaps
Chilvers et al. (2018)	Chilvers et al. (2018) propose a first framework for system integration in new energy systems, where multple producers participate in the development of socio-technical sysetms. The conceptual framework presented, "ecologies of participation", provides a systemic view of looking at and stimulating socio-technical energy systems from three different interconnected dimensions: ▪ The subjects of participation ('who'; the participating stakeholders) ▪ The objects of participation ('what'; issues or material devises) ▪ The models of participation ('how'; structures and tools to facilitate the participation) These ecologies of participation describe the way different stakeholders collaborate, their relationships, the way they communicate, what drives them, what helps them, what decisions they make, etc. In these ecologies, public engagements with energy transitions is diverse, continually emerging, and are overflowing currently accepted framings of energy systems. Chilvers et al. (2018) conclude in highlighting the importance of understanding the complex dynamics of participation in socio-technical (energy) systems.	A systemic approach is taken including a systemic mapping methodology. This includes the collection of empirical analysis of 30 case studies in the UK between 2010 and 2015, and a secondary data analysis. The cases were compared to each other in order to uncover system-wide patterns, and compared to mainstream approaches to highlight the attribution to existing research.	While this research shows the first valuable example of understanding e-hubs as socio-technical, multi-actor complex systems in existing literature, the research is very descriptive of nature and therefore **lacks actionability.** Proof and examples are given why e-hubs can be seen as such systems, however no knowledge is presented on how to stimulate the development of such systems.	This represents the first research in existing literature that approaches e-hub research as socio-technical, multi-actor and complex. However, the **scope of the research is not similar** to the scope of this master thesis, focussing on the UK between 2010 and 2015. Next to this, Chilvers et al. (2018) recommend to conduct further research using in-depth action-based methodologies like ethnography in order to deepen empirical understanding of nuances of interactions and complexity in new energy systems.
Hess & Sovacool (2020)	Hess & Sovacool (2020) also integrate science and technology studies with energy social science. Four perspectives are combined: policy, socio-technical systems, cultural meaning and the publics. Findings include that public participation in current studies often fall short of expectations. Main reasons identified for this are a lack of public understanding of science and technology, highlighting issues like one-way communication, a limited engagement scope, weak connections between consultation outcomes and policy decisions. Hess and Sovacool describe the research on participation processes in new energy systems as 'constructing the public', rather than discovering a pre-existing public. This means that new energy solutions are often designed and then assigned to a pre-drafted system, instead of listening to the existing system, creating energy-democracy and using participation for new energy system design.	A systematic literature review is conducted, including a qualitative content analysis of the relevant articles. This analysis aimed to identify and categorise different perspectives used in the publications, leading to the four perspectives presented in the knowledge generated. This included an iterative coding process to categorise the articles into the different perspectives. The review focuses on literature published between 2009 and 2019.	While the research provides insights on what needs to be included in the new proposition (e.g. increasing public understanding, stimulating engagement and two-way communication, listening to the existing system to design new solutions), little knowledge is presented on how this can be implemented. Therefore, **actionability is lacking.**	The **scope of the research differs** from the scope of this master thesis, leaving a methodological gap in the research of e-hubs on business parks in the Netherlands in 2024. Only secondary data was reviewed, **without researching e-hubs as being multi-actor and complex systems**. This leaves a gap in researching empirical data, focussing on differentiating different actors and their relationships as well as causal relationships between elements, emergent behaviour and evolution of the system.

Table 4 continues on the next page.

Table 4 (part 2/2): Academic literature with a focus on a system integration of the social and technical dimensions of e-hubs

Paper	What knowledge is generated?	How this researched?	Knowledge gaps	Methodological gaps
Revesz et al. (2022)	Revesz et al. (2022) state co-design of local energy networks using community participation is crucial and should be an integral part of the community engagement strategy, to ensure that the integrated energy system provides maximum benefits for the local community. A lack of holistic design approaches including technical design, commercial models and stakeholder engagement is acknowledged, and a first integrated design approach for smart local energy systems is proposed. The approach includes a systematic methodology including technical and commercial aspects of the design, whilst also explaining the importance of effective stakeholder engagement and co-design with local communities. The stakeholder engagement plan outlined in the approach is being implemented concurrently with the technical design and comprises seven consecutive steps, making up a customer journey: 1. Introductory engagement 2. Introductory meeting(s) 3. Data gathering 4. Site visit(s) 5. Advanced dialogue 6. Letter of Intent (LOI) signing 7. Detailed design Corresponding initial business and ownership models and consequently tailored commercial models are designed towards the end of the engagement plan, using targeted consultation events and community co-design. However, Revesz et al. mainly research the involvement of end-users in the detailed design phase, in the latter part of the technical design of the new energy system. Only in this phase, contextual barriers and enablers are researched, such as personal attitudes, organisational or community culture or wider societal influences.	A design approach is taken in this research, starting by identifying, mapping and engaging stakeholders, defining a site and component specifics for the system, including a technical integration and control of these selected components and conducting Techno-Economic (TE) modelling and optimisation. Also, new business models are developed based on the results of the TE modelling and stakeholder feedback, tailored to meet the commercial requirements of all end-users. The initial concept design is shared with key stakeholders, and feedback is collected to update the design. Research is based on one case study in the UK, no specific year is mentioned but the text mentions the newly developed design being implemented in 2022.	While this study describes valuable insights into possible orchestration methods for the development of e-hubs, what they fail to address is the complexity of the multi-actor system that e-hubs are. As Warbroek et al. (2019) describe (see table 3 in 'the social aspects'), there is no one-size fits all solution possible. **A knowledge gap remains in including flexibility of the stakeholder engagement plan, allowing for the complex systems nature of e-hubs.** This gap is similar to the gap in current practices as described in the previous sections. Next to this, Revesz et al., mainly involve the participants in the detailed design phase, in the latter part of the technical design of the new energy system. Only in this phase, contextual barriers and enablers are researched, such as personal attitudes, organisational or community culture or wider societal influences. However, as described in the research direction the orientation phase is essential to research and stimulate, and therefore the focus of this master thesis. Knowledge produced for the **orientation phase of e-hub development is therefore a remaining knowledge gap.**	As stated in the knowledge gaps, the **research does not perceive e-hubs as being complex systems**. While socio-technical and multi-actor elements are discussed, no research is conducted to emerging behaviour, evolution of the system and self-organisation. Next to this, only one case is researched in the UK before 2022, leaving a methodological gap in the **research scope** of the Netherlands in 2024 and a focus on **multiple cases.**
Conclusions	Publications that focus on combining both social and technical elements of e-hubs all highlight the importance of active stakeholder participation in the research and design of e-hubs. Also emphasised is the importance of listening to the system; involving stakeholders into the decision-making processes in order to optimise technical outputs instead of first making a design and then offering it to the stakeholders. One research is conducted that incorporates the socio-technical, multi-actor and complex systems nature of e-hubs, validating the need for research and design of e-hubs as such (Chilvers et al., 2018)	Reviewed literature incorporates methods such as a systemic approach of collecting and systemicly mapping empirical data to discover system-wide dynamics, and human-centred design approaches where understanding and addressing the needs, preferences and experiences of the end-users (the participants) into the iterative problem-solving and design process.	A knowledge gap remains in **combining actionability with complexity**. Actionable knowledge produced does not take into account the complex nature of e-hubs, showing little flexibility, while knowledge on the complexity of e-hubs is merely descriptive in nature and does not provide actionable insights to stimulate participants of potential e-hubs in the orientation phase of their development.	Methodological gaps remain in researching **multiple cases in the Netherlands in 2024**, while viewing e-hubs as socio-technical, multi-actor complex systems. This includes a **gap in in-depth action-based methodologies** used in researching e-hubs in order to deepen empirical understanding of nuances in interactions and complexity, like ethnography.

ACADEMIC LITERATURE WITH A FOCUS ON **DRIVERS AND BARRIERS** EXPERIENCED BY ACTORS OF POTENTIAL E-HUBS

Table 5 (part 1/2): Academic literature with a focus on drivers and barriers experienced by actors of potential e-hubs

Paper	What knowledge is generated?	How this researched?	Knowledge gaps	Methodological gaps
Sadeghi et al. (2019)	Sadeghi et al. (2019) research the state-of-the-art of e-hubs. A few drivers and barriers for the development of e-hubs are described: Drivers: ▪ Enhanced level of whole system reliability ▪ Increase demand flexibility in a multi-carrier energy system ▪ The opportunity to achieve more optimal and realistic planning strategies ▪ Synergetic impacts of the e-hub on improving the efficiency of the energy system Barriers: ▪ Modeling and optimising multi-carrier systems, each with different natures, is complex ▪ Coordination among planning authorities is complex, especially in liberalized energy markets ▪ Legal frameworks with minimal bureaucracy are needed.	By conducting a literature review, aiming to understand and analyse various different definitions and models of e-hub concepts. These different definitions and models are compared, resulting in an understanding of the factors that influence the development of e-hubs. No specific scope is mentioned.	However a few drivers and barriers are described, there is no deep understanding provided of drivers and barriers as experienced by participants in the orientation phase of developing e-hubs. As the orientation phase exists out of forming new coalitions and stakeholder engagement, these topics are missing in the research of Sadeghi et al. (2019). This l**eaves a gap in the actionability** of the knowledge produced.	The **scope** of the research differs from this master thesis, not representing e-hubs in the Netherlands in 2024. Only **secondary data** is analysed, leaving a gap in in-depth understanding of nuances in e-hub development. Next to this, the drivers and barriers mainly focus on the technical and legal and institutional dimensions, leaving a gap in **researching the organisational dimension** of e-hub development.

Table 5 continues on the next page.

Table 5 (part 2/2): Academic literature with a focus on drivers and barriers experienced by actors of potential e-hubs

Paper	What knowledge is generated?	How this researched?	Knowledge gaps	Methodological gaps
Meijer et al. (2019)	Meijer et al. (2019) review barriers and drivers for technology commercialisation of renewable energy innovations in the Dutch sustainable energy sector. Drivers (ranked top to bottom on amount of times mentioned out of 20 interviews): ▪ Entrepreneur as pivotal figure ▪ Financial investment ▪ Prototypes & pilots ▪ Stamp of technology ▪ Knowledge ▪ Network ▪ Technology focus ▪ Staff ▪ Commercialization speed ▪ Reputation of company Barriers (ranked top to bottom on amount of times mentioned out of 20 interviews): ▪ High market competition ▪ Limited financial resources ▪ Risk averseness ▪ Complexity of technology ▪ Deficient legitimacy ▪ Limited end user interaction ▪ Time-waste ▪ Institutional inertness ▪ Short-term planning ▪ Firm accountability Meijer et al. (2019) also include an actor-based model, which suggests that the various barriers and drivers arise from the interactions between policy makers, industry partners and end-users.	A comprehensive literature review was conducted to identify existing theories, barriers, and drivers in the renewable energy market. A qualitative multiple-case study is employed, focussing on the Dutch renewable energy market. Data was collected through semi-structured interviews with 20 EMEs in the Dutch renewable energy sector. Data was also collected from secondary sources like company website, annual reports, newspaper articles, etc. Data was analysed through two coding cycles; the first cycle involved initial coding of barriers and drivers, while the second cycle focused on identifying relationships among these codes. Findings from interviews were triangulated with data from the literature review and secondary sources. Feedback from interviewees was also used to validate transcripts and reports.	Interviewees included Small and Medium-sized enterprises that want to commercialise new renewable energy innovations. Similarities coud be seen to e-hubs, as e-hubs can be seen as a new innovation that is to be commercialised as well. However, **no research is conducted on drivers and barriers experienced by actors of e-hubs specifically.** This leaves a knowledge gap.	As data was derived in 2017, a gap remains in researching drivers and barriers in **2024.** Because the energy transition is fast-paced, and net congestion is a rather new subject, drivers and barriers experienced in 2017 are very likely different from drivers and barriers experienced in 2024. A socio-technical and multi-actor view is taken, however **complexity,** including causal effects and evolution is still lacking. Meijer et al. (2019) recommend to further research the connections between drivers and barriers.
Conclusions	Drivers and barriers of e-hubs and the commercialisation of renewable energy innovations are researched, resulting into clear drivers and barriers experienced as well as their forthcoming from interactions between policy makers, industry partners and end-users.	Both studies conducted a literature review. Meijer et al. (2019) also conducted a qualitative multi-case study useing semi-strucuted interviews, analysed through two coding cycles which focused on initial coding and identifying relationships between the codes.	Knowledge is missing on drivers and barriers experienced by actors around, as well as actors inside e-hubs (participants). Also, the drivers and barriers researched are not in de same scope as this master thesis. As explained in the introduction of this literature review, due to the fast pace of the energy transition and its different implications on different geographical locations, a knowledge gap remains in research to the drivers and barriers of e-hubs in the Netherlands in 2024.	A methodological gap remains in conducting research in 2024, incorporating analysis of the complexity of the retreived data (focussing on causal effects, evolution and self-organisation)

CONCLUSIONS OF THE LITERATURE REVIEW: ACADEMIC KNOWLEDGE GAPS

Current academic research focuses on different dimensions and aspects of e-hubs, including the technical dimension, the social dimension, a system integrated perspective of the social and technical dimensions, and the drivers and barriers experienced by actors.

Knowledge on the technical dimension focuses mainly on technical and economic optimisation strategies of assets and software. Knowledge gaps however remain in the actionability of the research, having no organisational implications that could contribute to the research direction. Next to this, little focus is put on the orientation phase in current literature on the technical dimension of e-hubs.

Knowledge on the social dimension of e-hubs includes success factors of developing e-hubs, including organisational, social and governance factors. Next to this, the relationship between actors of renewable energy projects and the public concern on these projects is researched, concluding in a recommendation to actively inform and involve the public in the planning process of these projects. Also underlined is the importance of aligning expectations of different stakeholders in order to create maximised societal value of new energy projects. While all studies reviewed are relevant for the orientation phase of e-hub development, generated knowledge is mostly descriptive in nature and therefore a knowledge gap remains in actionable knowledge on how to stimulate the orientation phase of e-hub development.

Publications that focus on combining the social and technical dimensions of e-hubs all highlight the importance of active stakeholder participation in the research and design of e-hubs in order to optimise technical and organisational outcomes. One research is conducted that incorporates the socio-technical, multi-actor and complex systems nature of e-hubs, validating the need for research and design of e-hubs as such (Chilvers et al., 2018). However, a knowledge gap remains in combining actionability with complexity; actionable knowledge produced does not take into account the complex nature of e-hubs, showing little flexibility, while knowledge on the complexity of e-hubs is merely descriptive in nature and does not provide actionable insights to stimulate participants of potential e-hubs in the orientation phase of their development.

Lastly, drivers and barriers experienced by actors of renewable energy projects like e-hubs are researched. As explained in the introduction of this literature review, due to the fast pace of the energy transition and its different implications on different geographical locations, a knowledge gap remains in research to the drivers and barriers of e-hubs in the Netherlands in 2024.

In conclusion, a knowledge gap remains in the following topics based on the proposed research direction of this master thesis:

- **Actionable knowledge** that directly stimulates actors in the development of e-hubs, focussing on the **organisational implications** in the orientation phase of their development.
- This actionable knowledge should however not be a linear approach, but **should consider the multi-actor and complex nature** of e-hubs.
- Knowledge on **drivers and barriers** of actors of e-hubs in the **Netherlands in 2024**, focussing on the orientation phase of their development, in order to be able to stimulate drivers and mitigate barriers in the new proposition.

CONCLUSIONS OF THE LITERATURE REVIEW: ACADEMIC METHODOLOGICAL GAPS

A wide variety of research method's were used across all different publications reviewed, including quantitative mathematical optimisation, qualitative research including semi-structured interviews and a vast amount of literature reviews supporting both quantitative and qualitative researches.

Methodological gaps remain however in the following topics based on the proposed research direction of this master thesis:

- Researching the orientation phase e-hub development in the Netherlands in 2024, as none of the reviewed literature applies this scope.
- Researches that collect empirical data mostly fail to integrate a complex systems-perspective, including analysing the interactions, causal relationships and evolution processes between actors, processes, drivers and barriers. On the other hand, researches that integrate this systemic view mostly use second-hand data, missing nuances of and applicability to real-life cases. A gap therefore remains in combining the collection of empirical data with a multi-actor complex system perspective on data analysis.
- Multiple papers reviewed recommended to deepen empirical understanding of nuances in interactions and complexity by using action-based research methods like ethnography.
- Only one example of the reviewed literature combines researching the organisational dimension of e-hub development with the design of an intervention (Revesz et al. 2022). This research however does not share the same resaerch scope as this master thesis, nor accounts for complexity of the system, including causal effects, adaptation and evolution.

In conclusion, a methodological gap remains in researching e-hubs by combining the following approaches:

- Action-based empirical qualitative data collection and analysis in order to create an understanding of the multi-actor, complex systems characteristic of e-hubs.
- Focussing on the organisational dimension in the orientation phase of e-hub development on business parks in the Netherlands in 2024
- Combining this research with the design of an intervention to stimulate the development of e-hubs.

INSPIRATION ON THE RESEARCH APPROACH DRAWN FROM THE REVIEWED LITERATURE

Multiple reviewed studies recommended to implement action-based research methods such as ethnography in order to deepen empirical understanding and discover real-life nuances of e-hubs as socio-technical, multi-actor complex systems.

Chilvers et al. (2018) compare different cases to each other in order to uncover system-wide patterns.

Revesz. et al. (2022) take a design approach by starting with the identification, mapping and engaging of stake-holders. They share their initial concept design with key stakeholders, in order to collect feedback and update their design.

Meijer et al. (2019) analyse empirical data through two coding cycles; first an initial coding cycle to discover themes and aspects of e-hubs, followed by a second cycle to identify relationships among these codes.

In order to fill the methodological gap, these research methods will be considered and used in the approach of this master thesis.

A COMPARABLE SYSTEM:
INDUSTRIAL SYMBIOSIS

WHY THIS SYSTEM IS INCLUDED IN THIS MASTER THESIS RESEARCH:

While there is **little academic knowledge** on stimulating the orientation phase of e-hub development in the Netherlands in 2024 with a focus on the organisational dimension, and there are **little practical examples** of scalable e-hubs (meaning that e-hubs that moved past the orientation phase are mostly pilots, meaning they experienced exceptions in law, regulation and available support and are therefore not scalable to all business parks in the Netherlands), **there are practical examples of a comparable systems that share the research scope of this master thesis**, being socio-technical, multi-actor complex system sharing the research scope of this master thesis on business parks in the Netherlands in 2024: **Industrial Symbiosis (IS)**.

In order to not reinvent the wheel but learn from similar contexts in the design of a proposition following the research direction, lessons learned from these practical examples on IS will be researched and used later in this master thesis research (Chapter 5: Exploring the Possibility Space). In order to sketch the context of these systems, this section will focus on explaining the context and concepts of IS on business parks in the Netherlands in 2024.

WHAT IS INDUSTRIAL SYMBIOSIS:

IS a term commonly used in the study of Industrial Ecology. It entails a concept where different industries or businesses collaborate to exchange resources, such as materials, energy, water, or by-products, in a mutually beneficial way. This cooperation aims to improve resource efficiency, reduce waste, and create environmental and economic benefits for all involved parties. In IS, one organisation's waste or by-product becomes another organisation's raw material, fostering a closed-loop system and promoting sustainability in industrial processes (figure 29).

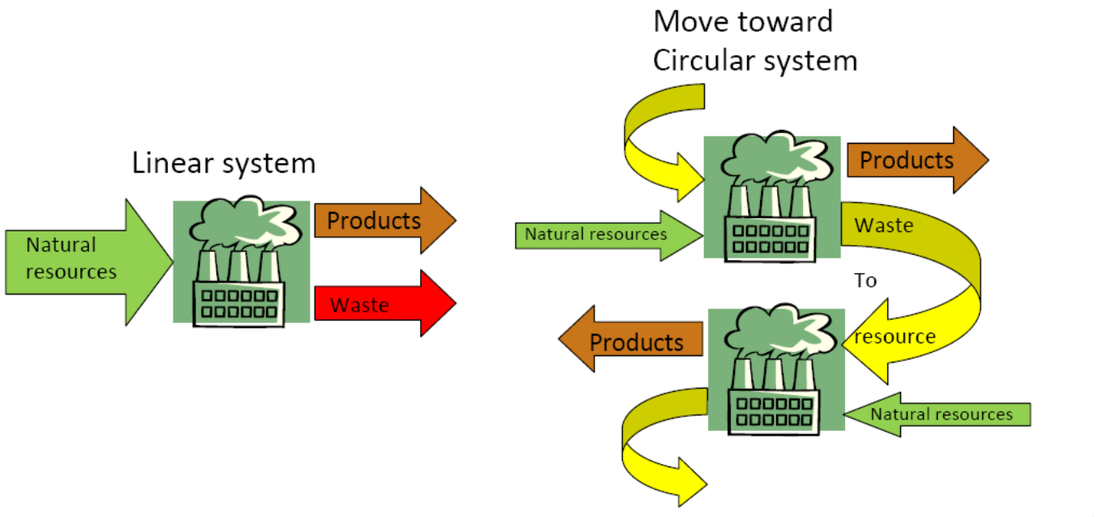


Figure 29: Industrial Symbiosis (EcoMENA, 2023)

HOW IS INDUSTRIAL SYMBIOSIS COMPAREABLE TO E-HUBS:

- Both concepts are socio-technical systems, referring to complex systems that involve the interaction between social and technical elements. In other words, these are systems in which people and technology work together to accomplish a particular goal. In such systems, both technical and social factors have to be taken into account during the design, implementation and management of the system.
- On a technical level, both concepts seek to optimise the use of resources to improve efficiency and reduce waste. For IS, these resources include materials, water and energy. For e-hubs, now the Dutch government mainly focuses on electricity.
- On a social/organisational level, both concepts involve collaboration among multiple stakeholders, including industries, businesses, utilities and government agencies in order to achieve shared goals related to resource management and sustainability.
- Both concepts are multi-actor systems. IS involves a collaboration and interaction among various stakeholders from different sectors, including industrial companies, government agencies, research institutions, communities, utilities and service providers.
- Both concepts are complex systems. IS involves interconnectedness amongst multiple actors, including non-linear relationships, emergent properties, adaptation and evolution.
- Both concepts offer similar benefits to its participants, such as optimised resource efficiency, decreased costs, increased sustainability performance, and resilience against disruptions in resource supply chains, enhancing the overall stability of participating businesses.
- Both concepts offer similar challenges to their participants, such as the need for coordination and logistics on a local level, something not previously on the agenda of most businesses. Also there are regulatory and legal barriers, such as permits, licensing and liability concerns.
- Lastly, both developments focus on companies on business parks, where a transition is noticeable from a focus on individual practices towards a community focus and collaborating, and being dependent on other stakeholders.

TOOLS, FRAMEWORKS AND RESEARCH METHODS COMMONLY USED IN INDUSTRIAL SYMBIOSIS RESAERCH

Tools, frameworks and research methods commonly used in IS research in academic literature can be structured into three main dimensions: an environmental/technical dimension, an economic dimension and a social dimension. Due to the limited timeframe of this master thesis, no extensive comparative analysis is conducted to discover differences and similarities between IS and e-hubs in academic literature. However, an exploration to IS in current academic literature is conducted in appendix K. More discussion on these findings and potential future research is provided in Chapter 7: Conclusions.

INDUSTRIAL SYMBIOSIS IN THE RESEARCH SCOPE OF THIS MASTER THESIS

In this master thesis research, no existing academic insights on IS will be included in the research of e-hubs due to the limited timeframe of this master thesis. Instead, practical examples of IS on business parks in the Netherlands in 2024 will be investigated and practical lessons learned from these examples will be included into the design of the new proposition as mentioned in the research direction.

There are multiple examples of IS on business parks in the Netherlands in 2024. Amongst them are the Port of Rotterdam (Port Of Rotterdam, 2019), Synergiepark Innofase in Duiven (InnoFase, 2021), Biopark Terneuzen in Zeeland (Quist & Korevaar, 2022), Industrial Park Kleefse Waard in Arnhem (Quist & Korevaar, 2022) and Chemelot in Limburg (ECRN, 2021).

A possible explanation why there are more successful examples of IS than of e-hubs is that IS is not dependent on a lock-in of infrastructure. Where e-hubs are dependent on the energy (institutional) infrastructure, law-and regulation and contracts with the DSO, IS experienced more freedom to evolve, leading to more scalable examples of IS than those of e-hubs in the Netherlands in 2024.

THESIS GOAL AND RESEARCH QUESTIONS

THE GOAL OF THIS MASTER THESIS:

E-hubs are an essential part of the solution for grid congestion and thereby facilitate the energy transition in the Netherlands, while offering multiple benefits for stakeholders. Their development should therefore be stimulated.

However, their development shows inertia, especially in the organisational dimension of the orientation phase of their development.

As e-hubs are socio-technical, multi-actor and complex systems, it is preferable to stimulate e-hubs to emerge from bottom-up, encouraging and guiding self-organisation of the participants (being companies on business parks in the Netherlands in 2024), instead of top-down. Current frameworks used by practitioners show limitations on this topic.

A new proposition that stimulates and guides potential participants to organise themselves into e-hubs, focussing on the orientation phase of their development process is therefore needed.

Knowledge gaps remain in academic literature on the design of such proposition, showing limitations in providing actionable knowledge that directly stimulate actors in the development of e-hubs, focussing on organisational implications of the knowledge outcomes. Also limited is academic knowledge an the multi-actor and complex nature of e-hubs, as well as the drivers and barriers experienced by actors of e-hubs in the Netherlands in 2024.

Current academic literature also shows methodological gaps on the research and design of e-hub development and a new proposition, leaving the need for action-based empirical qualitative data collection and analysis incorporating the multi-actor and complex systems nature of e-hubs while focussing on the organisational dimension of e-hub development, and combining this research with the design of an actual intervention; a new proposition that stimulates the development of e-hubs on business parks in the Netherlands in 2024.

In conclusion, the goal of this master thesis is to:

- **Research** the dynamics of e-hubs on business parks in the Netherlands in 2024 as socio-technical multi-actor complex systems, by means of action-based empirical qualitative data collection and systemic analysis. Focus is put on the organisational dimension of the orientation phase of e-hub development, and dynamics of drivers and barriers e-hub participants is researched.
  - The goal of this research is to find leverage points in the system, where small innovation efforts have cascading effects on the behaviour of the system (please refer to the theoretical background of research methods for more information). Research will be concluded in the definition of an Opportunity for design.
  - This part of the thesis research is focussed on *'Solving the Right Problem.'*
- **in order to Design** of a new proposition that stimulates the orientation phase of developing e-hubs in business parks in the Netherlands in 2024, by focussing on the organisational dimension.
  - The goal of this design phase is to not reinvent the wheel, but learn from similar systems like Industrial Symbiosis and e-hub pilots, and constantly involve end-users and experts in order to tailor the proposition design and provide actionable research knowledge to pracitioners and academics.
  - This part of the thesis research is focussed on *'Solving the Problem Right.'*

MAIN RESEARCH QUESTION:

"How can the orientation phase of developing e-hubs on business parks in the Netherlands in 2024 be stimulated?"

SUB-RESEARCH QUESTIONS:

The main research question is answered by answering six sub-research questions:

What problems are experienced in the development of e-hubs on the large scale in the Netherlands in 2024, and what knowledge gap on overcoming these problems remains in existing literature?

What is the key role that needs to be stimulated in the orientation phase of e-hub development?

What are drivers and barriers experienced by the key role in the orientation phase of e-hub development, and what drivers and barriers serve as strategic points for intervention (leverage points) to stimulate this phase?

What key leverage point represents the most relevant and effective opportunity for intervention to stimulate the orientation phase of e-hub development?

What success factors and lessons learned in similar socio-technical, multi-agent complex systems development can inform the design of a new proposition that stimulates the orientation phase of e-hub development?

How can the success factors and lessons learned in similar systems be included in a new proposition that stimulates the orientation phase of e-hub development on Dutch business parks in 2024?

CORRESPONDING CHAPTERS:

1 Investigating the Paradigm

2 Framing the system

3 Understanding the system

4 Discovering the opportunity

5 Exploring the possibility space

6 Designing the proposition

7 Conclusions

Solving the right problem

Solving the problem right

RESEARCH APPROACH

FILLING THE KNOWLEDGE AND METHODOLOGICAL GAPS WITH SYSTEMIC DESIGN

The thesis goal states both researching e-hubs as socio-technical multi-actor complex systems - in order to identify leverage points - as well as design interventions - to push these leverage points - and thereby stimulate the development of e-hubs. In order to both research and design these systems, a systemic design approach is taken in this master thesis.

Systemic design is an approach that combines systems thinking with human-centred and social-centred design thinking to address highly complex challenges. As explained in the theoretical perspective, e-hubs are socio-technical, multi-actor complex systems, and therefore require a systems thinking approach. Additionally, this research aims to not only analysing, but also actively stimulating e-hubs in order to prevent and mitigate the pressing effects of grid congestion (Chapter 1 > Societal Context). Therefore, an action-oriented design thinking approach is essential to add to systems thinking. Systemic design bridges systems thinking and design thinking, focusing on designing for positive societal impact rather than just analysing systems (figure 30) (van der Bijl Brouwer, 2023).

Systems thinking and design thinking reinforce each other, overcoming each other's limitations (Jones & Kijima, 2018). As shown in figure 31, systems thinking causes breadth and depth of understanding of the systems, viewing problems as part of larger systems, considering not only superficial factors but also the broader context and interdependencies. However, this can be intimidating, expert-driven and even cause analysis paralysis due to overwhelming complexity and information overload (for example, figure 32). Design on the other hand is often driven by desire than improvement, answering consumer demand instead of addressing interconntected problems and improving larger societal contexts. On the other hand, design does incorporate participatory elements, humanising solutions by (also) focussing on the social aspects of the system, and call for action. Please refer to the last chapter of this master thesis: 'Contribution and ode to Industrial Ecology and Systemic Design', where more discussion is provided on combining systems analysis and design.

In conclusion, systemic design includes both the ability to identify relationships and make connections between problems and contextual factors, and the ability to translate deep insights into actionable steps and to learn rapidly from real-world experiences (Ryan, 2016). It is therefore a relevant approach to both research and design for e-hubs, including complexity and a need for actionable outcomes.

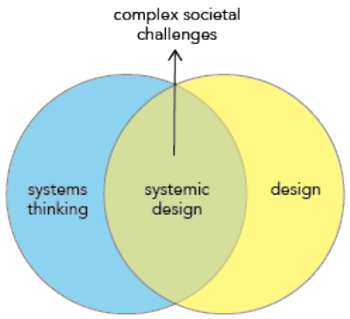


Figure 30, Systemic Design combines systems thinking and design (Source: van der Bijl Brouwer, 2023)

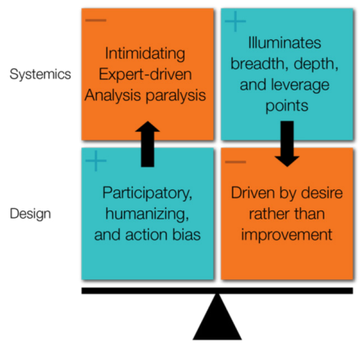


Figure 31 : Systemics and design overcome each other's limitations. Source: Mars Solutions Lab, n.d.

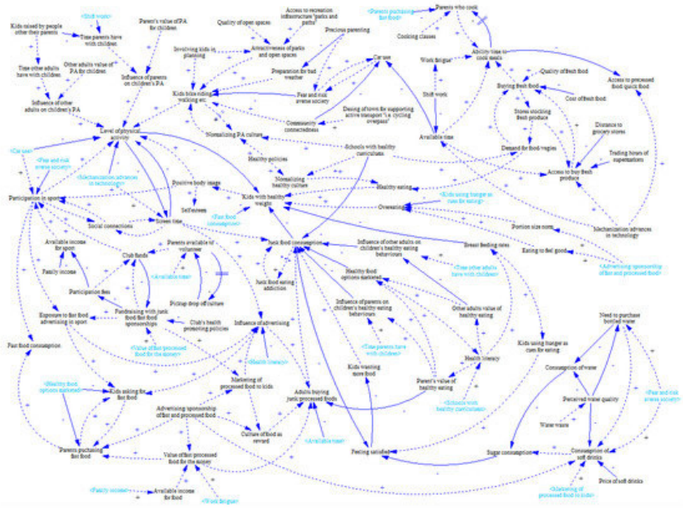


Figure 32, Exmample of intimidating complexity, potentially causing analysis paralysis (Bures, 2017)

An example of what a systemic design approach could look like is depicted in figure 33. This approach can be split into two main parts. Steps 1-3, framing, listening to and understanding the system, have the goal to discover leverage points (Meadows, 2008), as explained in the theoretical perspective. Steps 4-7 focus on designing an intervention to push the leverage point, causing preferable effects on a systems level. However, systemic design is not a step-by-step-approach but a pluralistic process, shaped by the (changing) system and its properties during researching and design activities (Van der Bijl-Brouwer, 2023).

In this master's thesis, the systemic design approach by Jones & van Aal (2022) (Figure 33) serves as a source of inspiration. However, modifications have been made to tailor it to the specific objectives of this research. Further explanations on these modifications and the research approach, methodologies, and methods will be discussed in the next sections.

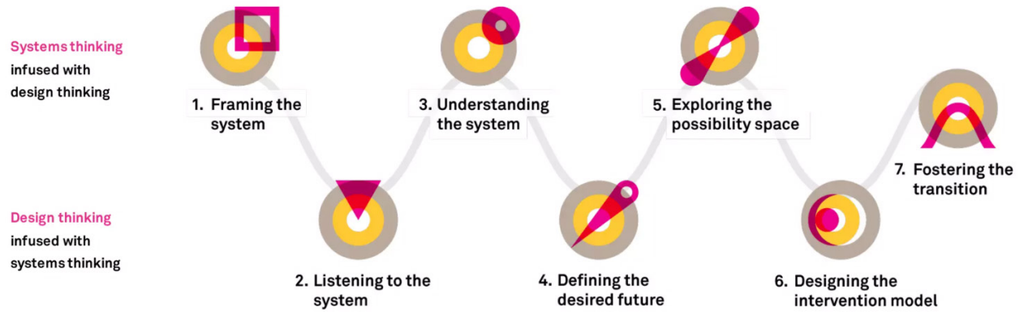


Figure 33: A framework to integrate systems thinking and design. Source: Jones & van Aal (2022)

SYSTEMIC DESIGN: A MEDLEY OF METHODOLOGIES

Systemic design is a rather new field. Appendix L describes an explorative review of the heritage of systemic design and possible tools used by systemic designers. Concluded can be that systemic design appeared in academic literature around the early 2010's, and is currently gaining momentum (van der Bijl Brouwer, 2023). There are little standardised or common methods that accompany the systemic design approach (Appendix L). However, a pattern can be recognized of the usage of Industrial Ecology terms in the scientific field of Design Engineering. For example, comparisons to 'ecologies' and 'evolution' within industrial systems are made in literature on systemic design.

Combining principles of Industrial Ecology (mainly systems thinking) with design methodologies, a medley of methodologies can be used to take a systemic design approach. In this master thesis, four main methodologies are focussed on to answer the thesis goal and fill the methodological gap left in current literature. These four methodologies include ethnography, systems analysis, open innovation and participatory innovation. These will be clarified by first describing what the methodology entails, followed by an explanation on why this methodology is included into the systemic design approach of this research.

ETHNOGRAPHY: FRAMING AND UNDERSTANDING THE SYSTEM

Multiple studies in current academic literature recommend action-based empirical qualitative data collection and analysis in order to create an understanding of the real-world dynamics of e-hubs (see Methodological Gap on page 60). Specifically ethnography is recommended multiple times as an effective methodology to build on this recommendation and address both the knowledge gaps and methodological gaps identified in the current academic literature (see Knowledge Gap on page 59)**.**

Ethnography is a methodology commonly used in social sciences and anthropology to study people and understand cultures (Miles & Huberman1994). It involves the researcher to immerse itself into the community being studied, usually over an extended period, to gain a deep understanding of their beliefs, behaviours and social structures (Brewers, 2000). Ethnographers typically use a combination of methods, including observations, interviews, document analysis, to collect mostly qualitative data on detailed descriptions and interpretations of the community that is studied. Data is analysed to identify patterns, themes and underlying meanings of the community. This provides rich, contextual insights into the lives and experiences of participants of the community.

In this thesis ethnography is used because it proposes an excellent strategy of conducting action-based empirical qualitative data collection and analysis in order to create an understanding of the multi-actor, complex systems characteristic of e-hubs as described in the methodological gap of this master thesis. The reviewed literature specifically recommends ethnographic research multiple times because of these characteristics. This methodology allows to discover nuances in the behaviour of and relationships between different actors, their decision-making, their culture and context, experienced drivers and barriers and the causal relationships and rootedness of these drivers and barriers. This presents an excellent mode of operation while researching the systemic dynamics of the organisational dimension in the orientation phase of e-hub development.

SYSTEMS ANALYSIS: UNDERSTANDING THE SYSTEM AND DISCOVERING THE OPPORTUNITY

The current academic literature leaves a methodological gap by not researching e-hubs as being both multi-actor and complex systems (see Methodological Gap on page 59). Therefore, systems analysis is used as a methodology in this master thesis in order to fill this methodological gap.

Systems analysis is a methodology that allows to understand and evaluate complex systems by breaking them down into smaller, manageable components while investigating the relationships and interactions between these components to understand how the system functions as a whole (Meadows, 2008). Systems analysis is used in a wide variety of applications, amongst others in logistics, computer science, policy analysis and environmental science. Systems analysis can be used with a broad spectrum of data sources. The goal of systems analysis is to gain insights into how the system functions, predict its behaviour, and develop strategies for optimization or intervention. Interventions can be designed by focussing on finding leverage points within the system that can be pushed in order to reach the desired future, see the theoretical background of research methods of this master thesis.

In this thesis, the complexity of the socio-technical multi-actor complex systems of e-hubs are used to understand what leverage point in the system is most efficient and most effective to push, in order to design for this opportunity in the second part of this thesis. To identify this opportunity, this master's thesis adopts an approach inspired by, but modified from, the systems analysis typically described in current academic literature

In order to allow for identification of this opportunity, the first four chapters of this master thesis focus on decreasing complexity of the system in the first phase of this report; 'solving the right problem' (figure 34) **This is done by continuously scoping the system boundaries in each chapter of this first phase. The following scoping cycles are conducted:**

1. Scoping down the socio-technical system boundaries towards a focus on the organisational dimension of e-hubs by **investigating the paradigm** (Chapter 1), and analysing the societal context, causes of the callenges of e-hub development and the gap in current practices. **The organisational dimension of e-hubs can bee seen as the leverage point within the socio-technical system;** stimulating this dimension means stimulating e-hub development.
2. Within this socio-technical leverage point, a new scoping cycle focuses on narrowing the multi-actor system boundaries **by framing the system** (Chapter 2), and identifying a key actor (key role) that has the most power over as well as the most involvement into the success of the e-hub development in its orientation phase. **This key role can be seen as the leverage point within the multi-actor system**; stimulating this role means stimulating e-hub development.
3. Within this multi-actor leverage point, a new scoping cycle focuses on narrowing the complex system by **understanding the system** (Chapter 3), analysing the drivers and barriers experienced by the key role in e-hub development, and examining the causal relationships and rootedness of these drivers. **This results into multiple leverage points** that could present an opportunity for design.
4. Based on these multiple leverage points, a new scoping cycle focuses on **defining the opportunity** (Chapter 4), narrowing down to one single leverage point that presents the opportunity for design by weighing the leverage points based on multiple criteria, leading to the selection of one main leverage point that adds the most to current knowledge and practices. This leverage point is the opportunity for design in the second phase of this master thesis; 'Solving the problem right.'

The methods that support this methodology and the scoping cycles are also inspired by, but modified from, existing methods commonly used in systems thinking and design thinking. More explanations on these methods will follow in the next sections, and their addition to academic literature and current practices will be discussed in Chapter 7: Conclusion.

On the right: figure 34: Solving the Right Problem (Author's image)

OPEN INNOVATION: EXPLORING THE POSSIBILITY SPACE

Current academic literature leaves a methodological gap in actionability, meaning very little studies focus on designing interventions to improve the system of e-hubs, rather than only describing processes within this system. This study fills this methodological gap by also including design efforts in the research project. To kickstart the design phase of this research, open innovation is implemented as a methodology.

Open innovation is a paradigm often used in the corporate sector, involving firms using both internal and external ideas to create value, such as new products and/or business models (West et al., 2006). This includes a collaborative approach that encourages the sharing of ideas, knowledge and resources across organisational boundaries to drive innovation. This can significantly enhance the research and design process of businesses by incorporating diverse perspectives, accelerating the discovery of new solutions, while reducing costs (Elmquist et al., 2009).

In this thesis, this approach is used as a research methodology. Given the limited timeframe of the thesis project, efficiency in seeking new solutions is crucial. Rather than reinventing the wheel, the methodology entails learning from external ideas that have already demonstrated success in similar contexts (figure 35). This approach optimises the use of available time and resources by leveraging proven concepts from systems in comparable contexts. External ideas include success factors from e-hub pilots as well as lessons learned in Industrial Symbiosis, as explained in the research methods in the next sections.

PARTICIPATORY INNOVATION: DESIGNING THE PROPOSITION

Current academic literature leaves a methodological gap in actionability as described in last section, as well as in research methods that deepen empirical understanding of real-life nuances within e-hubs as being socio-technical, multi-actor systems. This study addresses this gap by including empirical insights through continuous real-life feedback and validation into the design process.

Participatory innovation is a collaborative approach that actively involves various stakeholders in the innovation process (Boer & Donovan, 2012). Engaging end-users and other stakeholders ensures that the developed solutions are more closely aligned with their needs and expectations, increasing the likelyhood of successful adoptation and implementation (Buur & Larsen, 2010).

In this thesis, this methodology is used to ensure the relevance, customisation and actionability of the research outcomes for practitioners (figure 35). As stated in the Societal Context, e-hubs are an important solution to the rapidly growing problem of grid congestion. Therefore, it is important to generate actionable research outcomes in order to stimulate the development and implementation of e-hubs in a timely manner.
Next to this, because of the fast pace of the energy transition and its accompanying innovations the ability to quickly adapt to changes is crucial. By leveraging participatory innovation, the design process can incorporate rapid identification and response to emerging challenges and opportunities.

Below: figure 35: Solving the Problem Right (Author's image)

RESEARCH METHODS USED IN THIS MASTER THESIS

In order to support the systemic design approach and medley of methodologies, a variety of research methods is used. These research methods are inspired on the following:

- The 'inspiration on the research approach drawn from the reviewed literature' (page 59)
- Practical tips and recommendations from the supervisors of this thesis. A meeting of one hour was held with Abhigyan Singh specifically to retreive information on Ethnography (A. Singh, personal communication, december 9, 2023), and during supervisor meetings throughout the thesis project practical tips on research methods was provided by both supervisors.
- Information from the course 'Systems Design for Industrial Ecology' by prof. A. Ramirez Ramirez, as discussed in the theoretical background on research methods of this master thesis.
- Personal experience and insight of the researcher based on the fields of both Industrial Ecology and Industrial Design Engineering.

The research methods used in this master thesis will be explained on the next pages. Methods used will be explained per thesis chapter, each explanation following the same structure:

- The sub-research question
- Inputs of the chapter
- Data collection methods
  - Limitations of the methods
  - How these limitations were mitigated in this master thesis
- Data derived
- Data processing methods
  - Limitations of the methods
  - How these limitations were mitigated in this master thesis
- Outputs of the chapter

On the next page, figure 36 shows an overview of the approach, research questions, chapters, methodologies, research methods and validation used throughout this master thesis. Consequently, in the remainder of this chapter details on all research methods will be provided in text.

MAIN RESEARCH QUESTION

"How can the orientation phase of developing e-hubs on business parks in the Netherlands in 2024 be stimulated?"

Approach	**Systemic Design**					
Phase	**Solve the right problem**: focus on Systems Thinking				**Solving the problem right**: focus on Design Thinking	
Chapter	Investigating the Paradigm	Framing the system	Understanding the system	Discovering the opportunity	Exploring the possibility space	Designing the proposition
	1	2	3	4	5	6
Sub-research question	1 | *What problems are experienced in the development of e-hubs on the large scale in the Netherlands in 2024, and what knowledge gap on overcoming these problems remains in existing literature?*	2 | *What is the key role that needs to be stimulated in the orientation phase of e-hub development?*	3 | *What are drivers and barriers experienced by the key role in the orientation phase of e-hub development, and what drivers and barriers serve as strategic points for intervention (leverage points) to stimulate this phase?*	4 | *What key leverage point represents the most relevant and effective opportunity for intervention to stimulate the orientation phase of e-hub development?*	5 | *What success factors and lessons learned in similar socio-technical, multi-agent complex systems development can inform the design of a new proposition that stimulates the orientation phase of e-hub development?*	6 | *How can the success factors and lessons learned in similar systems be included in a new proposition that stimulates the orientation phase of e-hub development on Dutch business parks in 2024?*
Methodology		Ethnography	Ethnography, Systems Analysis		Open Innovation	Participatory Innovation
Data collection methods	Systematic search on grey literature and exploratory search of academic databases, review of IE course materials	28 semi-structured interviews, 9 e-hub knowledge-sharing events attended		Online research, attending presentations and conversating with experts during attended events	Expert interviews and field observations of e-hub pilots, 2 expert interviews and literature review of Industrial Symbiosis	Hanging interactive posters at a knowledge-sharing event, brainstorming survey, 4 expert interviews, 5 user interviews
Data derived	Government reports, news messages, forum pages, market research reports, webinars, academic papers, lecture recordings	Interview recordings and transciptions, field notes, thematic summaries of interviews and events attended		Tools and methods that stimulate (the orientation phase of) e-hub development that are currently in development	Interview recordings and transcripts, field notes, a report with data from interviews with 14 stakeholders of IS in the Netherlands	Post-its with feedback on posters, 16 online survey answers,
Data processing methdos	Content analysis, thematic analysis, theoretical synthesis	Inductive thematic analysis, power-involvement analysis	Inductive thematic analysis, combined Causal Loop Diagram and Iceberg Model analysis (CLD/IM analysis)	Gap analysis, Multi-Criteria Decision Analysis	Inductive thematic analysis	Inductive thematic analysis, collaborative data analysis, iterative data analysis
Outputs	Problem definition, Research direction, Research Scope, Knowledge gap, Theoretical Background, Thesis Goal, Research questions	Role overview, engagement map, power/involvement grid, the key role and supporting roles, narrowed system boundaries and assumptions	The experiences and thoughts of the key role, rooted in drivers and barriers experienced during orientation phase, multiple leverage points	One key leverage point: the Opportunity, Design Statement	Design cues translating the opportunity into actionable starting points for design, based on lessons learned on the opportunity in similar systems	Four themes of ideas, resulting in a new Proposition comprising four interventions in the orientation phase of e-hub development
Validation	Data triangulation, peer debriefing	Data triangulation, peer debriefing	Data triangulation	Data triangulation, peer debriefing	Data triangulation, peer debriefing	Focus group discussion, user interviews

Thesis goal: Research multi-actor complex dynamics of e-hubs in order to design a proposition that stimulates the orientation phase of developing e-hubs on business parks in the Netherlands in 2024

Figure 36: Outline of the master thesis approach (Author's image)

RESEARCH METHODS OF CHAPTER 1: INVESTIGATING THE PARADIGM

SRQ

1 | What problems are experienced in the development of e-hubs on the large scale in the Netherlands in 2024, and what knowledge gap on overcoming these problems remains in existing literature?

Inputs

A basic explanation on e-hubs provided by the supervisors from Stedin, knowledge and experiences from the MSc. Industrial Ecology and BSc. Industrial Design Engineering.

Data collection methods

- **A systemic search on grey literature** such as news articles, government reports, LinkedIn messages, webinars, etc. to discover the societal problem
- **A systematic exploratory search of academic databases**, mainly through Google Scholar, Web of Science, Scopus and ScienceDirect. Search terms included a.o. "e-hubs, energy hubs, smart energy hubs, energy cooperations, local energy, energy community, peer-to-peer energy trading, socio-technical systems, multi-agent systems, complex systems, systems design, systemic design, Industrial Symbiosis)
- **A search through materials of IE courses** attended by the researcher during the MSc. Industrial Ecology, such as the course 'Systems Design for Industrial Ecology' by Prof. Andrea Ramirez Ramirez.

Limitations of these data collection methods include:

- A bias in information sources: available data online may not always be accurate, complete or representative for the specific research context.
- As the development of the energy transition and e-hubs moves very fast, there is a high chance of a **temporal bias**, as information online (especially academic literature) is quickly out-dated.
- Next to this is a **coverage bias**, as not all relevant literature may be indexed or accessible through the selected academic databases, potentially leading to incomplete results. A coverage bias also exists in the search to grey literature, possibly leading to an incomplete image of the societal problem.

These **limitations are mitigated by:**

- **Constant cross-validating** findings from different data sources
- Using **multiple databases** for academic literature
- **Reviewing citation networks** where citation trails were followed examining the references cited in relevant articles and the articles citing those references. The temporal bias
- **Constantly comparing** outcomes of the literature research to outcomes of the interviews and field observations in the following research steps, to ensure ongoing accuracy of data.

Data derived

- Grey literature on the societal problem: government reports, news messages, forum pages, market research reports, NGO reports, webinars, etc.
- Academic papers on e-hubs, their social and technical sides as well as an integrated systems perspective, academic papers on drivers and barriers experienced by stakeholders in the development of e-hubs
- Academic papers on socio-technical systems, multi-actor systems, complex systems, research and design methods for such systems
- Academic papers on Industrial Symbiosis, Master thesis report of the TU Delft on IS in the Netherlands, information websites, news messages, LinkedIn messages on the development of IS in the Netherlands and examples of cases.
- Lecture recordings, lecture slides and lecture notes of IE courses

Data processing methods

- In order to find the societal problem stated in the introduction, a **content analysis** was conducted on grey literature, systematically categorizing and analysing data to identify recurring themes, patterns and relationships within the data, as well as the magnitude and importance of certain gaps in current practices causing the societal problem. This included deriving both **knowledge gaps** (based on the research output, or 'what' was researched) as well as **methodological gaps** (based on the research approach, or 'how' was researched).
- In order to find the knowledge gap a **thematic analysis** was conducted, dividing academic literature into themes and compared to the societal problem(s), in order to identify what gap remains between literature and practice, and within literature.
- In order to define the theoretical background a **theoretical synthesis** was conducted, integrating theories from multiple disciplines or theoretical frameworks to develop a more comprehensive understanding of the structures underlying the research topics.

Limitations of these methods include a lack of peer review and subjectivity in analysis causing an interpretive bias. Next to this, the theoretical synthesis is limited by possibly overlooking alternative perspectives and theories.

These **limitations are mitigated** by cross-validating findings with findings from peer-reviewed sources, incorporating reflexivity by reflecting on the researchers own biases and assumptions throughout the analysis. Reflexivity was stimulated by a **(visually) clear presentation** of each finding and its corresponding conclusions (knowledge gaps as well as methodological gaps).

Outputs

- The introduction and societal problem are concluded in a problem definition and therefrom following a research direction.
- The literature review is concluded with a knowledge gap.
- The theoretical background results in a general understanding of underlying theories and constructs, that are used to establish appropriate and relevant research methods.
- The three chapters conclude in a thesis goal and a main research question that is supported by six sub-research questions.

RESEARCH METHODS OF CHAPTER 2: FRAMING THE SYSTEM

SRQ	2 | *What is the key role that needs to be stimulated in the orientation phase of e-hub development?*
Main methodology	Ethnography
Inputs	The problem definition, research direction, knowledge gap, background knowledge on theoretical constructs and thesis goal.
Data collection methods	While collecting data to answer SRQ2 (Chapter 2: Framing the system), data was simultaneously collected to answer SRQ3 (Chapter 3: Understanding the system). This is due to the limited amount of time and availability of interviewees. Data was mainly collected during interviews with stakeholders and attended events on the topic of e-hub development. Data was also collected by constantly communicating with employees of Stedin, continuously following news articles and LinkedIn posts, and by actively following communication in a Whatsapp-group called 'PowerVrouwen,' where 56 stakeholders and experts of e-hub development share knowledge and experiences. These methods, their limitations and mitigation techniques are discussed below. Experts and stakeholders of developing e-hubs were interviewed, using **semi-structured interviews.** ▪ Interviews involve three parts: one focussing on the roles involved in the development, one focussing on the development processes of current e-hubs, and one focussing on drivers and barriers for the development of e-hubs. ▪ Interviews are structured by preparing a set of questions, which can be found in appendix C. These questions provide guidance, but the interviews were conducted semi-structured. By means of constant probing (e.g. constantly asking: 'why?' 'can you give an example?' 'can you elaborate on that?') a more complete picture of the system is obtained instead of only asking closed questions. ▪ To make effective use of time and not lose any information, during the interviews an interview template is filled in together with the participant, by screen-sharing or by together looking at a laptop screen. Real-time notes could be made by means of sticking notes in a Miro board of this template. This way, there are no misconceptions on what roles are involved, what the development processes look like and what drivers and barriers are experienced by the participant of e-hubs, being the key stakeholder as further explained in Chapter 2: Framing the System. The template can be found in appendix C. ▪ By means of constantly probing during interviews and observations, the participants beliefs and experiences related to the visible and hidden aspects of the system were discovered. ▪ In total, 28 semi-structured interviews of one hour were conducted. Participants of the semi-structured interviews and their roles can be found in appendix A. ▪ After each interview, two hours were reserved by the researcher to zoom out, put the results in the larger context, reflect on all insights and consider the indirect cues conveyed during the conversation, such as jokes made, frustrations outed, tones of voice, agreement or disagreement signals (e.g. nods, shaking heads, etc.).

Data collection methods	Next to conducting semi-structured interviews, **events** on knowledge-sharing and networking for stakeholders and experts of e-hubs were attended. In total 9 events were attended. Please visit appendix B for further explanation on the attended events. ▪ During these events, presentations (if provided) were analysed, what these presentations were focussing on, what questions were asked about these presentations, with what emotions attendees reacted to these presentations. Next to this, most events included a networking part, during which the researcher immersed itself in the community being studied, probing participants to tell more about their roles, their experienced development processes, drivers and barriers. Not only was attention paid to the direct answers of the participants, but also to tacit information, e.g. by the type of jokes made, questions asked by the participants to the researcher, etc. ▪ By means of **constantly probing** during conversations held with attendees of the events, the participants beliefs and experiences related to the visible and hidden aspects of the system were discovered. ▪ Data was collected by taking field notes during the events, and by taking voice recording of the researchers own voice with all highlights and insights of the event, just after the event ended. Same as after the interviews, at least two hours were reserved by the researcher to zoom out, put the results in the larger context, reflect on all insights and consider the indirect cues conveyed during the conversation, such as jokes made, frustrations outed, tones of voice, agreement or disagreement signals (e.g. nods, shaking heads, etc.). ▪ During one of the events attended, in order to **validate the identified roles** that are connected to the development of e-hubs as researched, A0-posters were hung up in the common area of the event where drinks were served during breaks and at the end of the event. These posters included all researched and defined roles, as well as a blank space next to each role. On this black space, attendees of the events could write comments by means of sticking post-its that were hung next to the poster (figure 37). Also, space was created on the posters where attendees could provide input about missing roles, new ideas and other feedback/input. Around 100-150 stakeholders and experts attended the event. A QR code on the poster led to the contact information of the researcher, in case attendees were interested in further brainstorming together, were curious about the results or had further questions. Attendees were led to the posters by means of two plenary announcements of the hosts of the event, and by means of the researcher who was actively attracting attendees towards the posters. Results of this session were integrated in the roles in the report. Pictures of the results of the posters at the end of the event can be found in Appendix G.

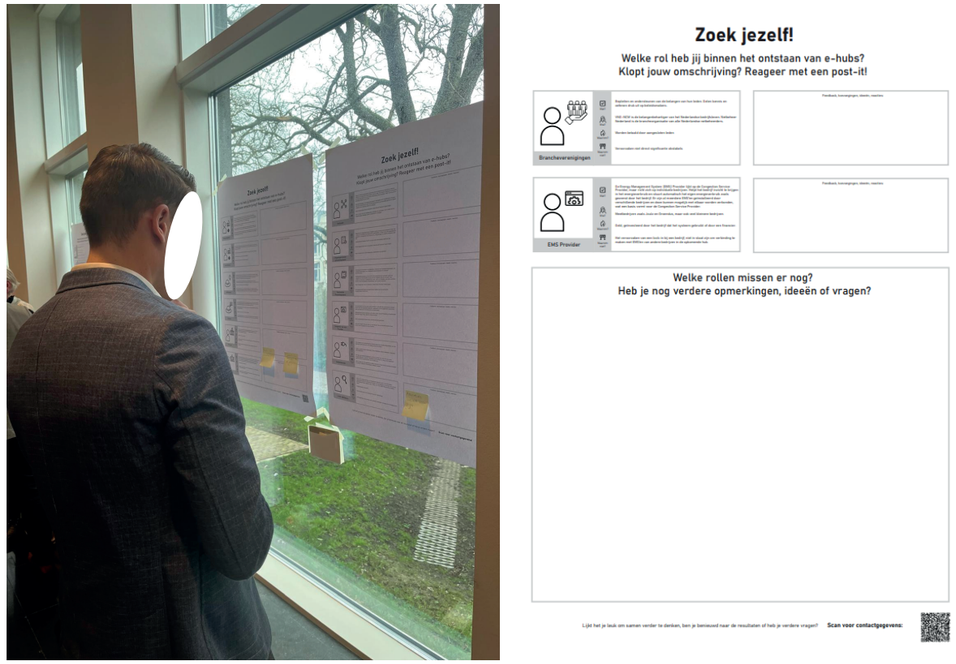


Figure 37: Attendees could react on their roles by sticking post-its with feedback on the posters. Picture on the left: situation sketch with the post-its next to the posters. Picture on the right: one of the posters.

Data collection methods

Possible limitations include:

- Sampling bias: a wide variety of stakeholders and experts from different roles were interviewed (Appendix A). Interviewees were mainly found trough other interviewees, and by connecting with attendees of attended events. However, there might be an inherent bias in the sample population, which can limit the generalizability of the findings.
- Interviewer influence: the presence, behaviour and characteristics of the researcher can influence the participant's responses, potential leading to interviewer effects or social desirability bias.
- Lastly, there is a temporal constraint: data collected is of a very specific moment in time. As described in the societal problem and literature review, the development of e-hubs moves very fast. Therefore, in a year the information retrieved from interviews and attending events might be out-dated.

Mitigating limitations includes:

- The sampling bias was reduced by aiming for a high amount of interviews, and interviewing as much different roles connected to different e-hubs. The role of focus was the participants of e-hubs (see results – Chapter 1), however sometimes supporting roles like facilitators who spoke to a lot of participants already and have a lot of experience with their experiences of the e-hub development process provided more valuable insights than the participants themselves, as these facilitators provided information from a larger sample group therefore reducing the sampling bias. The sampling bias was also reduced by pursuing data triangulation, constantly comparing multiple data sources such as interviews, observations, meetings, presentations, webinars, events attended etc. in order to corroborate findings (Miles & Huberman, 1994). Still, is hard to truly overcome the sample bias within the given timeframe of this master thesis. It is therefore recommended to continue with interviewing stakeholders and experts of e-hubs, while aiming for a large and varied sample group.
- The interviewer influence is also hard to overcome. By providing a picture of the characteristics and the context of the interviewer (figure 38), peer reviewers of this master thesis or researchers that use the outcomes of this master thesis can take into account, understand and contextualise the interviewer bias.

Figure 38: A picture of the characteristics and context of the interviewer

- The temporal constraint is impossible to overcome within the given timeframe of this master thesis. Same as overcoming the sampling bias, it is recommended to continue with interviewing stakeholders and experts of e-hubs, focussing on keeping track of all new developments in e-hubs.

Data derived

Derived data includes Interview recordings and transcriptions, field notes, thematic summaries capturing key insights and themes discussed during the interviews, thematic summaries capturing key insights and themes discussed during presentations and during interactions with attendees of events (experts and/or participants of potential hubs).

Derived data includes information on:

- Different roles connected to the development of e-hubs, what their key is to the success of e-hub development, who possible role bearers are per role, what drives this role to stimulate e-hub development and what possible barriers this role imposes on the development of e-hubs.
- The power and involvement these roles have in the development of e-hubs
- The development processes of currently developing e-hubs

Data processing methods

A thematic analysis was conducted, a qualitative research method to identify, analyse and interpret patterns or themes within the insights from interviews and attended events (Miles & Huberman, 1994). The analysis was performed inductive, as stated in the literature mot information on roles, development processes and drivers and barriers are researched out of the scope of this research and/or outdated. Inductive analysis allowed the researcher to derive new insights directly from the data, making it useful for exploring under-researched topics and/or scopes. Atlas.ti was used as a software tool to perform this analysis in.

According to Miles & Huberman (1994), data analysis in qualitative research consist of three activities that occur simultaneously: data reduction, data display and drawing conclusions.

Data processing on the engagement map:

- Data reduction: The collected data in the shape of post-its on the template in appenix H (see: data collection methods of this section) were collected from all boards over all participants. All described development processes were laid on top of each other, comparing them and seeking recurrence in mentioned steps. Based on recurrence, and based on interpretive insight from the researcher (what development steps seemed logical and essential for the development of e-hubs, based on all conversations held and data sources studied), different steps were distinguished.
- Data display: By means of an engagement map, that was inspired by a customer journey (For more discussion, please see Chapter 7 > Methodological Highlights), all steps are displayed. All steps described by research participants were displayed, each with their corresponding 'step owner,' the role that has to take the lead in that step, as well as the 'engagement,' meaning what roles were engaged with the e-hub development of each step.
- Drawing conclusions: In the engagement journey, the steps within the process that are the hardest to overcome / take the most time are highlighted. This is a validation of the societal problem / introduction, showcasing the orientation phase is one of the largest bottlenecks in current experiences of e-hub development. Next to this, the engagement journey provided an indication of the involvement and power all roles have in the different steps of current e-hub development processes. This map allowed the researcher to zoom in on the orientation phase and specify roles with large power and involvement into this phase.

Data processing regarding the power-involvement grid included:

- Data reduction: The collected data in the shape of post-its on the template in appendix H (see: data collection methods of this section) were collected from all Miro boards resulting from all interviews. These were compared to all roles gathered from conversations between the researcher and experts/stakeholders during attended events. This way, based on constant comparison and looking for frequency and recurrence over multiple data sources, different roles surrounding the development of e-hubs were established.
- Data display: The roles were displayed by means of a 'yearbook' layout, introducing the role by means of stating the name of the role, the key this role has to the development of e-hubs, the possible stakeholders that could be the role bearer of the specific role, and possible barriers the role could impose on the development of e-hubs.
- Drawing conclusions: by constant data triangulation over multiple sources of data, seeing who attended events and what roles they took during the events, and based on conversations with stakeholders, conclusions were drawn about how close every role is connected to the success of a particular hub.
- This was done by first putting the roles across a power-involvement grid, putting against each other the power a certain role has (how important this role is for the success of an individual/ specific hub), and the involvement (how closely the role is involved with the success of the individual/specific hub). The key role was identified by means of the power involvement grid. This power-involvement grid was later translated into a visual where key stakeholder is put in the middle, directly surrounded by the roles that are closely connected to the key stakeholder and indirectly surrounded by the roles that are less closely connected to the key stakeholder.

Data processing methods	**Limitations include:** ▪ Subjectivity and bias: a large limitation to the reproducibility and a large influence on the outcomes is that ethnographic data processing involves interpretation by the researcher. The personal perspectives, experiences and background may influence how the data is interpreted. ▪ Data volume and complexity: the large amount of interviews conducted and events attended caused large volumes of rich and detailed qualitative data. Processing and managing these datasets is very time-consuming, and will inherently cause some data to get lost by not making it to the final themes and conclusions drawn. **Mitigating these limitations includes:** ▪ Subjectivity and bias: By constantly execute data triangulation from multiple sources of data, the reliability of results was enhanced. Subjectivity is also overcome by continuously validating and iterating on insights and results throughout the research project, by constantly speaking to experts and stakeholders of e-hubs. ▪ Data volume and complexity: because of the privacy of all interviewees and participants of the research, data is deleted after the publication of this master thesis. Because of the given timeframe for of this thesis research not all data that was not used for the final themes and conclusions is therefore, sadly, lost. This limitation is therefore not possible to mitigate by means of conducting additional research, nor peer reviews.
Outputs	▪ An overview of what roles are involved in the development process ▪ The engagement of these roles in current e-hub development processes, visualised in an engagement map ▪ Identification of the key stakeholder ▪ System boundaries and assumptions

RESEARCH METHODS OF CHAPTER 3: UNDERSTANDING THE SYSTEM

SRQ	3 | *What are drivers and barriers experienced by the key role in the orientation phase of e-hub development, and what drivers and barriers serve as strategic points for intervention (leverage points) to stimulate this phase?*
Main methodology	Ethnography and Systems Analysis
Inputs	Knowledge on the societal problem, bottlenecks in e-hub development, existing methods to stimulate e-hubs, some (outdated) drivers and barriers experienced in the development.
Data collection methods	While collecting data to answer SRQ2 (Listening to the system), data was simultaneously collected to answer SRQ3 (Understanding the system). This is due to the limited amount of time and availability of interviewees. For the data collection methods of 'Understanding the system', please refer to the data collection methods of 'Listening to the system.'

Data derived	Derived data includes Interview recordings and transcriptions, field notes, thematic summaries capturing key insights and themes discussed during the interviews, thematic summaries capturing key insights and themes discussed during presentations and during interactions with attendees of events (experts and/or participants of potential hubs).
Data processing methods	A thematic analysis was conducted, a qualitative research method to identify, analyse and interpret patterns or themes within the insights from interviews and attended events (Miles & Huberman, 1994). Atlas.ti was used as a software tool to perform this analysis in. The analysis was performed inductively, as stated in the literature most information on roles, development processes and drivers and barriers are researched out of the scope of this research and/or outdated. Inductive analysis allowed the researcher to derive new insights directly from the data, making it useful for exploring under-researched topics and/or scopes. According to Miles & Huberman (1994), data analysis in qualitative research consist of three activities that occur simultaneously: data reduction, data display and drawing conclusions. ▪ Data reduction: this stage involves simplifying and condensing the raw data to identify key patterns and themes. This was performed by data coding, following the following steps based on Caulfield (2019): 1. Data preparation, by transcribing interviews and explaining notes taken during and/or after events. 2. Data familiarisation: the researcher becoming familiar with the data by reading and re-reading it to gain a deep understanding of its content and context. 3. Initial coding: coding the data line-by-line in Atlas.ti, assigning descriptive labels (codes) to segments of text that represent meaningful insights. 4. Theme development: codes are grouped together based on similarities or patterns to identify broader themes that emerge from the data. Themes capture key concepts or recurring insights across the dataset. Themes were developed by constantly comparing different data sources (different interviewee transcripts, different events notes, etc.), constantly zooming in and zooming out. Defining a new theme was based mainly on the following principles: ▪ Frequency and recurrence: if a particular code, concept or idea appeared multiple times across different data sources, an initial theme was formed ▪ Interpretive insight of the researcher: patterns, connections and implications that may not be immediately apparent from the data were interpreted by the researcher in order to add depth and richness, and a contextual understanding to the data. For example, if an interviewee makes a particular joke, or a small but meaningful interaction is happening between two stakeholders on an event, the researcher formulated its own interpretations, forming the basis of new themes. 5. Review and refinement: reviewing and refining themes, ensuring they accurately represent the data in a coherent and meaningful way ▪ Data display: 1. First the experiences and thoughts of the key role during the orientation phase of e-hub development were mapped and visualised. These are the results of all underlying drivers and barriers. 2. In order to dive deeper into these underlying drivers and barriers, tables are showing all drivers and barriers experienced by the key stakeholder, an explanation on why a certain driver or barrier exists, and a small representation of empirical data by means of using one or two quotes that resulted into the formulation of the specific driver or barrier.

Data processing methods

3. In order to truly understand the systemic behaviour of the key participant, causal relationships and rootedness of the drivers and barriers are analysed by means of a combined Causal Loop Diagram and Iceberg Model Analysis (CLD/IM Analysis).
    - The causal loop diagram was constructed by examining the coded data on drivers and barriers to identify causal links between variables. Based on data derived from interviews and observations, combined with interpretive insight of the researcher, it was determined whether changes in one variable lead to changes in another variable, either positively (reinforcing) or negatively (balancing). Causal loops were discovered that illustrated feedback loops within the system, either reinforcing or balancing.
    - In order to divide the drivers and barriers amongst the different layers of the iceberg model, data derived from interviews and observations were combined with interpretive insight of the researcher in order to decide whether a driver/barrier are more on the surface, and what drivers/barriers represent hidden aspects that are below the surface.
    - Consequently, the drivers and barriers in the causal loop diagram where visually divided over the different layers of the iceberg model. This way, a combination of the causal loop diagram and the iceberg model was used to process the data and find relevant leverage points.
    - Figure 39 shows examples and explanations of how the CLD and IM were combined.
    - The CLD/IM including the identified leverage points was constantly refined based on feedback and insights during interviews with four stakeholders and/or domain experts.

Figure 39: An example of the CLD/IM Analysis

Data processing methods

- Drawing conclusions:
    - By means of analysing feedback loops in the system, leverage points were identified. These are points within the system where a relatively small intervention leads to cascading effects within, and a large change in output of the system.

Limitations include:

- Subjectivity and bias: a large limitation to the reproducibility and a large influence on the outcomes is that ethnographic data processing involves interpretation by the researcher. The personal perspectives, experiences and background may influence how the data is interpreted. This subjectivity can form a bias and influence the representation of the system.
- Data volume: the large amount of interviews conducted and events attended caused large volumes of rich and detailed qualitative data. Processing and managing these datasets is very time-consuming, and will inherently cause some data to get lost by not making it to the final themes and conclusions drawn.
- Simplification of the complex system is a large limitation of the data processing methods. Both the causal loop diagram and the iceberg model aim to simplify complex systems for analysis and visualisation. However, this simplification may cause a loss in nuances, interactions and contextual factors that are crucial to understand the full complexity of the system (Meadows, 2008). As a result, the outcomes may provide an incomplete or oversimplified representation of reality.
- A temporal limitation: the CLD/Iceberg model represents a snapshot of the dynamic system at a specific moment in time due to the short timespan available for this master thesis. However, the system is constantly evolving and will change over time in response to internal or external

Mitigating these limitations includes:

- Subjectivity and bias: by constantly execute data triangulation from multiple sources of data, the reliability of results was enhanced. Next to this, the CLD/IM Analysis including resulting leverage points were presented and peer-reviewed by two experts on e-hubs, by means of screen-sharing during online meetings. However, the peer-review was somewhat superficial due to time constraints during the meeting and the lack of a deep understanding of the system by the peers needed to provide relevant insights. Subjectivity is also overcome by continuously validating and iterating on insights and results throughout the research project, by constantly speaking to experts and stakeholders of e-hubs.
- Data volume and simplification of the complex system: because of the privacy of all interviewees and participants of the research, data is deleted after the publication of this master thesis. Because of the given timeframe of this thesis research not all data that was not used for the final themes and conclusions is therefore, sadly, lost. This limitation is therefore not possible to mitigate by means of conducting additional research , nor additional peer reviews.
- The temporal limitation: recommending follow-up research with iterative analysis and constant revision of the data and the outcomes
- Stakeholder engagement and co-creation: by involving stakeholders in the research process (see: chapters 5 and 6), constantly evolving input, feedback and validation of the findings is included in the research and in the development of the new proposition. This mitigates the limitations of subjectivity and bias, simplification of the complex system and the temporal limitation.

Outputs

- The experiences and thoughts of the key stakeholder in the orientation phase of e-hub development
- Drivers and barriers experienced by the key stakeholder during the orientation phase of the development of e-hubs, including their causal relationships and rootedness
- Leverage points within the system of drivers and barriers

RESEARCH METHODS OF CHAPTER 4: DISCOVERING THE OPPORTUNITY

SRQ	4 | *What key leverage point represents the most relevant and effective opportunity for intervention to stimulate the orientation phase of e-hub development?*
Inputs	▪ Four leverage points within the system ▪ Drivers and barriers supporting and surrounding these leverage points ▪ Underlying raw data to the drivers and barriers
Data collection methods	▪ Online research was conducted to tools and methods to stimulate the development of e-hubs that are currently in development. ▪ This was combined with attending presentations during events about new tools, and by speaking to stakeholders during networking events (appendix B) **Limitations of these data collection methods include:** ▪ A sample bias: because the demand towards e-hubs is large, the development of tools and methods evolves quickly, meaning some tools and methods still in development can be overseen during the timeframe of this master research. **These limitations can be mitigated by:** ▪ Continuously building upon the insights and results of this master thesis during future research.
Data derived	Existing and developing tools and methods to stimulate the development of e-hubs
Data processing methods	▪ The evolving tools, methods and developments were compared to the drivers and barriers in the CLD/MA, depicting what drivers and barriers were already being covered. ▪ Remaining gaps between currently evolving tools/methods/developments and the drivers and barriers experienced by the key stakeholder and problems within the orientation phase of e-hub as identified in the introduction and literature research were identified. ▪ A Multi-Criteria Decision Analysis (MCDA) was conducted, evaluating and comparing the four leverage points identified in Chapter 2: Understanding the System. The four leverage points were weighed based on three criteria: 1. To what extent it has not yet been covered by other tools, methods and developments 2. The feasibility to design interventions within the timeframe of this master thesis The feasibility of designing interventions within the timeframe of this master thesis is assessed by considering the depth at which the leverage point lies within the iceberg model. If the leverage point is situated at the surface level, a designed intervention will primarily address the symptoms of the system. On the other hand, if the leverage point is deeply embedded into the lowest level, it becomes very challenging to make significant changes because the leverage point is deeply entrenched within the system. Preferably, the leverage point is situated in the middle two levels of the iceberg model. 3. Its impact on the outcomes of the system. This impact is assessed by analysing how well pushing the leverage point will stimulate the orientation phase of e-hub development on Dutch business parks in 2024. This is assessed by considering what effects pushing the leverage point will have on the system. By looking at how many drivers will be stimulated and barriers will be overcome as a causal effect of pushing the leverage point, it can be considered how cascading the effect of pushing the leverage point will be and therefore what impact it will make on the outcome of the system
Data processing methods	▪ The key leverage point identified through the MCDA is translated into 'the Opportunity', this concludes the first phase of the master thesis (Solving the right problem – resulting in the opportunity) and marks the beginning of the second phase of the master thesis (Solving the problem right – starting from the opportunity). ▪ The Opportunity is translated into a Design Statement that will be used as a starting point for the design of a new solutions to stimulate the orientation phase of e-hubs on business parks in the Netherlands in 2024. **Limitations of the data processing methods include:** ▪ Subjectivity and bias, as data processing involved interpretation and judgment by researchers. This subjectivity can form a bias and influence the representation of the system. This is true for the identified remaining gaps, the MCDA, and the definition of the Design Statement. ▪ Sensitivity to changes: as the drivers, barriers, leverage points and currently evolving methods/ tools/developments all have temporal limitations and the energy transition is progressing at high speed, over time the inputs and parameters and thus the outcomes to the MCDA can change significantly. This means also the opportunity and the design statement are sensitive to changes in the landscape of e-hubs. **Mitigating these limitations include:** ▪ By triangulating data amongst all previously mentioned data sources and constant validation during conversations with domain experts and stakeholders, subjectivity and bias is mitigated. ▪ Due to the timeframe of this master thesis, the temporal limitations cannot be resolved, and thus the sensitivity to changes cannot be mitigated. However, recommended is continuous future research, validation and improvements of the findings to keep the results current and relevant.
Outputs	▪ The Opportunity – the key leverage point, that concludes the first phase of the master thesis (Solving the right problem – resulting in the opportunity) and marks the beginning of the second phase of the master thesis (Solving the problem right – starting from the opportunity). ▪ The Design Statement, that will be used as a starting point for the design of a new solutions to stimulate the orientation phase of e-hubs on business parks in the Netherlands in 2024.

RESEARCH METHODS OF CHAPTER 5: EXPLORING THE POSSIBILITY SPACE

SRQ

5 | *What success factors and lessons learned in similar socio-technical, multi-agent complex systems development can inform the design of a new proposition that stimulates the orientation phase of e-hub development?*

Main methodology

Open innovation

Inputs

- The Opportunity
- The Design Statement

Data collection methods

After identifying the right problem and defining the opportunity (the key leverage point), knowledge and experiences from similar contexts were explored in order to avoid reinventing the wheel but rather learning from these context to boost innovation. Two similar context were explored: successful e-hub pilots on business parks in the Netherlands, which have undergone a different development process than the currently developing e-hubs as they have benefited from exceptions in legislation and regulations, as well as in collaboration with the DSO and other supporting roles. The other similar context explored is Industrial Symbiosis (IS). This is a similar socio-technical, multi-actor complex system on Dutch business parks in 2024, as explained in the literature review.

These systems in other contexts were consulted in order to discover what lessons were learned in the orientation phases of their development, focussing on pushing the key leverage point identified for e-hubs.

- Experts and stakeholders of successful e-hub pilots were mainly spoken to during attended events (the same events as discussed in chapter 1 and 2). During these events success factors were discussed, and in conversations with speakers during and after these events, success factors and lessons learned were distilled. Also, information on lessons learned was retrieved during the semi-structured interviews of chapter 1 and 2.
- Two experts of IS were interviewed on their experiences related to the key leverage point. Interview questions can be found in appendix A. Data from these two interviews was compared to and triangulated with a report on a cross-case analysis of three Eco-Industrial Parks (involving IS), which contains data retrieved from interviews with 14 stakeholders and researchers of three Eco-Industrial Parks in the Netherlands (Valladolid Calderón, 2021).

Limitations of these data collection methods include:

- A limited scope of experts on IS. Consulting experts from IS provides insights from a related field, but it may not directly translate to the unique challenges within the context of e-hubs. Differences in industry dynamics, stakeholder involvement and technological infrastructure could limit the applicability of insights gained.
- A sample bias: Due to the time constraint of this master thesis, only two experts on IS were interviewed on their experiences with the key leverage point during the orientation phase of IS development. It is possible that the selected sample does not accurately represent the larger population, leading to inaccurate conclusions.
- An interpretation bias exists in the lessons learned by successful e-hub pilots. No structured or semi-structured interviews were conducted towards how these pilots handled the key leverage point in their orientation phase. Already retrieved data from chapter 1 and 2 was revisited to discover success factors related to the key leverage point. The researcher's subjective perspectives influenced the interpretation of data, potentially leading to inaccurate conclusions.
- Limited exploration of alternatives: the focus on analysing data from IS and e-hub pilots may overlook alternative perspectives, contexts or solutions for socio-technical multi-actor complex systems, potentially constraining innovation in the design process.

These limitations are mitigated by:

- Recommending for future research, in order to iteratively expand on the diversification of expertise and data collected
- Conducting data triangulation between the outcomes of the two interviews with a report from a master thesis of a TU Delft student (Management of Technology) containing data retrieved from interviews with 14 stakeholders and researchers of three Eco-Industrial Parks in the Netherlands in 2021 (Valladolid Calderón, 2021)

Data derived

- Interview recordings and field notes of lessons learned in successful e-hub pilots, in regard to the key leverage point in their orientation phase
- Interview recordings and transcriptsa of two expert interviews and a report including data from interviews with 14 stakeholders and researchers of three IS examples in the Netherlands in 2021 (Valladolid Calderón, 2021) on lessons learned in IS, in regard to the key leverage point in their orientation phase

Data processing methods

- For the lessons learned by successful e-hub pilots, codes and themes identified in Chapters 1 and 2 were revised. Codes and themes that are related to the key leverage point were highlighted, creating new themes called 'success factors.'
- For the lessons learned by IS, the same data processing methods were used as for chapters 1 and 2. A thematic analysis was conducted, a qualitative research method to identify, analyse and interpret patterns or themes within the insights from interviews and attended events (Miles & Huberman, 1994). The analysis was performed inductive. By asking to lessons learned on the key leverage point by experts from another context, new insights were created on success factors to push the key leverage point found for e-hubs, in the orientation phase of IS development. Atlas.ti was used as a software tool to perform this analysis in. According to Miles & Huberman (1994), data analysis in qualitative research consist of three activities that occur simultaneously: data reduction, data display and drawing conclusions. These three activities will be explained below:
- Data reduction: collected recordings were transcribed and notes taken during the conversations were added to the transcriptions. By means of looking for frequency and recurrence, the weight the experts gave on certain topics and the interpretive insight of the researcher, themes were discovered that form the lessons learned in pushing the key leverage point discovered in e-hubs during the orientation phase of IS development. The themes were validated and refined by comparing them to data in the report of Valladolid Calderón (2021).
- Data display: the lessons learned in IS were displayed in a table, showing the name of the lesson learned, the relevance (an explanation on why this is a relevant lesson learned) and a small representation of empirical evidence by means of using one or two quotes that resulted into the formulation of the lesson learned. Consequently, the lessons learned were put into a Miro board, clustering them in order to narrow them down into actionable inputs for the design of solutions for pushing the key leverage point in the orientation phase of e-hub development.

Data processing methods

- Drawing conclusions: the clusters of themes of lessons learned in IS were compared to the lessons learned in successful e-hub pilots. Recurrence was analysed, and the lessons learned from both contexts were translated into Design Cues that form an actionable foundation for the design of a new proposition that stimulates the orientation phase of e-hub development.
- The design cues were stated in a chronological order, based on what cues should be in front of the proposition and cues that need to be included later on in the orientation phase of e-hub development.
- One specific design cue appeared to be supported by a high frequency of lessons learned from both IS and successful e-hub pilots. In order to effectively design for this design cue, chapter 5 dedicates special attention to this cue, incorporating expert input on the topics mentioned in the design cue.

Limitations of these methods include:

- Limited generalisability: the insights derived from expert input and thematic analysis is context-specific and may not be generalisable beyond specific cases studied, limiting the broader applicability of the findings.
- Subjectivity and bias: the process of revising codes and themes for successful e-hub pilots, as well as conducting thematic analysis for IS involves subjective interpretation by the researcher, which may introduce bias into the identification and interpretation of themes and insights.
- Design cues that form an actionable foundation for the design of a new proposition that stimulates the orientation phase of e-hub development.

These limitations are mitigated by:

- The limited generalisability is considered to be not significant limitation for the goal of this master thesis, as the insights and design cues derived are not meant to represent scientific outcomes of the research but rather serve as inspirational sources for design of a new proposition that stimulates the orientation phase of e-hub development. Therefore, no additional mitigation technique is recommended.
- Subjectivity and bias is mitigated by constantly comparing multiple sources of data. For the lessons learned by successful e-hub pilots, this included constantly comparing and refining themes to multiple sources of data (interviews, observations, etc.) For the lessons learned in IS, this included constantly comparing data from the two expert interviews to each other and to the report by Valladolid Calderón (2021).

Outputs

Design cues that form an actionable foundation for the design of a new proposition that stimulates the orientation phase of e-hub development.

RESEARCH METHODS OF CHAPTER 6: DESIGNING THE PROPOSITION

SRQ	6 | *How can the success factors and lessons learned in similar systems be included in a new proposition that stimulates the orientation phase of e-hub development on Dutch business parks in 2024?*
Main methodology	Participatory Innovation
Inputs	Design cues that form an actionable foundation for the design of a new proposition that stimulates the orientation phase of e-hub development.
Data collection methods	By engaging the intended end-users in the design process of solutions, more effective and sustainable outcomes are generated, stimulating the orientation phase of e-hub development in an efficient way. In order to maximise these outcomes, extensive efforts were made to engage users throughout the design process. The research structure described by Casali (2013) was used for this (figure 40), first collecting many inputs and ideas based on the design cues developed based on inputs from users, stakeholders and experts, synthesising and prioritising these ideas into themes, and consequently designing a first prototype and constantly test, improve and validate this prototype with input from users and stakeholders until it results into a final proposition that stimulates the orientation phase of e-hub development.

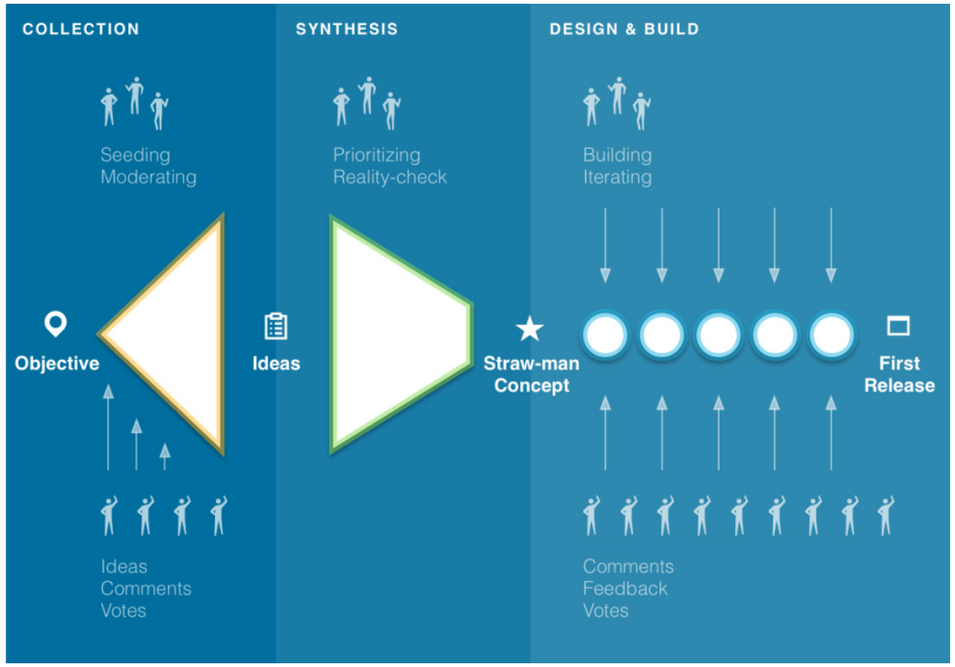


Figure 40: Participatory innovation in this master thesis. (Source: Casali, 2013)

Data collection methods

The following data collection methods were used for this:

- Collection of ideas:
  - First, focus was put on identifying the right people to collect input and ideas from. The selected participants included:
  - The key stakeholder, being the end-user of the proposition
  - Experts from supporting roles that also attended the events on which brainstorms with the key stakeholder were conducted
  - Experts on co-creation and social cohesion, as this appeared the most important design cue resulting from chapter 4.
  - Later, after an initial design was prototyped, supporting roles that were included into outcomes of the proposition were also included in collaborative brainstorming, validating and improving to ensure the proposition is also feasible and tailored to their needs and possibilities.
  - Then, focus was put on what design cues to brainstorm on collaboratively.
  - Not all design cues were used to collaboratively brainstorm on. In order to prevent an information-overflow for the participant of the brainstorming session and rather receive relevant brainstorming input on a smaller set of cues, a selection was made by examining how relevant the cues are to ask to participants, and how well they are able to answer them providing insightful and innovative ideas.
  - To collaboratively brainstorm with the key stakeholder and experts from supporting roles, the design cues were translated into questions that could be asked to the participant of the brainstorm. The effectiveness and relevance of the brainstorming questions were validated and improved using ChatGPT. By using the questions as prompts in ChatGPT, the answers to the questions were analysed and the questions were improved until desired answers resulted. This was not to steer the answers to the brainstorming questions, but to ask questions that effectively represent the design cues and are understandable and answerable by participants of the brainstorm.
- Collaborative brainstorms, validation and constant improvement sessions were conducted threefold:
- First, A0-posters were hung up in the common area of a knowledge-sharing event for e-hubs (figure 41). These posters included the brainstorming questions for the key stakeholder and experts from supporting roles. Next to the poster hung post-its and pens, enabling bypassing participants to comment on the brainstorming questions. This way, they could also see and build on each other's input. Around 100-150 stakeholders and experts attended the event. A QR code on the poster led to the contact information of the researcher, in case attendees were interested in further brainstorming together, were curious about the results or had further questions. Attendees were led to the posters by means of two plenary announcements of the hosts of the event, and by means of the researcher who was actively attracting attendees towards the posters. Pictures of the results of the posters at the end of the event can be found in appendix H.
- During the same event, a break-out session focussed on e-hubs that were in their orientation phase ('e-hubs for dummies'). During this break-out session, the researcher gave a very brief presentation on the outline of the research, and handed out flyers with QR-codes leading to a survey with the same brainstorming questions as presented on the posters (figure 42). This way, as many ideas and inputs as possible were collected. In order to maximise the amount of answers generated on the brainstorm, creative methods have been devised to encourage as many people as possible to take five minutes to participate in the brainstorm (figure 28).
- The survey led to 16 responses, and the posters led various post-its with ideas (Appendix H)

Data collection methods

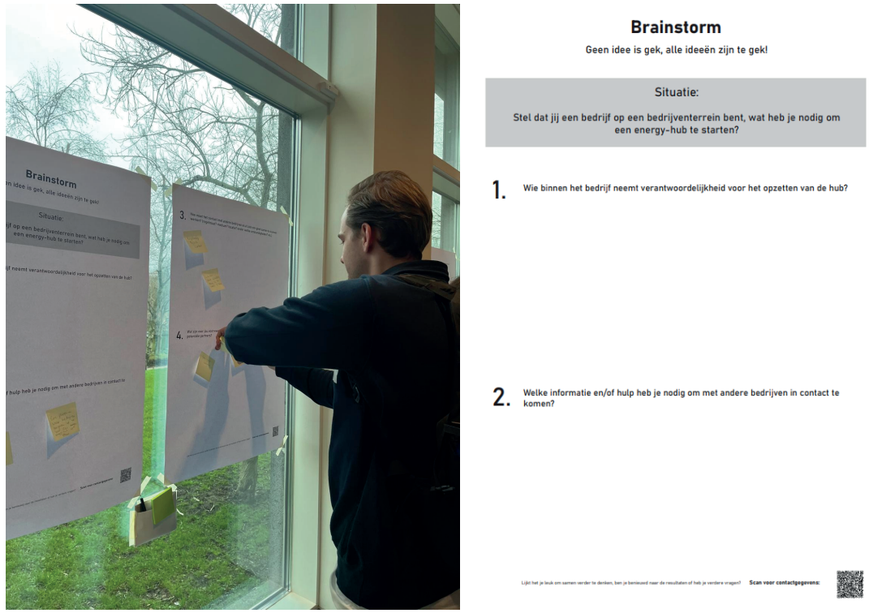


Figure 41: A0-posters for brainstorming were hung up in the common area of the event. Left and right: pictures of the event. Middle: one of the posters.

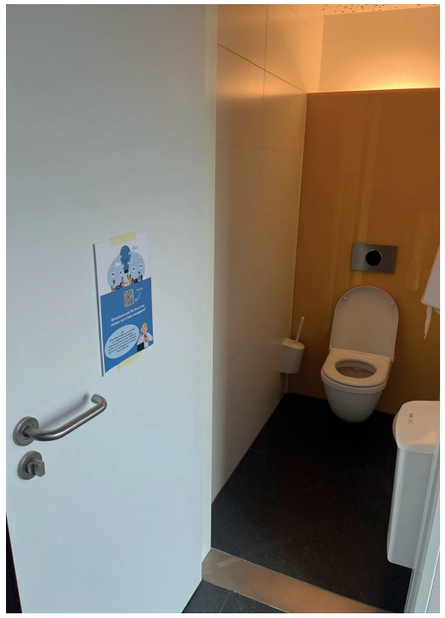


Figure 42: The flyer that was handed out to participants of the 'e-hubs for dummies' session (left) and creative methods to encourage as many people as possible to take five minutes to participate in the brainstorm (right)

Data collection methods	▪ Synthesis:
	  ▪ In order to synthesise all ideas collected, 4 synthesising themes were drafted. These themes formed the basis for the design of a first prototype. This prototype was designed in continuous collaboration with experts on co-creation and social cohesion, as this appeared the most important design cue resulting from Chapter 4. The brainstorming sessions with experts were very open; first, the context was outlined, the problem explained and the ideas and inputs from users were expressed, after which the researcher and the expert brainstormed together for possible solutions and followed up by asking about their practical experiences. These brainstorming sessions took place mostly in coffee shops, using sheets of A3 paper, markers, and a laptop to explain the context, problems and inputs from users and stakeholders.
	  ▪ The prototype had the embodiment of a PowerPoint presentation, which could be shown to users and stakeholders during the next phase.
	
	▪ Designing and Building:
	  ▪ The first prototype was presented to two facilitators (being one of the users of the prototype) and two participants (being the other users of the prototype).
	  ▪ Input and feedback was integrated into the design of the prototype, designing a new version: the proposition.
	  ▪ The proposition was presented during a meeting of front-runners of e-hubs on business parks in the Netherlands (figure 43). Around 25 front-runners attended. The front-runners included key players in the development of e-hubs, representing both participants and supporting roles. The presentation was continuously paused in order to discuss findings, feedback and new ideas with the attendees. During this meeting, minor last improvements were proposed on the prototype, and the prototype was validated. An employee of Stedin joined during this meeting to take minutes and notes while the researcher was presenting and discussing. The meeting lasted approximately one hour.

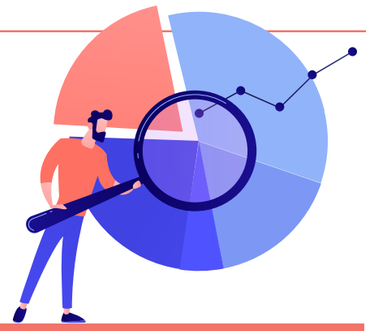
Figure 43: presentation for front-runners of e-hub development on business parks in the Netherlands.

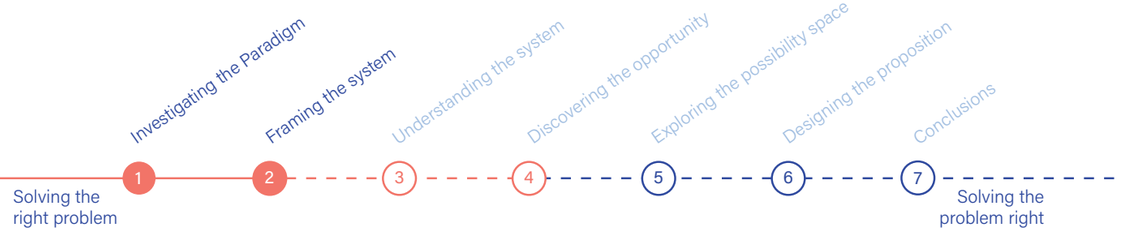
This collaborative approach not only fosters creativity but also enhances the relevance, usability and acceptance of the final proposition design.

Limitations include:

- For the participatory brainstorming with experts on co-creation and social cohesion, there might be an expertise dependency bias by interviewing a small number of experts, limiting a comprehensive understanding of best practices or innovative approaches. Dependency on a limited pool of experts risks overlooking alternative perspectives and ideas.
- For testing the prototype, there might be a selection and sample bias. Selection of the two participants and two facilitators relied on identifying individuals based on perceived relevance based on earlier contact between the researcher and the participants and facilitator, rather than systematically sampling from the entire target population. Also, as the sample size is rather small, a larger or different sample could have resulted in different outcomes of the results.
- A temporal constraint: same as the limitations mentioned in earlier chapters, the research

Data collection methods	conducted reflects a very specific moment in time. Because the energy transition is moving very fast, a few months after the research is conducted the results can already be outdated. ▪ Lastly, due to time constraints of the master thesis, no final test was conducted with the intended users, focusing on improving and validating the entire intended use of the proposition. **Mitigating these limitations includes:** ▪ By making use of the researchers own experiences, familiarity with the problem, constant reality-checking and referring to earlier collected data, the above-mentioned limitations were partly mitigated. However, due to time constraints of the master thesis, the mentioned limitations cannot be entirely mitigated within the timeframe of the master thesis. Therefore, continuous future research is advised.
Data derived	▪ Input and ideas from users and stakeholders based on the design cues resulting from chapter 5: Exploring the possibility space ▪ Input and ideas from experts on co-creation and social cohesion ▪ Validation and input from users and experts
Data processing methods	▪ The inputs and ideas from the key stakeholder and supporting roles, conducting an inductive thematic analysis. Tlhemes were developed by means of clustering and constantly comparing different ideas. The themes were displayed in a table, explaining each theme, the relevance of each theme (why a certain theme exists and what it adds to the understanding of the design possibilities) and some highlights of the empirical evidence per theme, by means of mentioning two or more quotes that support the theme. ▪ For the interviews on co-creation and creative facilitation, which also functioned as collaborative brainstorming sessions, collaborative data analysis: the researcher and interviewees engaging in brainstorming sessions during or immediately after the interview to analyse and interpret the data gathered. This allows for real-time exploration of ideas, insights, and patterns emerging from the interview. (Andrew et al., 2017). ▪ All other feedback, ideas and validation was continuously processes in a growing design of the final proposition. Limitations include: ▪ As design is a creative and iterative process and caused by the limited time available for this master thesis, it was impossible to write down all choices made and precise steps taken. This limits the reproducibility of the design process. ▪ As design is a creative and iterative process, this inherently causes a researcher bias. Outcomes may be influenced by subjective interpretation and solution-seeking. These limitations are mitigated by: ▪ Constantly validating, testing and reality-checking with users, stakeholders and experts throughout the design process decreases subjectivity of design choices and increases relevance of the outcomes.
Outputs	A proposition that stimulates the orientation phase of e-hub development





2

FRAMING THE SYSTEM

INTRODUCTION

This chapter focuses on answering the second Sub-Research Question:

What is the key role that needs to be stimulated in the orientation phase of e-hub development?

This chapter focuses on narrowing down the system boundaries in order to decrease complexity of the socio-technical multi-actor complex systems that e-hubs are, allowing for research and design of the system.

First, the system of focus will be explained. This is followed by an analysis of what roles are involvend in this system, what their contribution to the success of an e-hub is, what actors can be the rolebearer of each role, what drives the role to stimulate e-hub development and what barriers the role can impose on this development.

As explained in Chapter 1, e-hubs are multi-actor systems. However, in order to decrease complexity and narrow down the system boundaries, a key role is identified in this multi-actor system. **This key role forms the leverage point of the multi-actor system**, by stimulating this role, the system including all other roles is stimulated in reaching its goal; the development of e-hubs on business parks in the Netherlands.

This key role is identified by first analysing the engagement of these roles in the development processes of currently developing e-hubs is investigated over the time of this development process.

The engagement of roles specifically in the orientation phase of e-hub development is analysed by means of a power involvement grid, showing the power each role has over the success of a single e-hub and how closely involved the role is in reaching this success.

The chapter concludes by identifying a key role, that has the most power over the success of the e-hub and is closely involved into its development. This role has to be stimulated in order to stimulate the development of e-hubs. The next chapters will focus on identifying and stimulating drivers while mitigating barriers experienced by this key role.

THE SYSTEM OF FOCUS: NARROWING THE SYSTEM BOUNDARIES

As explained in the literature review, an e-hub can be seen as a socio-technical, multi-actor complex system. Before we start talking about 'the system', let's clarify what the system of focus during this master thesis research entails by scoping down to precise system boundaries.

In systems thinking, a 'system' typically refers to a set of interconnected elements that work together to achieve a common purpose or function. This can be any combination of elements, size of scope, any kind of interactions, etc. In order to map and analyse multi-actor complex systems, system boundaries have to be defined (Meadows, 2008). This means that a specific area of focus is selected in order to be able to research and design within the system.

In the remainder of this section, each time the system's scope is narrowed, an arrow will indicate the step of refining the scope:

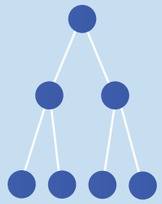
In the context of this master thesis, the system could be understood as the old energy system with its centralised and hierarchical structure, or as the new decentralised energy system with integrated e-hubs. However, this master thesis focuses on the **system in transition**, being the **development** of e-hubs (figure 44). The structural composition of this system includes social elements, technical elements, multi-actor dynamics and complexity (figure 44).

More specifically, as explained in 'Defining the Gap in Current Practices' in Chapter 1, the system of focus is the **organisational dimension of the orientation phase** of the development of e-hubs. In this phase, participants of potential e-hubs start to reach out to each other, exploring for new coalitions, forming groups and start envisioning collaborations in their energy supply and demand.

Within this system, social elements, technical elements, multi-agent dynamics and complexity can be recognised. The large variety of elements interacting in the systems complicates the mapping and analysis of the system and makes it almost impossible to research all system dynamics. Therefore, in order to simplify the system, **a key actor is selected. This does not mean that the multi-actor dynamics are neglected** in researching system mechanics, but rather selecting a focal point within the multi-actor dynamics of the socio-technical multi-actor complex system.

The next section will explain more about the selection of a key actor.

OLD SYSTEM: CENTRALISED ENERGY SYSTEM



SOCIAL ELEMENTS: stakeholders, social networks, institutionas and organisations, law and regulation, cultural factors, beliefs, values, language, etc.

TECHNCIAL ELEMENTS: infrastructure, assets, technological sysetms and processes, data and information, etc.

MULTI-ACTOR DYNAMICS: actors, interactions, interdependencies, emergent properties

COMPLEXITY: non-linearity, emergent behaviour, adaptation and evolution, self-organisation, uncertainty and risk

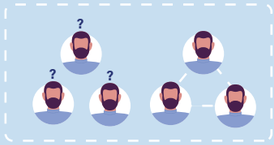
SYSTEM IN TRANSITION: THE DEVELOPMENT OF E-HUBS

SOCIAL ELEMENTS: stakeholders, social networks, institutionas and organisations, law and regulation, cultural factors, beliefs, values, language, etc.

TECHNCIAL ELEMENTS: infrastructure, assets, technological sysetms and processes, data and information, etc.

MULTI-ACTOR DYNAMICS: actors, interactions, interdependencies, emergent properties

COMPLEXITY: non-linearity, emergent behaviour, adaptation and evolution, self-organisation, uncertainty and risk



SYSTEM OF FOCUS: organisational dimension of the oientation phase

NEW SYSTEM: DECENTRALISED ENERGY SYSTEM WITH INTEGRATED E-HUBS

SOCIAL ELEMENTS: stakeholders, social networks, institutionas and organisations, law and regulation, cultural factors, beliefs, values, language, etc.

TECHNCIAL ELEMENTS: infrastructure, assets, technological sysetms and processes, data and information, etc.

MULTI-ACTOR DYNAMICS: actors, interactions, interdependencies, emergent properties

COMPLEXITY: non-linearity, emergent behaviour, adaptation and evolution, self-organisation, uncertainty and risk

Figure 44: Definition of the system of focus (Author's image)

THE **ROLES** INVOLVED IN THE SYSTEM

In order to select a key actor, first the different roles in the system are explored and defined.

Roles are defined instead of actors, as roles can be filled by multiple actors. As new actors constantly appear in the system and/or actors change roles in different points in time in the development of e-hubs, defining roles provides more insight into the dynamics between the roles and their contribution to the development of e-hubs.

Based on the interviews and events attended (please refer to Chapter 1 > Research Approach), a wide variety of roles can be defined. Figure 46 explains all different roles connected to e-hub development. Figure 45 shows a legend of how these roles are defined, including different tasks the role as in the development of e-hubs, what actors could fill this role, the drivers of the role as well as the barriers the role can impose on the development of e-hubs. The roles can contribute to one or multiple of the dimension of e-hubs, as defined in Chapter 1 > The Societal Context); the legal dimension, the organisational dimension and/or the technical dimension.

Based on the interviews conducted it appeared that there are two different types of participants to be distinguised; the early participant and the late participant. The early participant is the first to explore for opportunityies, coalitions and collaborations and establish a starting e-hub. The late participant on the other hand joins the e-hub when a group, agreements and collaborations are already implemented.

The colour of the role depicts what dimensions of e-hub development this role mostly influences:

Yellow: legal dimension

Red: organisational dimension

Blue: technical dimension

Role name

- Task this role have in the development of e-hubs
- The actors that could fill this role
- The drivers of this role: why this role is supporting the development of e-hubs
- The barriers this role can impose on the development of e-hubs

Figure 45: Legend of the roles involved (Author's image)

Initiator

- Is a hat that can be worn by multiple other roles. Whoever wears this hat gets the ball rolling; be the first to express the wish for an energy hub, gather relevant stakeholders, organise the first meetings
- Mostly worn by the municipality, the province, organisational process manager, technical process manager, early participants.
- Varies per role that fills this hat
- Varies per role that fills this hat, mostly being unaware of the possibilities, or being limited by available data, relationships on the park, and/or law and regulation

Funder

- Is a hat that can be worn by multiple other roles throughout the process of emergence. Whoever wears this hat is funding or investing in one or multiple steps of the hub emergence, documented in contractual agreements.
- Mostly worn by the municipality, the province, early participants, banks, investment funds
- Varies per role that fills this hat, out of public or own interest
- There are long waiting lists for subsidies, investmens are only possible with viable business cases which are not always there.

Early Participant

- Be the first companies on the park to join the hub. Investing time and money, sharing data, taking the risk to start. When the hub succeeds, this role acts as an ambassador of the possibilities for other companies on the park (see the role 'late patricipants') and to potential hubs on other parks
- Mostly a group of 4 - 15 of companies on the park, who experience the most drivers
- Can be multiple, see: Chapter 3 Understanding the System
- Can be multiple, see: Chapter 3 Understanding the System

Late Participant

- Not experiencing as strong drivers as the early participants to join the e-hub and therefore not be the first companies to put time and effort into the e-hub, but join after observing the possibilities and successes of the starting e-hub caused by the early participants.
- Any company on the park experiencing drivers to join the hub
- Can be multiple, same as the early participant
- Can be multiple, same as the early participant

Organisational Process Manager

- Guide the organisational steps of the emergence process. Finding and connecting important stakeholders. Ensuring all necessary data. Coordinating funding, permits and other legal steps.
- Independent advisor that has 10+ hours per week available per hub
- Money, paid by one or multiple roles wearing the 'funder' hat
- Not being able to connect all important stakeholders

Technical Process Manager

- Obtaining and processing data. Making feasability studies, a feasability report, an in-depth system design and robust business cases.
- Independent advisor, or a company that offers consultancy services next to their congestion service provider (see the role of congestion service provider). Can be fulfilled by measuring companies like Joulz and Groendus, additional benefit here is that data is already available at these companies
- Money, paid by one or multiple roles wearing the 'funder hat'
- Not having enough and/or true knowledge on the technical possibilities of the hub

Figure 46 (part 1/2): The roles involved (Author's image)

Municipality

- Being the first point of contact for a company or group of companies experiencing net congestion, and/or drivers and barriers in the emergence of an e-hub. Has closer contact with individual companies than the province. Funding and granting permits for assets.
- Any municipality in NL
- Public wellbeing, wanting to achieve (sustainability) goals in their Regionale Energie Strategie (RES)
- Having limited knowledge and (human) resources, long waiting lists for subsidies and permits

Province

- Sharing knowledge between all stakeholders, connecting different e-hubs to share knowledge and lessons learned, assigning a technical and/or organisational process manager, funding
- Any province in NL
- Public wellbeing, wanting to achieve (sustainability) goals in their Regionale Energie Strategie (RES)
- Having limited (human) resources, having long waiting lists for subsidies

Connector

- This role has personal connections with the companies on the park, and knows drivers and barriers experienced by (most) companies on the park, thus knows who can fulfill the role of first participants. Keeps communicating and keeping everyone on board. **This role is however not available on most business parks.**
- A park manager, a business circle or association, an independent advisor with a lot of connections and a neutral perspective, a concerned municipaliy (only possible for smaller towns)
- Money, paid by one or multiple roles wearing the 'funder' hat
- Not being able to convince necessary companies, being unable to balance conflicting interests well

DSO

- Facilitating quarter-hourly data on the usage profiles of all companies, facilitating data on the grid topology, facilitating new group contracts
- Stedin, Liander, Enexis Netbeheer, Coteq Netbeheer, Rendo Netbeheer, Westland Infra Netbeheer
- Being (government-determined) responsible for a sustainable, accessible to everyone, affordable, reliable, and safe (supply secure) integrated energy system of the future
- Not being able to share data, not yet being able to sign group contracts, having limited (human) resources

Congestion Service Provider (CSP)

- Designing a grid controll platform, software that automatically directs energy to the assigned companies, based on the in-depth system design made by the technical process manager.
- Measuring companies expanding their services like Joulz or Groendus, or upcoming companies like Firan, Spectral, Resourcefully
- Money, mostly paid by participating companies
- Causing a lock-in, meaning the hub is dependent on only one CSP

Asset Provider

- Providing assets, like batteries, solar panels, small wind turbines, infrastructure, measuring devices, software like Energy Management Systems and according hardware
- Asset providing companies like Kenter, Joulz, Groendus
- Money, paid by the role wearing the 'funder' hat
- Not directly causing any relevant barriers because of its replaceability

Measuring company

- Quantifying, monitoring and analyzing energy usage and production data to facilitate informed decision-making and optimised decision-making. Not every company has a contract with an energy measuring company, but most larger companies do. This role has some overlapse and could fill the same role as the CSP and asset provider.
- Companies like Joulz, Groendus, Fudura.
- Money paid by companies that have a contract with the measuring company
- Causing a lock-in if all companies in the hub should have a contract with the measuring company to obtain data

Banks and investment funds

- Invest in projects that give a return rate, manage risks.
- Any bank in NL, in the context of e-hubs mainly Rabobank and ABN Amro (both banks) and Invest-NL (investment fund) are named by interviewees.
- Generating monetarial returns, mitigating risks while doing so
- Not wanting to provide funding if there is not yet a critsal clear business case.

Consortium

- Stimulating innovation and collaboration, obtaining and sharing knowledge. Provinding a network of experts, providing guidance during the emergence process. Can also help with funding and legal advise
- Programma Verduurzaming Bedrijventerreinen (PVB), Topsector Energie, TKI Urban Energy, Landelijk Actieprogramma Netcongestie (LAN), Rijksdienst voor Ondernemend Nederland (RVO), but this role can also be filled by foundations like Energy Scale-up, or knowledge institutes like TNO.
- Public interest, stimulated by the Dutch government / Ministerie van Economische Zaken en Klimaat (EZK)
- Not directly causing any relevant barriers

Branche organisation

- Advocating and supporting the interests of their members. Shares knowledge and pushes policymakers.
- VNO-NCW is the Confideration of Netherlands Industry and Employers and represents the interests of all Dutch businesses, actively stimulating the development of e-hubs by placing representatives locally on business parks. Netbeheer Nederland is the branche organisation of all Dutch DSOs, actively stimulating e-hub developmant by developing standardised group contracts.
- Money received from their members
- Not directly causing any relevant barriers

Policymaker

- Changing policy to stimulate innovation and collaboration, changing laws and regulations to allow for innovation and collaboration. Mostly allows for funding and legal possibilities.
- Ministerie van Economische Zaken en Klimaat (EZK), Autoriteit Consument & Markt (ACM).
- Public interest
- Being slow in changing law and regulations and creating funding possibilities.

Consultants

- This role is needed when there are open gaps in the technical, organisational or legal dimensions of the hub emergence, that are left behind by any other role. This role is not always needed on top of other roles.
- Independent advisors
- Money, paid by the role wearing the 'funder' hat
- Not directly causing any relevant barriers because of its replaceability

Figure 46 (part 2/2): The roles involved (Author's image)

THE ENGAGEMENT OF DIFFERENT ROLES IN THE DEVELOPMENT OF E-HUBS

In order to understand the engagement of the different roles to the current development of e-hubs, an **engagement journey** is mapped (figure 47).

This engagement journey shows at what points of the development process of currently developing e-hubs certain roles are involved. This will consequently lead to conlusions on what roles are closely involved with the development of e-hubs, and what power they have on the success of not on the societal development of e-hubs, but specifically on one e-hub.

The steps of the engagement journey are based on 26 interviews with practitioners and experts (see Capter 1 > Research Approach). The list of interviewees can be found in appendix A.

It should be noted that the development steps are an aggregation and simplification of current processes, and not a standard for e-hub development. Complexity is not depicted in this process. This analysis is merely conducted in order to explore current processes, the engagement of current roles over time, and to eventually identify a key role in the next section.
An explanation on how the engagement journey should be understood will follow:

- Above the journey, the steps as mentioned in current practices are added to the development steps described by interviewees (see Chapter 1 > Defining the Gap in Current Practices). Overlap can be identified, however interviewees mention a step that precedes the four development steps as defined by current practitioners. Before the orientation phase of e-hub development, companies will first take individual measures.
- Steps taken in different dimensions of e-hub development (see Chapter 1 > Societal Context) do always happen one after another, but are somewhat flexible in their relative timelines. Therefore, the steps of different dimensions are depicted in three different layers of the development timeline.
- Per step, the central is identified. This is the role that has the most power over the success of the step.
- Interviewees highlight two steps as main bottlenecks during the development process, indicated with red boxes above the journey. **This validates the conclusion drawn in Chapter 1**, that the orientation phase is indeed a large bottleneck in the development of e-hubs and should be further researched and stimulated.
- On the bottom of the engagement journey, the system of focus for this master thesis is shown; the orientation phase.

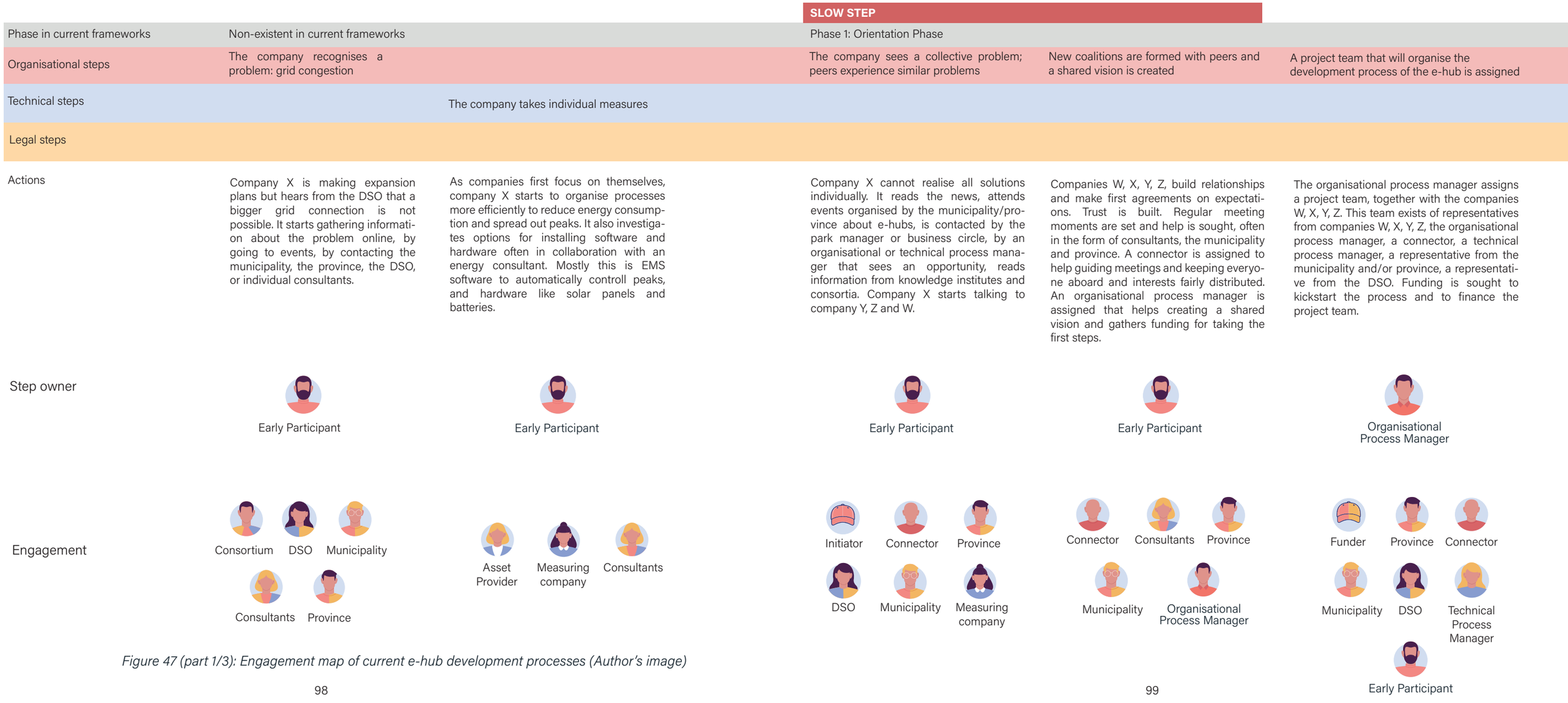


Figure 47 (part 1/3): Engagement map of current e-hub development processes (Author's image)

				SLOW STEP	
Phase in current frameworks	Phase 2: Preparation phase		Phase 3: Realisation phase		
Organisational steps		Based on an interim report, common interests are defined and collaborations are further explored		Determine conditions of collaboration	
Technical steps	Doing an energy scan; a first feasibility study		In-depth system design		Finalise the hub design
Legal steps	Companies have to give consent for the usage of their data		Companies have to give consent for the usage of their data		
Actions	The technical project manager acquires historical data and future plans from companies W, X, Y, Z, for example by means of a survey. The technical process manager makes an energy scan of this data, showing the potential feasibility of the hub. If it appears the energy usage profiles of the companies are not compatible, en e-hub is not the best solution and the group falls apart. If the profiles are compatible, some first scenario's for a potential hub are sketched that can be food for discussion in the next step.	Based on the potential scenarios companies W, X, Y, Z start discussing their possibilities, under supervision of the organisational process manager. The connector ensures a smooth discussion and a representation of everyones interests. Companies W, X, Y, Z decide if they all want to go through to the next step.	The technical process manager facilitates an in-depth system design based on quarterly-hour data that needs to be obtained from the DSO. Potentially needed assets are investigated and possible business cases are designed.	Companies W, X, Y, Z decide whether their individual business case is viable and if they want to proceed collaborating. Under supervision of the organisational process manager and the connector, the conditions for the collaboration are defined including questions like: 'how can flexibility be created?' 'who needs energy when?' 'who pays for what?' 'under what conditions?' 'what happens if someone uses too much?'	With the companies that want to go through, the technical process manager designs the final hub design and robust businses cases. All agreements of last step are taken into account in the final design of the hub and its business cases.
Step owner	Technical Process Manager	Early Participant	Technical Process Manager	Organisational Process Manager	Technical Process Manager
Engagement	Early Participant, Organisational Process Manager, Funder, Measuring company	Connector, Organisational Process Manager, Technical Process Manager	Connector, Early Participant, Organisational Process Manager, Funder, DSO	Connector, Early Participant, Technical Process Manager	Connector, Early Participant, Funder, Organisational Process Manager

Figure 47 (part 2/3): Engagement map of current e-hub development processes (Author's image)

Phase in current frameworks				Phase 4: Exploitation phase
Organisational steps			Assigning a board to maintain the e-hub	Maintain, learn and expand
Technical steps		Design software to control the hub and install assets		
Legal steps	Formalise the collaboration			
Actions	Companies have to make the final call whether they trust each other and the agreements made, and decide whether the business cases are profitable enough for them. A decision is made whether the hub is worth the risk. Then, a legal entity is formed (e.g. a foundation, a cooperation, a PLC) and group contracts are signed with the DSO.	The grid control platform is installed and made ready to automatically act on the agreements of the collaboration. If needed, assets (e.g. a battery) are bought or leased and installed.	The project team finishes the emergence process. To maintain the hub, a hub board is assigned. This board consists of a technical (mostly the grid control platform representative) and a legal advisor, an independent chairperson and representatives from an equal amount of two types of companies within the hub; companies with capacity and those without. This way, all interests are represented and balanced.	The hub is repeatedly evaluated, lessons learned are documented and improved on, investments are returned. All companies are kept involved by the hub board. Successes are celebrated, and the hub forms an example to other hubs and other companies on the park. Through an ambassador-effect, more companies on the park will most likely join the hub.
Step owner	Early Participant	Technical Process Manager	Organisational Process Manager	Early Participant, Late Participant
Engagement	Connector, DSO, Organisational Process Manager	Congestion Service Provider (CSP), Funder, Asset Provider, Early Participant	Connector, CSP, Consultants, Early Participant	Connector, Province, CSP, Municipality, DSO

Figure 47 (part 3/3): Engagement map of current e-hub development processes (Author's image)

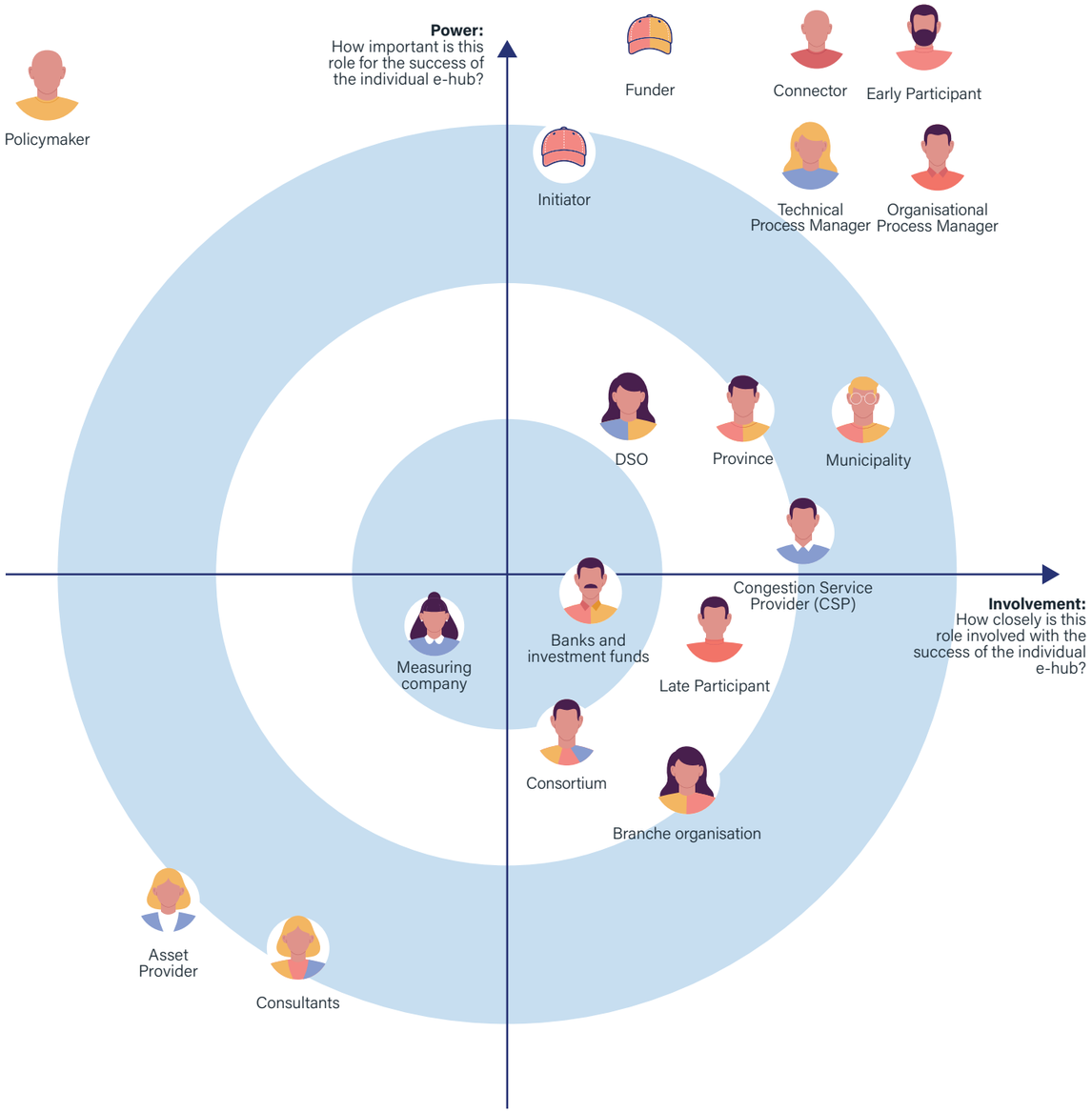


Figure 48: Power-involvement grid of the roles involved (Author's image)

IDENTIFYING THE KEY ROLE

Based on the engagement journey, the involvement and power that all different roles have on the orientation phase of e-hub development are investigated. Figure 48 shows a power-involvement grid to visualise this analysis. This grid plots the power of roles, meaning how important this role is for the success of an individual e-hub, to the involvement of roles, meaning how closely the role is involved with the success of an individual e-hub.

Almost all interviewees agree that the early participant is the end-user of the e-hub, and is therefore the role with the most power and involvement in its development. All other roles try to facilitate the e-hub in order to support the early participant. This makes **the early participant the key role of focus for this master thesis.**

The key role is depicted in figure 49, directly supported by roles that have high power and involvement into the success of the e-hub and indirectly supported by roles that have lower power and involvement into the success of the e-hub.

Quotes from interviewees that support this conclusion include:

"The entrepreneur Is the central player. They must be willing to share their information and be open to exploring opportunities."
– P6

"In the end, the entrepreneur is the one who has to want the e-hub to happen. They are the user, we are just there to facilitate."
– P11

"The technology will follow, we also managed to get people on the moon. Now, first we have to focus on the organisation of the entrepreneurs. They are the most important piece of the puzzle."
- P17

"All efforts made in e-hub development are focused on the businesses. They are the ones with the problems and they have to be part of the solution."
– P13

P[number] refers to the list of interviewees in Appendix A.

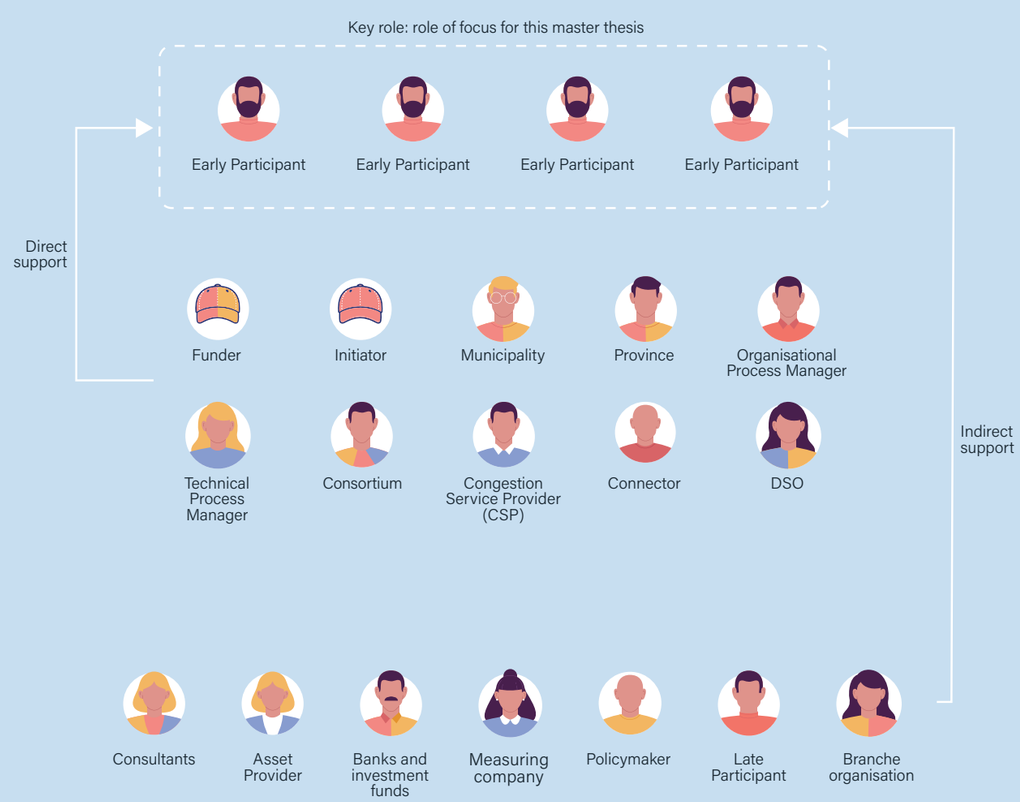


Figure 49: The key role, roles that contribute directly and indirectly (Author's image)

THE SYSTEM **BOUNDARIES**

The general system boundaries for this master thesis are defined as only focussing on the orientation phase of e-hub development. This includes the following boundaries:

- Geographical boundaries: the Netherlands, with a strong focus on (but not entirely limited to) e-hubs within the geographical area in which Stedin operates, being the provinces of Zuid-Holland, Utrecht and Zeeland.
- Spatial boundaries: the system researched is only focused on e-hubs on business parks.
- User-centric boundaries: the system researched is researched with a strong focus on (but not limited to) businesses that are interested in starting an e-hub ('the participant').
- Actor boundaries: the system researched is focused on actors that are directly or indirectly related to the participant.
- Functional boundaries: only electricity is researched as a function of the system.
- Temporal boundaries: 2024
- Legal boundaries: the laws and regulations of act in 2024 in the Netherlands
- Action boundaries: this research does not focus on suggesting policy interventions, but on designing applicable interventions that do not directly require a change in policy. This way, conclusions can be directly applied to tackle the societal problem.

By focussing on the organisational dimension as explained in Chapter 1, the system boundaries are scoped down from the socio-technical system at large towards a focus on the multi-actor system of the orientation phase of e-hub development (figure 50).

By selecting a key role, the system boundaries are again scoped down from the multi-actor system towards the complex system of drivers and barriers experienced by this key role in the orientation phase of e-hub development on business parks in the Netherlands in 2024 (figure 50).

Within these system boundaries, leverage points will be explored and one key leverage point that represents the Opportunity for intervention will be discovered in order to change the system's behaviour of first the complex system of drivers and barriers as experienced by the key role, resulting to cascading effects and changes in the system's behaviour in the multi-actor system, resulting to cascading effects and changes in the system's behaviour of the socio-technical system.

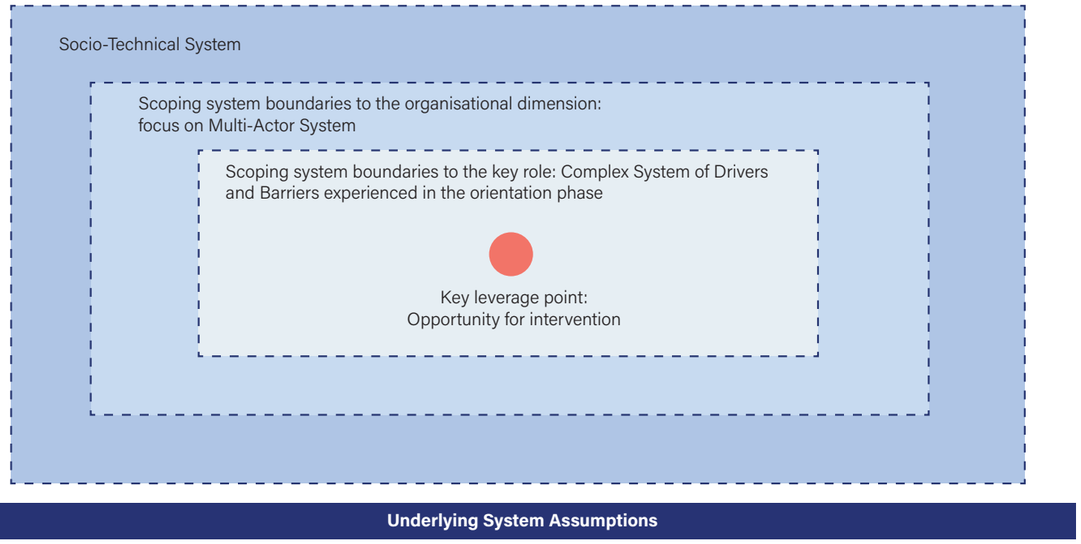


Figure 50: Power-involvement grid of the roles involved (Author's image)

THE SYSTEM **ASSUMPTIONS**

Underlying to these system boundaries, the following assumptions are made:

- On a technical level, e-hubs will most likely become a standardised product, including the following aspects:
  - Standard availability of data, and/or standardised channels to quickly share data
  - Standard calculation models to make first feasibility scans
  - Availability of standard group contracts with the DSO
  - Law and regulation will make e-hubs legally possible
- There is sufficient capacity of asset such as batteries
- There is sufficient capacity of installers of assets
- As only 20% of business parks in the Netherlands has an existing organisation form (like a park manager or a business association) (RLI, 2023), it is assumed that the system of the business park has no existing organisation form.

CHAPTER 2 - FRAMING THE SYSTEM: **CONCLUSIONS**

The 'system' resulting from Chapter 1 involves the organisational dimension during the orientation phase of e-hub development. In order to research and intervene in this system, the complexity of the multi-actor system is reduced by narrowing down the system boundaries and identifying one key role that has most influence on this multi-actor system. This key role therefore functions as the leverage point within the multi-actor system; stimulating this role results into cascading effects that activate the entire system.

Therefore this chapter focussed on answering the second sub-research question:

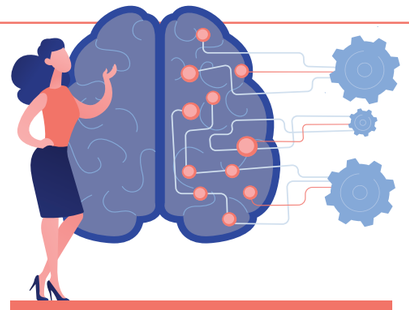
What is the key role that needs to be stimulated in the orientation phase of e-hub development?

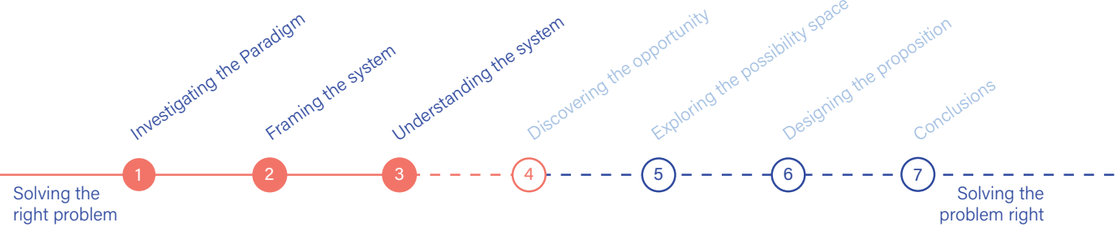
The key role is defined by mapping all involved roles and evaluating their characteristics, as well as assessing their engagement within the organisational dimension of e-hub development. In order to holistically understand the dynamics of the multi-actor system, first the engagement of actors in the entire development process of e-hubs is assessed, after which focus is redirected on the orientation pase in order to assess the power and involvement each role has in the targeted system of this thesis research.

This leads to the identification of the early participant as the key role. This key role functions as a leverage point of the multi-actor system; stimulating the key role will have cascading effects on the system's behaviour of the multi-actor system.

Consequently, the system boundaries are narrowed down from the multi-actor system researched in this chapter towards a focus on the complex system of drivers and barriers as experienced by the key role in the orientation phase of e-hub development. Next to this, system assumptions are stated.

Chapter 3 will focus on identifying leverage points within the complex system of drivers and barriers as experienced in the orientation phase of e-hub development.





3

UNDERSTANDING THE SYSTEM

INTRODUCTION

In this chapter, the third sub-research question will be answered:

What are drivers and barriers experienced by the key role in the orientation phase of e-hub development, and what drivers and barriers serve as strategic points for intervention (leverage points) to stimulate this phase?

In Chapter 2 the system frame is narrowed down to a focus on the early participant (the key role) within the multi-actor and socio-technical systems of e-hub development. By stimulating this key role, the development of e-hubs will be stimulated.

In order to understand this system and therefore understand how to stimulate the early participant, first the experiences and thoughts of the experiences and thoughts of the early participant during the orientation phase of e-hub development is drafted. Consequently, drivers and barriers that underly these thoughts and experiences are researched.

First, these drivers and barriers explained by the early participant in the orientation phase of e-hub development are defined and explained. Consequently, the causal relationships between, and rootedness of these drivers and barriers are researched. This allows for the identification of leverage points; points within the system where a small intervention has cascading effects causing a large change in the behaviour of the system.

UNDERSTANDING THE **THOUGTS** AND **EXPERIENCES** OF THE KEY ROLE

In order to stimulate the early participant in the orientation phase of e-hub development, it is important to understand what this role experiences and things during this phase. Figure 51 visualises the orientation phase of e-hub development through the eyes of the early participant. These results are based on interviews with early participants as well as with supporting roles who have heard the thoughts and experiences of early participants in real-life cases, along with observations made during events where early participants attended. More information on the interviewees and attended events can be found in appendix A and B, and in Chapter 1 > the research approach.

UNDERSTANDING THE **DRIVERS** AND **BARRIERS** OF THE KEY ROLE

The thoughts and experiences of the early participant as visualised in figure 51 are rooted in drivers and barriers that this key role experiences during the orientation phase of e-hub development. Based on the same research as discussed in the section above (Understanding the thoughts and experiences of the key role), these drivers and barriers are defined and explained in tables 5 and 6.

The analysis on drivers and barriers experienced by the key role resulted not only in drivers and barriers within the system boundaries, also barriers outside of these boundaries and the research scope were identified. These are not further researched, however as they can be relevant information for further research by practitioners and academia, they are provided in appendix F.

The P[number] after each quote is referred to the list of interviewees in appendix A.

After the drivers and barriers are explained, this chapter will continue to investigate the causal relationships between and rootedness of these drivers and barriers, in order to discover leverage points to intervene.

LOOKING THROUGH THE EYES OF **THE EARLY PARTICIPANT**

The early participant **EXPERIENCES:**	A problem and/or opportunity in its energy provision	Unclarity in possible solutions	Unclarity in possible partners	Unclarity in data collection	Unclarity in available help
The early participant **THINKS:**	Is this my problem? Shouldn't the DSO solve this?	Where should I start? I don't know anything of energy, and I have no time to look for solutions. I saw something on LinkedIn about e-hubs, where can I find more about this?	Who is also experiencing these problems? Can we even collaborate, are we on the same cable? Do I trust you?	What data should I collect? With whom do I want to collect data? What is expected of me? This is not my core business, I actually don't want to deal with this.	Who should I involve? The municipality? The province? VNO-NCW? PVB? Grid operator? CSP? Consultancies?

Underlying **DRIVERS** and **BARRIERS** further explained in tables 5 and 6

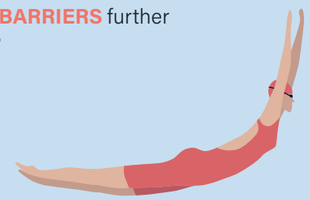


Figure 51: The thoughts and experiences of the key role (Author's image)

THE **DRIVERS** EXPERIENCED BY THE KEY ROLE

Table 6 (part 1/4): The drivers experienced by the early participant in the orientation phase of e-hub development

#	Driver	Explanation	Empirical Evidence
D1	Grid congestion – not having another option	Because of grid congestion, companies are hit in their core business. They have to look for solutions in order to stay in business.	24 quotes, a.o.: "The primary goal of companies is to stay alive. For this, delivery reliability is essential." – P9 "Business operations are the basis for companies. If the business operations are compromised, companies will do everything to invest in their future. Affordable energy is essential for this." – P12
D2	Having a small group of enthusiastic companies that are willing to put time and effort into the hub	To gain initial momentum for the development of e-hubs, having small group of enthusiasts is essential.	15 quotes, a.o.: "It is essential to have a few idealists, for example 'green entrepreneurs'; people within companies who prioritise sustainability and are willing to invest a lot of time and effort into it without immediately seeing results." – P16 "The beginning of the e-hub is on a voluntary basis, you won't see immediate effects. Therefore it is important to have a few motivated companies who see an opportunity and dedicate themselves to creating a potential hub." – P6 "The first group of companies who joined did not necessarily have the biggest problems, but they had a proactive attitude and think about their future." – P8
D3	Ambassador-effect: first movers pull more companies into the hub	Companies in (successful) e-hubs become ambassadors for the hub's goals and benefits. These ambassadors promote and expand the reach of the e-hub, causing the e-hub to grow.	17 quotes, a.o.: "Start small with a few companies, so that communication between them is easy. Then, use these companies as a proof of concept and have them take on an ambassadorial role to bring other companies on the premises along as well." – P7 "In our hub, one or two people understood the idea of the hub well and brought many other local parties along." – P23
D4	Having knowledge on lessons learned in other e-hubs	When companies have examples of successful e-hubs and information on their lessons learned, it becomes easier to be aware of and understand what the possibilities, benefits and pitfalls are, and to understand how to make possible technical designs.	11 quotes: a.o.: "Companies need to have enough trust in the hub before they are willing to invest. Trust can be cultivated by increasing knowledge. However, it must be ensured that enough, but not too much knowledge is shared, as this can lead to information overload and sluggishness." – P9 "We need to have more examples, we don't know the possibilities" – P27

Table 6 (part 2/4): The drivers experienced by the early participant in the orientation phase of e-hub development

#	Driver	Explanation	Empirical Evidence
D5	Existing companies want to expand	Supporting to D1, companies who want to expand need a bigger grid connection. These are not available due to grid congestion.	5 quotes: a.o.: "If companies want to expand, they need a bigger grid connection. This is not always possible due to grid congestion." - P2 "Some companies cannot expand anymore. Then, energy problems hit them in their business and they are willing to do investments look for other solutions" -P13
D6	New companies want to settle	Supporting to D1, new companies who want to settle need a new grid connection. These are not available due to grid congestion.	3 quotes: a.o.: "New companies cannot settle due to grid connection." – P4 "A new company here on the park now has a diesel generator running day and night, because they cannot obtain a grid connection. That is litres of diesel and thus money down the drain." – P28
D7	Companies want to become more sustainable and therefore want to electrify	Supporting to D1, companies who want to become more sustainable electrify their processes or mobility, and sometimes install solar panels or energy storage systems like batteries. Becoming more sustainable is not always a choice, but can also be stimulated through policy, law and regulation.	7 quotes: a.o.: "How enthusiastic a company is about joining a hub depends on how significant the risk of grid congestion is and how sustainability ambitions are shaped." – P21 "Money also plays a central role: sustainability and collective shaping are great for the narrative around it, but if it doesn't bring in revenue, companies won't participate. Sustainability also generates money nowadays." – P12
D8	The realisation there is a shared problem; other companies have the same problem	Once companies notice that other companies struggle with the same problems, they are more likely to start collaborating.	5 quotes, a.o.: "There must always be a reason for companies to organize themselves. They need to recognize that they share the same interest." – P14 "E-hubs emerge from sheer necessity. These may not necessarily be related to the existing level of organisation. If an area is not yet organised, grid congestion, with the solution being an e-hub, can lead to an organisational form. For this, it is essential that companies understand that more companies deal with the same problems as themselves." – P20

Table 6 (part 3/4): The drivers experienced by the early participant in the orientation phase of e-hub development

#	Driver	Explanation	Empirical Evidence
D9	Realising it is possible to work together to overcome problems	Companies often don't realise that working together is an option. When awareness increases on this possibility, companies are more driven to collaboratively look for solutions	3 quotes, a.o.: "I know that e-hubs are possible and have benefits, like at Schiphol. I don't know how it works, but I know that it is a possible solution. That is how we started exploring." – P22 "They realised; it is not up to one company to solve these kind of problems. We all need to solve these problems together. With multiple entrepreneurs, but also the province, municipality and DSOs." – P9
D10	Being drawn towards new technology; having the desire to be the first mover	Entrepreneurs are drawn towards new opportunities and new technologies. This motivates them to join an e-hub, being a new innovation.	4 quotes, a.o.: "Entrepreneurs find new gadgets and technologies 'sexy' and appealing; entrepreneurs want to distinguish themselves." -P10 "Our community was always late in adopting new technologies. Now, everyone is driven to be at the front-end of innovation and show everyone that we are capable of." – P25
D11	Save on costs by sharing assets and saving on grid fees	Entrepreneurs want to save costs. By sharing assets and grid fees, they reduce their energy costs which increases their competitive advantage.	3 quotes, a.o.: "Companies not only think from problem perspectives (grid congestion), but also from opportunity perspectives (we have to move away from gas and become more sustainable and self-sufficient). Sharing assets is one of these opportunities, sharing assets for this purpose provides financial advantage" - P5 "These batteries are a large investment, we can spread the risk of this investment by collaborating." – P23
D12	Motivations of company X: Group independency	Being part of an e-hub causes dependency on neighbours, but independency from regional or (inter) national developments.	3 quotes, a.o.: "Self-sufficiently is certainly theme for us." – P23 "Entrepreneurs have the desire for a less vulnerable energy system. By keeping the system locally controlled, it is less likely that the entire region will experience failure or hacking. Also the system is less vulnerable to crises and international influences, such as the high energy prices from Russian gas resulting from the war." – P11

Table 6 (part 4/4): The drivers experienced by the early participant in the orientation phase of e-hub development

#	Driver	Explanation	Empirical Evidence
D13	Motivations of company X: Wanting to be future-proof	In order to ensure long-term viability, resilience and relevance in a rapidly evolving business and innovation landscape, companies strive to adapt to current times and developments.	5 quotes, a.o.: "We see a shift from a centralised to a decentralised energy system, with all solar panels and batteries currently in the market. We want to keep exploring the possibilities." – P22 "We are not experiencing problems from grid congestion yet, however we know that it might become a trend in the future and we find it very interesting to stay up to date with all developments and act on that as well." - P24
D14	A change in attitudes is happening; people are more open to new technologies and solutions	Businesses, especially their younger employees, are less focussing on the 'if it ain't broke, don't fix it' mentality, but have an increasing acceptance and enthusiasm for adopting new technologies and innovative solutions.	3 quotes: a.o.: "Certainly younger people within a company are more willing to take risks in adopting new technologies and innovation, they have a different mindset than their older coworkers who want to play it safer." - P17 "There are more and more 'green entrepreneurs'; individuals within companies who prioritise sustainability and are willing to invest a lot of time and effort into it (sometimes on a voluntary basis) without immediately seeing results." – P6
D15	Companies want to earn money	This driver forms the basis of why a business exists; to earn money.	12 quotes, a.o.: "Below the line, no company will do anything that will lose them money." – P10 "Companies will not do things that will not gain money, either in the short term or in the long term. They need to sustain their operations, invest in growth and provide returns to stakeholders. That is just how companies work." – P13
D16	Companies always want to have energy, energy is the basis of business operations	Without energy, businesses cannot continue their business operations. Energy security is one of the most important subjects for businesses to stay alive.	14 quotes: a.o.: "Today, without energy no-one can do anything. We are all dependent." – P24 "Look at the energy crisis after the war between Russia and Ukraine, what effects that had on the economy. We all need cheap and reliable energy." -P22

THE **BARRIERS** EXPERIENCED BY THE KEY ROLE

Table 7 (part 1/6): The barriers experienced by the early participant in the orientation phase of e-hub development

#	Barrier	Explanation	Empirical Evidence
B1	There is a lack of capacity in supporting roles	There is not enough (human) resources to support the development of e-hubs top-down. Therefore, entrepreneurs are essential in the transition towards e-hubs, not only are they the ones who have to 'want' e-hubs, they also have to actively contribute to their development.	15 quotes, a.o.: "It is essential to have a few idealists, for example 'green entrepreneurs'; people within companies who prioritise sustainability and are willing to invest a lot of time and effort into it without immediately seeing results." – P16 "The beginning of the e-hub is on a voluntary basis, you won't see immediate effects. Therefore it is important to have a few motivated companies who see an opportunity and dedicate themselves to creating a potential hub." – P6 "The first group of companies who joined did not necessarily have the biggest problems, but they had a proactive attitude and think about their future." – P8
B2	Companies hold a grudge to DSOs and think someone else has to fix their problems	Companies think grid congestion is a problem that the DSO should solve. They don't understand or agree with their own role in finding and realising solutions like e-hubs.	17 quotes, a.o.: "Start small with a few companies, so that communication between them is easy. Then, use these companies as a proof of concept and have them take on an ambassadorial role to bring other companies on the premises along as well." – P7 "In our hub, one or two people understood the idea of the hub well and brought many other local parties along." – P23
B3	Companies do not want to or cannot invest time and effort into the hub next to their core business	Entrepreneurs are busy people. They want to spend minimal time and effort into looking into energy problems and solutions next to their daily business.	11 quotes: a.o.: "Companies need to have enough trust in the hub before they are willing to invest. Trust can be cultivated by increasing knowledge. However, it must be ensured that enough, but not too much knowledge is shared, as this can lead to information overload and sluggishness." – P9 "We need to have more examples, we don't know the possibilities" – P27
B4	Companies do not want to take risks	Companies avoid taking risks to maintain investor confidence	5 quotes: a.o.: "If companies want to expand, they need a bigger grid connection. This is not always possible due to grid congestion." - P2 "Some companies cannot expand anymore. Then, energy problems hit them in their business and they are willing to do investments look for other solutions" -P13

Table 7 (part 2/6): The barriers experienced by the early participant in the orientation phase of e-hub development

#	Barrier	Explanation	Empirical Evidence
B5	Companies have false expectations about what a hub can mean for them	Developing an e-hub is not an effortless or short process. E-hubs are not (yet) a standardised product, and entrepreneurs should understand this. Else, entrepreneurs will have false expectations.	20 quotes, a.o.: "Participating in the hub is not a simple offer to a company. The hub entails an integrated energy supply with different conditions and goals than a typical energy contract. It must be clear what companies can expect from this and how it will look in the near future." – P3 "People quickly make assumptions about what is possible from the DSO. They often start calculating themselves, forming expectations, and then become disappointed when these cannot be met. Provision of the right information before they start forming an e-hub is essential." – P2
B6	It is hard to find financing	Especially in the orientation phase, finding financers and investors can be a challenge.	10 quotes, a.o.: "Finding financing is hard, especially for the initial phase (covering the costs of a catalyst role). Participants also need to have just expectations on financing and investing e-hubs, as they are long-term projects and investments will pay of only after a long time. For this, it is important to have a strong core group for the initial financing." – P10 "Financing the hub is still a big question mark; who invests? Does everyone pay the same, or do some pay more than others?" – P21
B7	There is a lack of public knowledge about energy, net congestion and e-hubs.	Entrepreneurs are not aware of their problems, and e-hubs are not on the radar of entrepreneurs. Once entrepreneurs have identified their problems and possible solutions, their knowledge on how to implement these solutions is	20 quotes, a.o.: "More clear and simple general knowledge is needed, as well as better publicly available documentation of success stories and pilots." -P23 "People are unconsciously incompetent; they don't understand the problem and don't realize that they need to fix it together. People don't understand what their energy usage entails; they don't understand what's on the bill. Congestion issues are not on companies' radar; I sent out a survey to ask how severe the problem was and what people expect for the future. Neither small and medium-sized businesses nor large corporations have this on their radar." -P7

Table 7 (part 3/6): The barriers experienced by the early participant in the orientation phase of e-hub development

#	Barrier	Explanation	Empirical Evidence
B8	Companies do not trust the innovation of e-hubs	Companies do not trust the concept of e-hubs, as there is little proof and/or clear guidelines.	5 quotes, a.o.: "Among entrepreneurs, there isn't much confidence yet that it will work. Trust in each other and the concept is important, but how do you stimulate this?" -P14 "There is a lot of uncertainty and thus insecurity about the playing field for e-hubs; for example, now that Tennet suddenly withdraws" – P20
B9	Companies do not have existing relationships on the park	There is little (reason for) existing connection between different companies on a business park. This is more true on business park in bigger cities, in smaller and/or religious towns entrepreneurs are more likely to be acquainted.	18 quotes, a.o.: "Getting acquainted and building relationships takes a very long time - how can you organize a business park? Most business parks in the Netherlands are not yet organized. This leads to the most problems; who takes the first step in organisation? Who takes the first step in financing and investment?" – P6 "Personal relationships are essential to build trust and get entrepreneurs aboard. However, this is also the hardest part." -P20
B10	There is a lack of communication between companies on park X	Businesses within industrial parks do not communicate effectively or frequently with each other.	16 quotes, a.o.: "Companies do not understand what is happening in the development of their hub and don't understand what they should contribute. This causes disunity between the entrepreneurs. When they don't communicate, nobody knows what to expect or what the different interests and offers are, making them more hesitant to participate." – P7 "Clear communication between the entrepreneurs is essential. Some e-hubs want to include all businesses on the business park, however this causes a lot of blur in the communication between them. There is also not a clear shared language, some entrepreneurs know nothing about energy while some do." – P11 "It is important to have everyone together at the same time, preferably physically. This shouldn't be a large amount of entrepreneurs, preferably one spokesperson per company and not too many at the same time." – P6
B11	There is a lack of communication between e-hubs	There is little communication and knowledge-sharing between different e-hubs. This prevents experiences and lessons learned from being transferred to other starting e-hubs that could benefit from them.	3 quotes, a.o.: "New initiatives keep starting from scratch. There is little communication between different initiatives, while they could learn a lot from each other." – P15 "There should be more continuity across different initiatives, they should be connected to each other." – P8

Table 7 (part 4/6): The barriers experienced by the early participant in the orientation phase of e-hub development

#	Barrier	Explanation	Empirical Evidence
B12	There are limited examples from successful hubs	Due to the little examples of successful e-hubs that are replicable (not experiencing examples in law and regulation and support), there is little knowledge on experiences and lessons learned.	13 quotes, a.o.: "The current toolkits are based on only one or two examples. This is no longer entirely relevant, as newer hubs are structured very differently from these old examples." – P10 "There is a lot of talk about e-hubs, but actually, there's still nothing concrete. There are only a few examples, who benefited from a lot of exceptions which makes them different from currently developing e-hubs. As a result, there is little accepted data, and there is little shared perspective. People cling to their own perspective of the problem of grid congestion, not considering collaboration." – P17
B13	Companies do not trust each other	Reliable energy is a crucial source for companies, making them hesitant to trust (collaborating with) other companies on this vital topic.	4 quotes, a.o.: "Energy security is such a big topic, entrepreneurs do not trust each other enough to take risks in such a big topic." – P10 "Trust in each other is essential, also to divide costs, efforts and interests. Transparency is very important to build trust." – P5
B14	Companies do not trust changing policies	Companies are hesitant to start an e-hub now, because they think policies and law and regulation will change in the near future. They don't know if these changes are beneficial or harmful.	5 quotes, a.o.: "Now you see Tennet pulling out, we do not know what will happen next month. We need certainty in policy, law and regulation." – P22 "Entrepreneurs don't want to take risks when they have no certainty on policies and contracts with the DSO. If the unclarity continues like this, I think there will be very few hubs." – P14
B15	Companies are primarily self-focused	Companies main attention and priorities are directed towards their own interests, goals and problems rather than those of others.	8 quotes, o.a.: "Managers/executives of companies do not focus on the collective. Each manager wants their own company to thrive to the maximum. Within the company, there is no one responsible for exploring collaborations. This is changing now that grid congestion is affecting business continuity. Now, executives are open to other ideas, but still want to focus on their own company." – P10 "Entrepreneurs never had to focus on their community, so they are not used to this. Especially in bigger cities and bigger companies, they do not take anyone into account except themselves." – P7

Table 7 (part 5/6): The barriers experienced by the early participant in the orientation phase of e-hub development

#	Barrier	Explanation	Empirical Evidence
B16	There is a lack of communication between supporting roles	Due to limited communication between roles surrounding the participant of e-hubs, duplicated efforts, delays in decision-making and overall inefficiencies in achieving common goals are	6 quotes, a.o.: "Different roles within the formation of the hub do not speak each other's language, preventing meaningful conversation and leading to differences in expectations regarding the process and the hub. Politicians want understandable language and flexibility. Technicians want grounded and detailed language and clear step-by-step plans." – P7 "Different parties are reinventing the wheel time and time again; there is little communication between them regarding initiatives aimed at facilitating the emergence of e-hubs." – P16
B17	It is hard to know who company X can collaborate with	Companies who would possibly be interested in starting an e-hub struggle to find like-minded peers to join forces in forming one.	4 quotes, a.o.: "I do not know who to collaborate with. I do not know who has the same problems and is open to looking for solutions together." – P27 "Entrepreneurs do not know who are on the same grid, and do not know how an e-hub works technically so who they can start approaching" – P1

Table 7 (part 6/6): The barriers experienced by the early participant in the orientation phase of e-hub development

#	Barrier	Explanation	Empirical Evidence
B18.1	Companies have different interests: There is a difference between renters and owners of facilities	When forming coalitions and exploring opportunities for collaborations, a barrier exists caused by different interests of different companies. These different interest cause inertia in group formation and e-hub establishment. Different examples are divided over B18.1 to B18.8.	12 quotes, a.o.: "Once you have everyone at the same table, and that is already hard, then the negitiations start and you see that everyone has his own agenda, their own future plans, different needs, etc." - P12 "It makes a large difference what the differences are between the companies, for example a small family company versus an international, or the owner of the buildnig versus the renter." - P9 "Some entrepreneurs are already friends and on the same page, and then other can feel left out" - P15
B18.2	Companies have different interests: There is a difference between the needed capacity per company		
B18.3	Companies have different interests: There is a difference in flexibility of the companies		
B18.4	Companies have different interests: There is a difference in future plans of the companies		
B18.5	Companies have different interests: There is a difference between the amount of time the companies expects to be settled on the park		
B18.6	Companies have different interests: There is a difference in the attitude of different companies		
B18.7	Companies have different interests: There is a difference in the motivation of different companies		
B18.8	Companies have different interests: There is a difference between the strength of personal relationships between companies on park X		

UNDERSTANDING **CAUSAL RELATIONAHIPS** AND **ROOTEDNESS** OF THE DRIVERS AND BARRIERS

In order to stimulate the key role and thereby stimulate the development of e-hubs, drivers should be stimulated and barriers should be mitigated. However, the key role experiences a lot of drivers and barriers, making it complex to understand where to intervene. In order to map this complexity, a Causal Loop Diagram (CLD) is combined with the Iceberg Model (IM) (please see Chapter 1 > Research Approach) in order to discover causal relationships between and rootedness of these drivers and barriers. This allows to identify leverage points within the system, where a small problem solving force has cascading effects on the system behaviour.

EXPLORING CAUSAL RELATIONSHIPS AND ROOTEDNESS: THE **DESIRED FUTURE**

First, the desired future is sketched (figure 52). In this future, there are no barriers witholding the key actor in the organisational dimension of the orientation phase of e-hub development. The drivers lead to two effects; e-ub formation, and the growth of these e-hubs.

Two reinforcing loops can be identified in this desried future. The formation of a group, the foundation of the e-hub, results into more knowledge on lessons learned in e-hubs (D4), which results into more awareness and companies realising that other companies have the same problems (D8) as well as the realisation that it is possible to collaborate to overcome these problems (D9). This results into reinforcing loop R1, which causes the societal adoptation of e-hubs to grow, and more e-hubs to develop on different business parks.

The second reinforcing loop in the desired future (R2) results from the ambassador-effect, a term often mentioned in the conducted interviews and attended events where data on drivers and barriers was collected. The ambassador-effect (D3) involves the first front-runner group of companies having formed a small e-hub, showcasing the possibilities and advantages, after which other companies want to join the e-hub as well. This results into a growing e-hub on a business park.

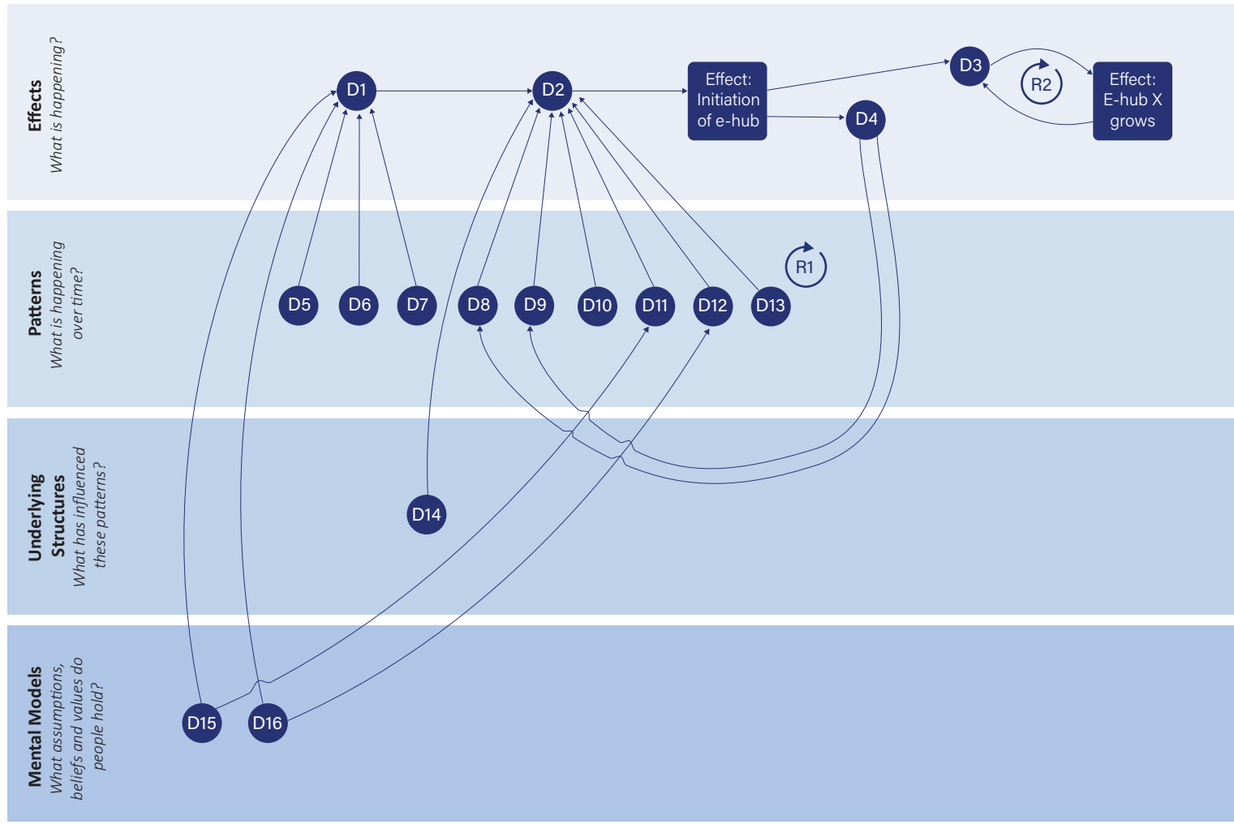
DEFINING CAUSAL RELATIONSHIPS AND ROOTEDNESS: THE **SYSTEM DYNAMICS OF DRIVERS AND BARRIERS**

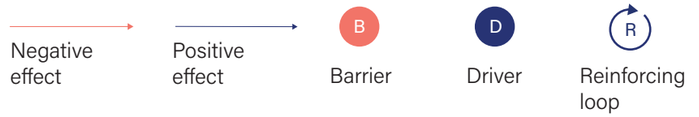
The desired future illustrated in figure 52 has not yet been achieved, as the key actor also faces barriers in the development of e-hubs. These are added to the system in figure 53 on the next pages.

Important to remember in reading the CLD in figure 53, is that a negative effect (red arrow) on a barrier (red circle) leading to a double negative, meaning that the barrier is decreased, causing a positive outcome on the system behaviour and e-hub development. For more information on how to read the CLD, please refer to Chapter 1 > Theoretical background on methodologies and Chapter 1 > Research Methods.

The same reinforcing loops can be identified as in the desired future, R1 and R2. Initially, R2 operated as a positively reinforcing loop, fostering a vicious cycle in the societal adoption and growth of e-hubs on the larger scale. However, due to the encountered barriers, it transformed into a negative reinforcing loop, effectively hindering the societal adoption of e-hubs.

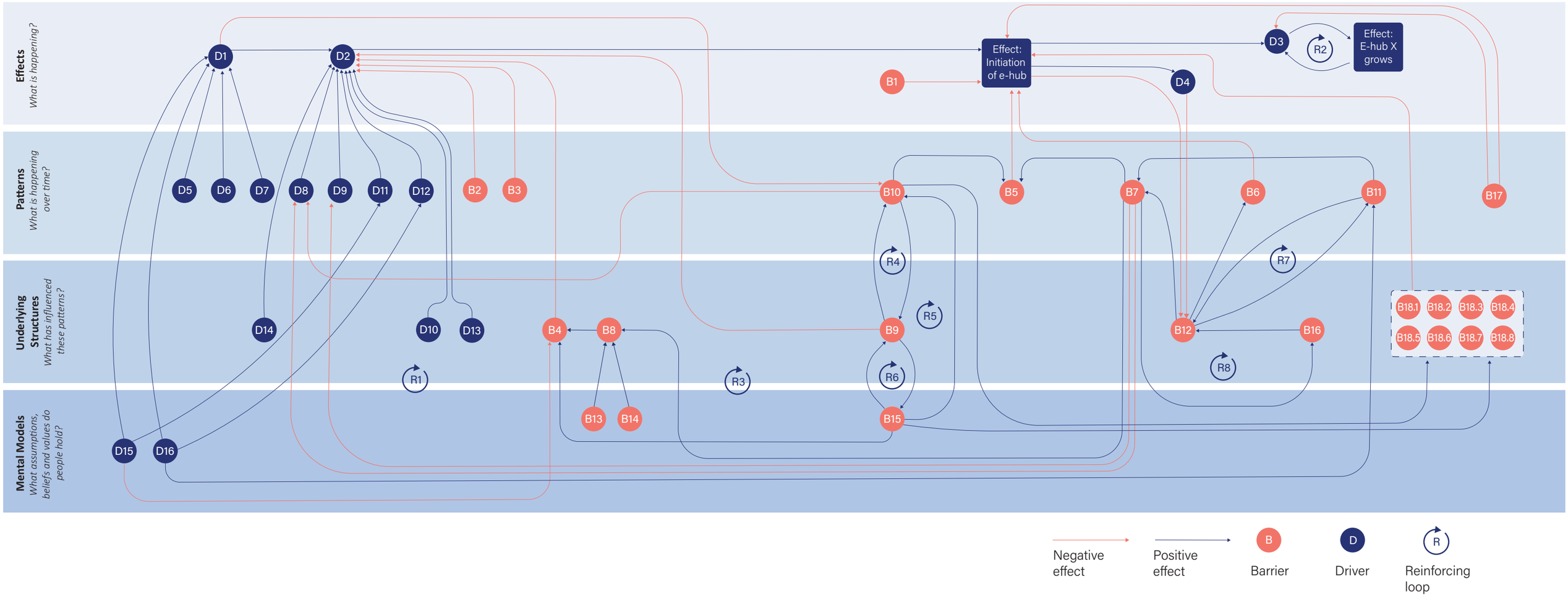
Highlights on further reinforcing loops in figure 53 are explained as leverage points over the next sections.





#	Driver
D1	Grid congestion – not having another option
D2	Having a small group of enthusiastic companies that are willing to put time and effort into the hub
D3	Ambassador-effect: first movers pull more companies into the hub
D4	Having knowledge on lessons learned in other e-hubs
D5	Existing companies want to expand
D6	New companies want to settle
D7	Companies want to become more sustainable and therefore want to electrify
D8	The realisation there is a shared problem; other companies have the same problem
D9	Realising it is possible to work together to overcome problems
D10	Motivations of company X: Finding new technology / new things interesting / sexy
D11	Motivations of company X: Save on costs by sharing assets and saving on grid fees
D12	Motivations of company X: Group independency
D13	Motivations of company X: Wanting to be future-proof
D14	A change in attitudes is happening; people are more open to new technologies and solutions
D15	Companies want to earn money
D16	Companies always want to have energy, energy is the basis of business operations

Figure 52: Combined CLD/IM Analysis of the desired future (Author's image)



#	Driver
D1	Grid congestion – not having another option
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D14	A change in attitudes is happening; people are more open to new technologies and solutions
D15	Companies want to earn money
D16	Companies always want to have energy, energy is the basis of business operations

#	Barrier
B1	The lack of capacity in supporting roles
B2	Companies hold a grudge to DSOs and think someone else has to fix their problems
B3	Companies do not want to or cannot invest time and effort into the hub next to their core business
B4	Companies do not want to take risks
B5	Companies have false expectations about what a hub can mean for them
B6	It is hard to find financing
B7	There is a lack of public knowledge about energy, net congestion and e-hubs.
B8	Companies do not trust the innovation of e-hubs
B9	Companies do not have existing relationships on the park
B10	There is a lack of communication between companies on park X
B11	There is a lack of communication between e-hubs
B12	There are limited examples from successful hubs
B13	Companies do not trust each other
B14	Companies do not trust changing policies
B15	Companies are primarily self-focused
B16	There is a lack of communication between supporting roles
B17	It is hard to know who company X can collaborate with
B18	Different companies have different interests (for more information, please refer to table 7)

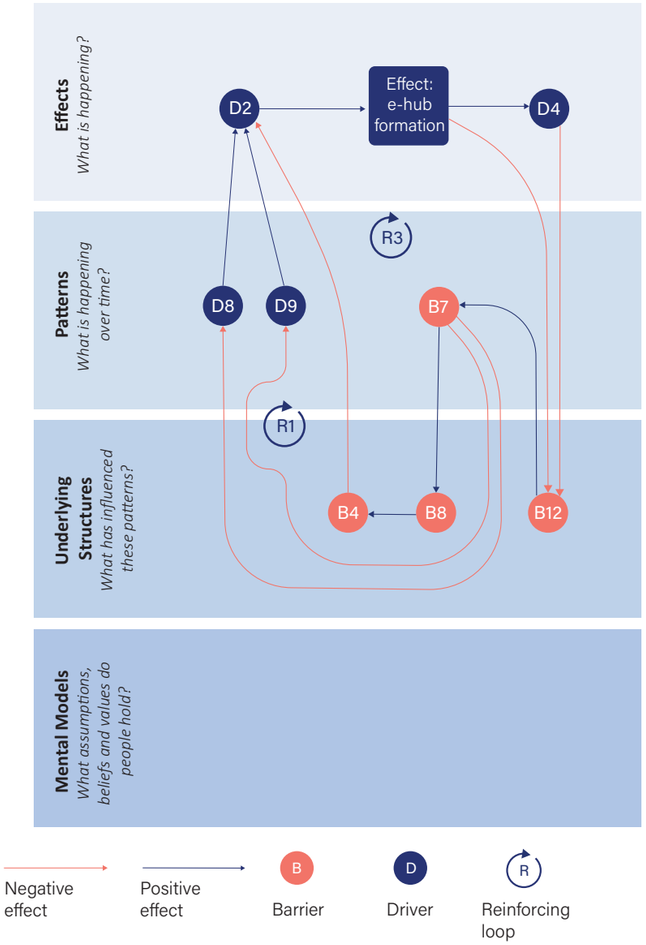
Figure 53: Combined CLD/IM Analysis of the drivers and barriers experienced by the key role (Author's image)

LEVERAGE POINT 1: A LACK OF EXAMPLES

A reinforcing loop can be found in the next highlight of the system, shown in figure 54. The lack of examples of existing e-hubs (B12) causes a lack of publick knowledge about energy, grid congestion and e-hubs (B7), causing companies not to trust e-hubs (B8), causing companies not wanting to take risks (B4), decreasing the small group of enthusiastic companies that are willing to put time and effort into the development of the e-hub (D2), causing less e-hub formation (effect), decreasing the knowledge on lessons learned in other e-hubs (D4) and increasing the lack of examples that can be found by other companies, leading to R3.

The lack of public knowledge (B7) also decreases the realisation that there is a shared problem by companies experiencing grid congestion or other drivers to participate in an e-hub (D8), and decreases the realisation that it is possible to collaborate in order to overcome these problems (D9), leading to reinforcing loop R1).

This is a large leverage point within the system. However, this leverage point is hard to overcome. More e-hub pilots could be conducted, and/or lessons learned from these pilots could be communicated more clearly and more effectively, however this requires large problem solving efforts. This will be discussed further in Chapter 4: Discovering the Opportunity.



#	Driver
D2	Having a small group of enthusiastic companies that are willing to put time and effort into the hub
D4	Having knowledge on lessons learned in other e-hubs
D8	The realisation there is a shared problem; other companies have the same problem
D9	Realising it is possible to work together to overcome problems

#	Barrier
B4	Companies do not want to take risks
B7	There is a lack of public knowledge about energy, net congestion and e-hubs.
B8	Companies do not trust the innovation of e-hubs
B12	There are limited examples from successful hubs

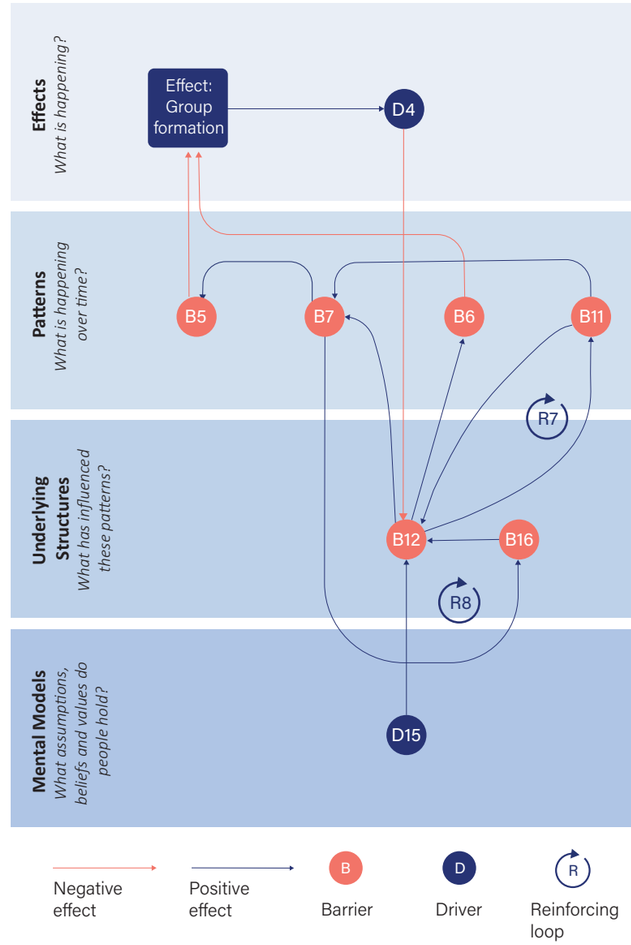
Figure 54: Leverage point 1: A lack of examples (Author's image)

LEVERAGE POINT 2: A LACK IN COMMUNICATION BETWEEN SUPPORTING ROLES

Another leverage point can be found in the lack of communication between hubs and supporting roles (figure 55).

Firstly, there is a reinforcing loop causing little communication between hubs (R7). The limited amount of examples (B12) is also caused by the small amount of public data and knowledge produced by the existing examples (e-hub pilots) and thereby causing a lack of communication between different e-hubs (B11). This lack of communication consequently causes a limited amount examples from these pilots that is accessible by other e-hubs (B12). This reinforcing loop is supported by companies that want to earn money (D15), as companies (within e-hubs, but mostly supporting companies such as consultants and process managers) profit from their knowledge on e-hub successes by selling and applying it to business parks that want to start an e-hub.

Second, there is a reinforcing loop caused by a lack of communication between supporting parties (R8). Participants of e-hubs as well as process managers interviewed indicate it is hard to gather all roles around the table, mostly referring to the DSO, the municipality and the province, leading to B16. Because these supporting roles have the power to collect and share knowledge over different business parks, a limited amount of communication between them causes a limited amount of examples from successful e-hubs (B12). This causes a lack of public knowledge about energy, grid congestion and e-hubs (B7), causing a decreased urgency for communicating and collaborating between supporting roles (B16).



#	Driver
D4	Having knowledge on lessons learned in other e-hubs
D15	Companies want to earn money

#	Barrier
B5	Companies have false expectations about what a hub can mean for them
B6	It is hard to find financing
B7	There is a lack of public knowledge about energy, net congestion and e-hubs.
B11	There is a lack of communication between e-hubs
B12	There are limited examples from successful hubs
B16	There is a lack of communication between supporting roles

Figure 55: Leverage point 2: A lack in communication around the e-hub (Author's image)

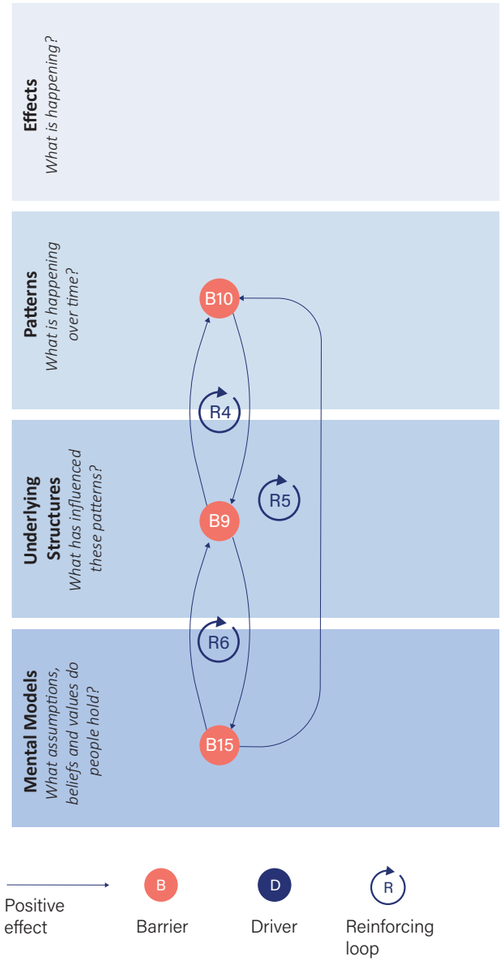
LEVERAGE POINT 3: A LACK IN COMMUNICATION WITHIN BUSINESS PARKS

A leverage point consisting of three reinforcing loops that keep reinforcing each other can be identified in the communication within the e-hub (figure 56).

Because companies are primarily self-focused (B15), focusing on their own strategy and successes and never had a reason to collaborate with their neighbours, there are no existing relationships between companies on business parks in which they collaborate (B9). Because of this, there is a lack in communication between the companies on the park (B10), and all vice versa, causing R4, R5 and R6.

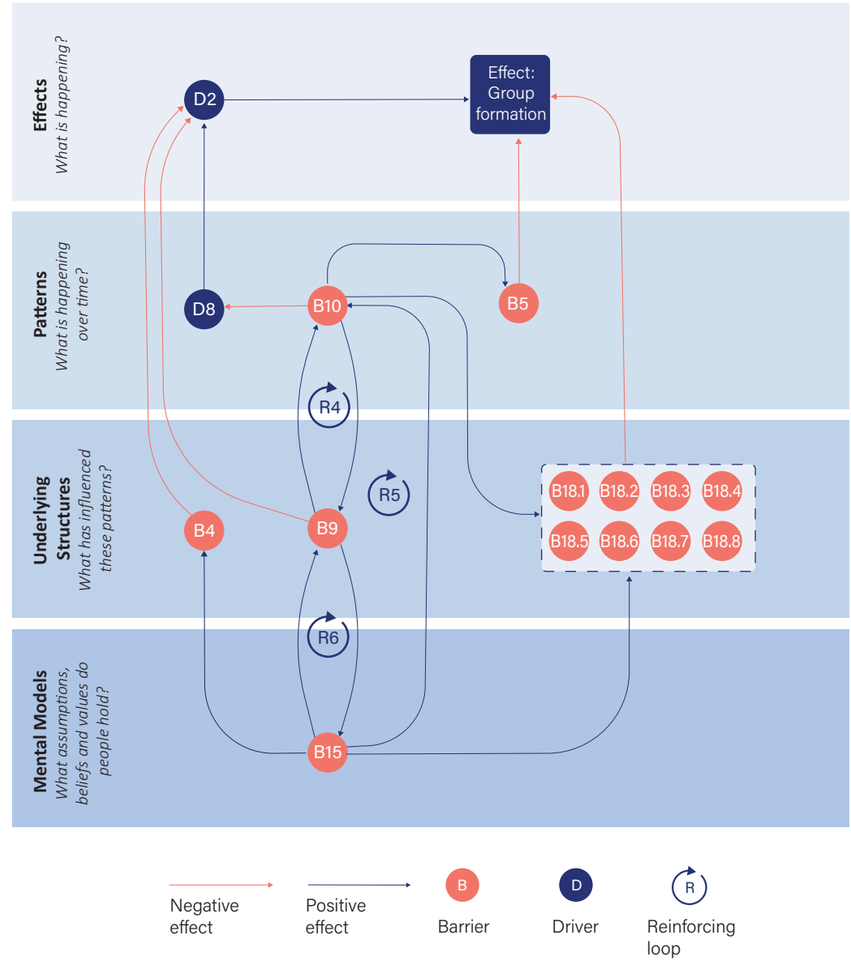
This leverage point limits the e-hub formation in three ways as shown in figure 57:

1. Firstly it limits e-hub formation by limiting the realisation there is a shared problem (D8) and it increases the amount of companies that do not want to take risks as they are not used to collaborate (B4), and thereby it decreases the small group of enthusiastic companies that are willing to put time and effort into the hub (D2).
2. It also increases the false expectations that companies have about what an e-hub can mean for them (D5), asas they lack awareness of the plans and expectations of other companies. Since an e-hub is shaped by the collective expectations and plans of all involved companies, it's essential for each company to be informed about the intentions and expectations of others to understand what they can anticipate themselves.
3. Thirdly, it increases the difference in interests of different companies (D18), instead of companies seeking for compromises together.



#	Barrier
B9	Companies do not have existing relationships on the park
B10	There is a lack of communication between companies on park X
B15	Companies are primarily self-focused

Figure 56: Leverage point 3: A lack in communication within business parks (Author's image)



#	Driver
D2	Having a small group of enthusiastic companies that are willing to put time and effort into the hub
D8	The realisation there is a shared problem; other companies have the same problem

#	Barrier
B4	Companies do not want to take risks
B5	Companies have false expectations about what a hub can mean for them
B9	Companies do not have existing relationships on the park
B10	There is a lack of communication between companies on park X
B15	Companies are primarily self-focused

Figure 57: The effects of leverage point 3 (Author's image)

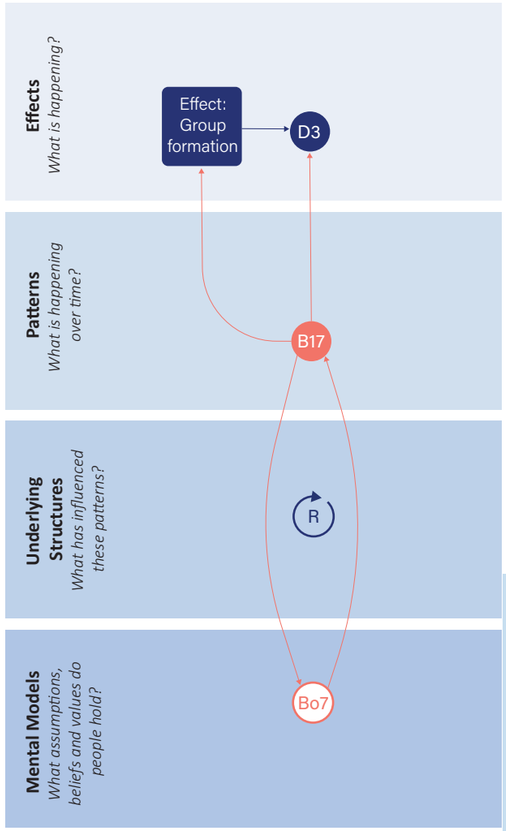
LEVERAGE POINT 4: A CHICKEN-AND-EGG SITUATION IN GROUP FORMATION AND DATA COLLECTION.

The fourth leverage point (figure 58) consists a barrier that falls outside of the system boundaries of this master thesis. However, as this barriers was mentioned in almost all conducted interviews and often heared during events attended, this leverage point is still discussed in this master thesis.

The barrier out of scope (Bo7) is caused by legal constraints that make it challenging to access and understand information about the grid structure and data on supply and demand of energy, which are essential for planning and implementing e-hubs. More information about this barrier can be found in appendix F.

A reinforcing loop emerges between Bo7 and B17. Currently, it is not possible for companies to request data before they have formed a group and all sign their approval for the sharing of this data amongst the group. However, only then it becomes clear what companies are on the same cable, and can therefore technically collaborate with each other. Companies instead want to first know with whom they can collaborate, ensuring that the process, efforts and investments of group formation are not for nothing.

This creates a chicken-and-egg situation in group formation and data collection, decreasing e-hub formation and the ambassador effect (D3).



#	Driver
D3	Ambassador-effect: first movers pull more companies into the hub

#	Barrier
B17	It is hard to know who company X can collaborate with

#	Barrier Out of Scope
BO7	It is hard to gain insight into net topology and data from DSOs due to law and regulation

Figure 58: Leverage point 3: A lack in communication within business parks (Author's image)

CHAPTER 3 - UNDERSTANDING THE SYSTEM: CONCLUSIONS

In this chapter, the third sub-research question is answered:

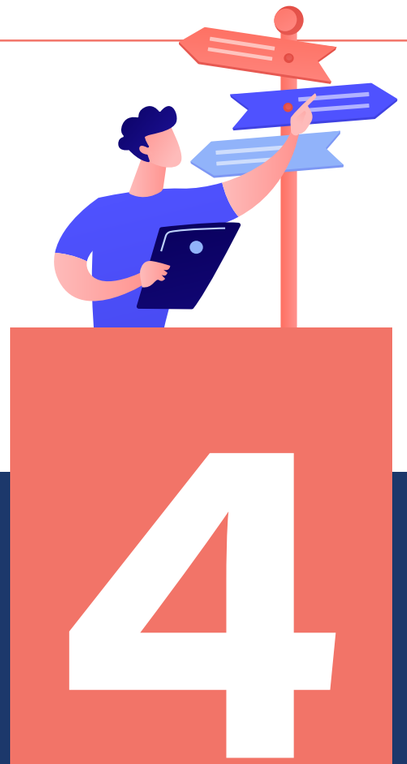
What are drivers and barriers experienced by the key role in the orientation phase of e-hub development, and what drivers and barriers serve as strategic points for intervention (leverage points) to stimulate this phase?

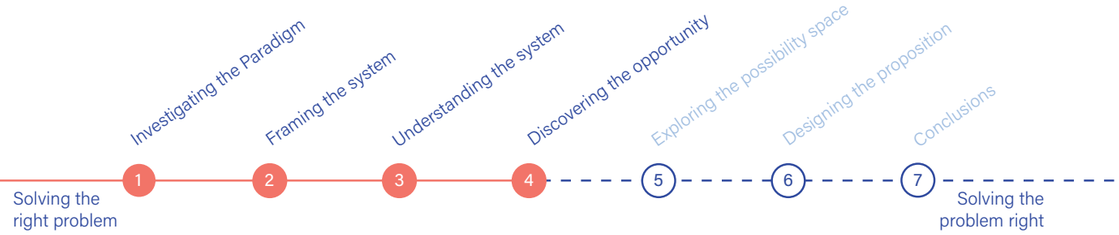
First, the orientation phase of e-hub development was regarded from the perspective of the key role identified in Chapter 2: Framing the System. The thoughts and experiences of this key role are caused by drivers and barriers it experiences. Consequently, these drivers and barriers were researched and defined. This led to the formulation of 16 drivers and 18 barriers within the system boundaries as defined at the end of Chapter 2. Next to this, 7 barriers were identified that fell outside of these system boundaries. As these could serve a basis for further research after this master thesis, these are mentioned in Appendix F.

In order to find places to intervene within the complex system of drivers and barriers, four leverage points were identified by means of a combined CLD/IM analysis. These leverage points emerge from multiple reinforcing loops within the system. The four leverage points include:

1. A lack of examples
2. A lack in communication around the e-hub
3. A lack in communication within business parks
4. A chichen-and-egg dilemma in group formation and data collection

In the next chapter (Chapter 4; Discovering the Opportunity), these four leverage points will be weighed based on multiple criteria in order to discover the opportunity for the design of a new proposition in order to change the behaviour of the system.





DISCOVERING THE OPPORTUNITY

INTRODUCTION

This chapter focuses on answering the fourth sub-research question:

What key leverage point represents the most relevant and effective opportunity for intervention to stimulate the orientation phase of e-hub development?

As outlined in the research direction and thesis goal, a new proposition is needed to stimulate the orientation phase of e-hub development in Dutch business parks by 2024. To design this proposition, a key leverage point within the socio-technical, multi-actor system of e-hub development must be identified. This leverage point is the Opportunity for intervention within the system, causing cascading effects (figure 59). This opportunity will serve as the foundation for the design phase.

The Opportunity is identified by weighing the four leverage point discovered in Chapter 3: Understanding the System using a Multi-Criteria Decision Analysis, including a Best-Worst Case Analysis. This results into the selection of one key leverage point that will serve as the Opportunity and therefore the foundation of the design of the new proposition. This Opportunity is translated into a Design Statement.

THE PROPOSITION

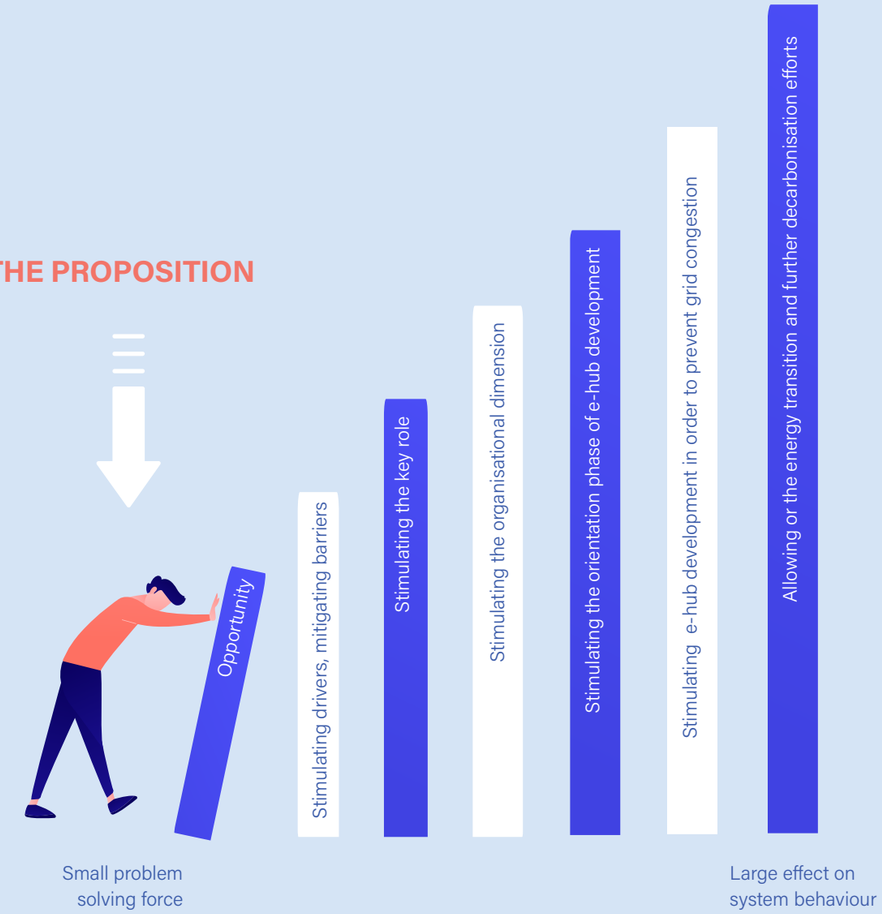


Figure 59: Pushing leverage points causes cascading effects (Author's image)

WHAT IS STILL MISSING IN CURRENT DEVELOPMENTS, METHODS AND TOOLS

For a thorough analysis on currently evolving methods, tools and developments please refer to appendix E and Chapter 1 > Gap in Current Practices (page 28). The conclusions of this analysis include that a gap in current practices is identified in focussing on the organisational dimension of the orientation phase of e-hub development, on business parks that are not yet organised (which are 80 to 90% of all business parks in the Netherlands in 2024 (CEDelft, 2023; RLI, 2024).

DISCOVERING THE OPPORTUNITY

The Opportunity will be discovered by conducting a Best-Worst Case analysis (BWC) in Multi-Criteria Decision Analysis (MCDA) (for more information, please see Chapter 1 > Research Methods). This includes weighing the four leverage points identified in Chapter 3: Understanding the System based on three criteria. These three criteria include:

1. To what extent the leverage point **is not yet touched** by currently evolving methods, tools and developments.

2. The **feasibility** to design interventions within the timeframe of this master thesis. The feasibility of designing interventions within the timeframe of this master thesis is assessed by considering the depth at which the leverage point lies within the iceberg model. If the leverage point is situated at the surface level, a designed intervention will primarily address the symptoms of the system. On the other hand, if the leverage point is deeply embedded into the lowest level, it becomes very challenging to make significant changes because the leverage point is deeply entrenched within the system. Preferably, the leverage point is situated in the middle two levels of the iceberg model. For more information about the iceberg model, please refer to the methods section.

3. Its **impact** on the outcomes of the system: how well it will stimulate the orientation phase of e-hub development on Dutch business parks in 2024, encouraging self-organisation of its participants. This is assessed by considering what effects pushing the leverage point will have on the system. By looking at how many drivers will be stimulated and barriers will be overcome as a causal effect of pushing the leverage point, it can be considered how cascading the effect of pushing the leverage point will be and therefore what impact it will make on the outcome of the system. For more information about causal effects, please refer to the methods section.

The four leverage points resulting from Chapter 3 are assessed by these three criteria in table 8.

The worst case scenario of the MCDA, and therefore the leverage point that is most inefficient to push in this master thesis, is leverage point 1: a lack of examples. While the impact on the system by pushing this leverage point is quite high (criterium 3), it is very complex to push this leverage point within the timeframe of this master thesis (criterium 2). Developing new pilots is not feasible within the timeframe of this master thesis, and clearly communicating the outcomes and lessons learned of current pilots is already touched by the currently developing MOOI EIGEN blueprint (MOOI EIGEN, 2023) (criterium 1).

The best case scenario of the MCDA, and therefore the leverage point that is most efficient to push in this master thesis, is leverage point 3: a lack of communication within business parks. This leverage point is not yet covered by other developments (criterium 1), will have significant cascading effects on the system behaviour (criterium 3), and can be challenging but feasible to push within the timeframe of this master thesis (criterium 2)

The remaining two leverage points, 2 and 4, will not be the central focus of the remainder of this master thesis. However, they will be set aside temporarily, with the possibility of revisiting them in Chapter 7 to explore if solutions designed for leverage point 3 can also address parts of leverage points 2 and 4.

Table 8: Multi-Criteria Decision Analysis (MCDA) to discover the Opportunity

Leverage point	Criterium 1: To what extent it has not yet been touched by other tools, methods and developments	Criterium 2: The feasibility to design interventions within the timeframe of this master thesis	Criterium 3: Its impact on the outcomes of the system
Leverage point 1: a lack of examples	While most methods, tools and developments focus on the technical aspects of e-hubs, the MOOI EIGEN blueprint provides a very clear example of what an e-hub and its development process entails.	While this leverage point is within the feasible layers of the iceberg model, it is very complex to push this leverage point as it is not feasible to develop new examples of e-hubs within the timeframe of this master thesis.	The impact on the system by pushing this leverage point is quite high, as it will cause more awareness of the possibility, advantages and examples of the development process of e-hubs. However, it will not directly lead to more stimulation of self-organisation in the orientation phase.
Leverage point 2: A lack in communication around the e-hub	This leverage point is not yet covered by other tools, methods and developments analysed in chapter 3.2.	Pushing this leverage point is feasible within the timeframe of this master thesis, as it mostly is situated within the middle layers of the iceberg model.	The impact on the system by pushing this leverage point is quite high, as an increasing amount of communication of facilitators of the e-hub will eventually support participants to organise themselves into e-hubs. However, as discussed before there is a limited amount of human resources available, so increasing the communication between supporting roles will not directly lead to availability in support for all e-hubs.
Leverage point 3: A lack in communication within business parks	This leverage point is not yet covered by other tools, methods and developments analysed in chapter 3.2.	While this leverage point is partly situated in the deepest level of the iceberg model, most of the barriers it consists of are situated in the middle levels of the iceberg model. This indicates that pushing this leverage point can be challenging but feasible within the timeframe of this master thesis.	Pushing this leverage point will have significant impact on the outcome of the system, both on stimulating more participants to start an e-hub as well as on creating new collaborations and a shared vision.
Leverage point 4: A chichen-and-egg situation in group formation and data collection	This leverage point is partly covered by changing law and regulation. However, it is unclear yet what possibilities in obtaining privacy-sensitive data will emerge from changes in law and regulation.	As changes in law and regulation are in the deepest level of the iceberg model, it is not very feasible to push this leverage point within the timeframe of this master thesis.	While this leverage point forms a significant bottleneck in the development of e-hubs, is often mentioned during interviews and events attended and is an important first step in the development of e-hubs, pushing this leverage point will not solely stimulate participants to start self-organisation in e-hubs.

DEFINING THE OPPORTUNITY

As stated in the previous section, leverage point 3, which addresses the lack of communication within business parks, appears to be the key leverage point to focus on in this master thesis. From this point forward, this key leverage point will be referred to as 'the Opportunity.' The opportunity is repeated in figure 60.

#	Driver
D2	Having a small group of enthusiastic companies that are willing to put time and effort into the hub
D8	The realisation there is a shared problem; other companies have the same problem

#	Barrier
B4	Companies do not want to take risks
B5	Companies have false expectations about what a hub can mean for them
B9	Companies do not have existing relationships on the park
B10	There is a lack of communication between companies on park X
B15	Companies are primarily self-focused
B18	Different companies have different interests (for more information, please refer to table 7)

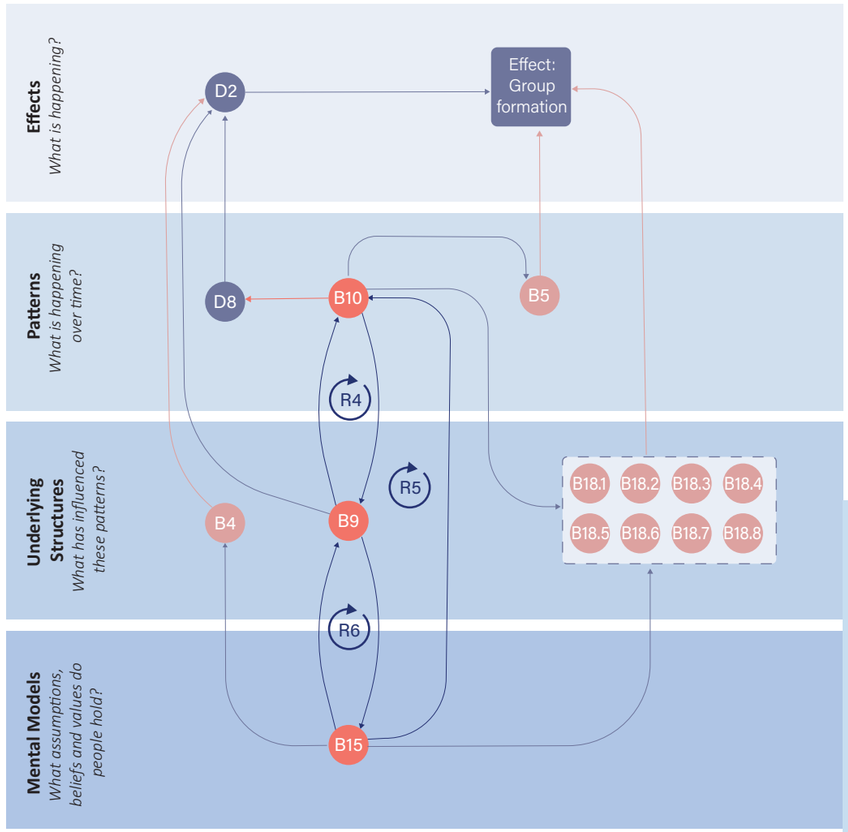


Figure 60: The opportunity and its cascading effects on the system behaviour (Author's image)

THE **DESIGN STATEMENT**

Following the Opportunity, the design statement that will be used as a take-away for the design of the new proposition is stated as follows:

"Design a new proposition to stimulate the organisational dimension during the orientation phase of e-hub development on Dutch business parks in 2024 by encouraging early participants to consider their surrounding community in their decisions and solutions, fostering communication and relationships among businesses."

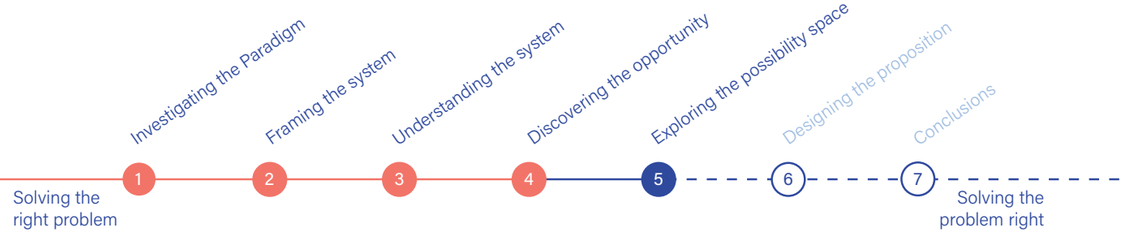
CHAPTER 4 - DISCOVERING THE OPPORTUNITY: **CONCLUSIONS**

Aiming to selecting one key leverage point that serves as the Opportunity for design, this chapter focuses on answering the fourth sub-research question:

What key leverage point represents the most relevant and effective opportunity for intervention to stimulate the orientation phase of e-hub development?

The Opportunity is discovered by comparing the four leverage points resulting from Chapter 3 based on three criteria; to what extent the leverage point is not yet touched by other currently evolving tools, frameworks and developments, the feasibility to design interventions to push the leverage point within the timeframe of the thesis project (based on the rootedness of the leverage point, the impact of pushing the leverage point on the system behaviour, and therefore the effectiveness of the to-be-designed interventions on stimulating e-hub development. The Opportunity is defined as the third leverage point: A lack of communication within business parks.

This Opportunity is concluded in a Design Statement, marking the end of the first phase of this master thesis; 'Solving The Right Problem.' The following chapters will focus on developing a new proposition based on this design statement, introducing the second phase; 'Solving The Problem Right.'



5

EXPLORING THE POSSIBILITY SPACE

INTRODUCTION

In this chapter, the fifth sub-research question will be answered:

What success factors and lessons learned in similar socio-technical, multi-agent complex systems development can inform the design of a new proposition that stimulates the orientation phase of e-hub development?

This chapter marks the beginning of the second part of this master thesis, 'Solving the problem right.' **Open innovation will be used to explore potential solutions for the Opportunity** as defined in Chapter 4, by looking at lessons learned in similar socio-technical multi-actor complex systems (figure 61). For more information on the research methods used, please refer to Chapter 1 > Research Approach.

The first similar system researched includes **succesful e-hub pilots** in Dutch business parks in 2024. These pilots were developed under different circumstances than the large-scale development of e-hubs, such as exceptions in law, regulations and available support, however they bear significant similarities to the system of focus in this thesis research. **Success factors** of these pilots, related to the Design Statement, are researched and translated into actionable takeaways for designing a new proposition in this master thesis.

The second similar system researched involves **Industrial Symbiosis (IS)**, as further explained in Chapter 1 > Industrial Symbiosis on page 60. By presenting the Opportunity to experts on IS, valuable lessons were learned about how the Opportunity was managed within this comparable system. These **lessons learned** are translated into actionable takeaways for designing a new proposition in this master thesis.

The design takeaways based on both the success factors in e-hub pilots and lessons learned in IS are translated into design cues, which form the basis for the design of the new proposition in Chapter 6.

In other words, this chapter focuses on **what** should be included in the new proposition based on the opportunity, resulting in design cues. Chapter 6 focusess on **how** these design cues should be included in the new proposition

Figure 61: Open innovation building on the Design Statement (Author's image)

SUCCESS FACTORS OF E-HUB PILOTS

There are some e-hubs on Dutch business parks that already passed the orientation phase of their development as of 2024. These e-hubs started years ago in their planning and development, and were often conducted as a pilot. This means that often exceptions were made in their context, for example in the law- and regulation and in the contractual agreements with the DSO. These pilots often had a lot of guidance from supporting roles, and did not start as bottom-up initiatives including a lot of self-organisation. However, by looking at their experiences in their orientation phase, examples can be used as lessons for e-hubs on the larger scale. Lessons learned regarded the following eight e-hubs that passed the orientation phase (energyscale-up, 2024):

- Tholen (Stedin, 2023)
- Schiphol Trade Park (SADC) (SADC, n.d.)
- Hessenpoort (OostNL n.d)
- Ecofactorij (Ecofactorij, n.d)
- Harderwijk (Transitiemakers, 2023)
- Veenendaal (Energietransitie Provincie Utrecht, 2024)
- Port of Amsterdam (Port of Amsterdam, n.d.)
- Lage Weide Utrecht (Lage Weide, n.d.)

During events attended and interviews held in this thesis research, information was gathered about what stakeholders learned from their orientation phase, and how they would advise other e-hubs to tackle this phase. Four main success factors were identified for the orientation phase by e-hub pilots, discussed in table 9.

Table 9 (part 1/2): Success factors based on lessons learned in e-hub pilots

#	Success factor	Explanation	Takeaway for design	Empirical evidence
1	The orientation phase is managed from top-down	For most e-hub pilots, the initiative started from top-down, for example by developers of the business park or local governments. For some e-hubs, it was even a prerequisite to join the e-hub if a company wanted to settle on the park. This facilitates the orchestration of the orientation phase.	As discussed before, a top-down approach is not always possible or desirable for an e-hub. However, a takeaway can be that at least some elements of the proposition should be top-down. By combining top-down and bottom-up initiatives in stimulating self-organisation, strategic direction is combined with empowering local communities, encouraging innovation and promoting decentralised solutions tailored to specific needs.	In all current e-hub pilots, the facilitator played a central and essential role - Researchers Observations. "Without him (the facilitator), we could never have done this. The facilitator is really essential." - P22 "I think there should be at least some element of neutral facilitation, without it the participants will have a hard time in making compromises and knowing what to do" - P19

Table 9 (part 2/2): Success factors based on lessons learned in e-hub pilots

	Success factor	Explanation	Takeaway for design	Empirical evidence
2	The potential e-hub is located in a small community	Small communities often have tighter-knit social networks and participants feel more solidarity to their neighbours, making it easier to engage residents in energy problems. The barriers of 'companies do not have existing relationships' and 'there is a lack of communication' are already overcome. Next to this, residents of smaller communities often take pride in their locality and are invested in the success of the e-hub as it reflects positively on their community.	The proposition should bring people together, get to know each other also on a personal level, and form a tight group. This way, they actively care for the success of the group and feel a sense of pride in the achievements of the e-hub, stimulating their commitment and investment into the e-hub.	"The e-hub in the village is different than the hub in Amsterdam. In the village, people know each other, and are proud of their community. This makes it very easy for them to collaborate, in opposite to Amsterdam where nobody knows each other or cares for each other." – P6 "Participants had a sense of pride, like 'we will show the world what we can do here', and they worked together really closely" – P9 During meetings, people ask how each other's families are doing, and are discussing the new deli in the village. This connects the participants – Researchers Observations
3	The potential e-hub is located in a religious community	This theme somewhat shows the same characteristics as the last theme (small community), however in the religious community there is a profound sense of care among participants. In accordance with the church's guidance to care for neighbours and future generations, individuals are motivated to engage in an e-hub and are more willing to make compromises in their own practices to support their neighbours. This fosters a smoother orientation phase in e-hub development.	In the proposition, a stimulant should be designed that fosters a feeling of caring, so that participants are more willing to make compromises in their own practices to support their neighbours instead of only pursuing their own agenda's and holding one's cards close to the chest.	"What made the difference is that the business owners belonged to a tight-knit, religious community. The faith really ensures that people care more for each other, as well as for future generations." – P11 "And of course, they see each other every Sunday at church, where they also shake hands." – P8
4	There is a strong 'connector' role present	The connector role facilitates communication, collaboration and coordination among the participants. It facilitates networking, knows the companies personally, knows who would be interested in joining the hub, who needs to be stimulated in what way, and the connector role fosters trust and engagement. This connector role is often the park manager, but in some cases also was an individual consultant who knew a lot of participants already.	In the proposition, there should be something that really connects the participants to one another. A context should be created where participants feel safe, can get to know each other, also personally, and foster open communication, collaboration and coordination.	"Our first step was to get invited to drink coffee with all business, together with the park manager. This was an essential role; he knew everyone on the park. If we wouldn't have had this support, it would have taken way longer to gain the trust and collaboration of all participants." – P9 "I know everyone personally. If participant X is not responding, then I know for example this is because a loved one just passed and I go by to send my condolences. This keeps everyone aboard and gives all participant a feeling of being heard." – P10

The four success factors discussed in table 9 are not applicable to all e-hubs on Dutch business parks on the larger scale, and are therefore translated into 'takeways for design', also in table 9. These takeaways for design can be used for the design of the new proposition and include:

1. **Blend top-down guidance with bottom-up self-organisation:** incorporate a balance of top-down guidance to steer strategic direction while preserving self-organisation principles of the bottom-up development of e-hubs. This approach facilitates innovation and encourages decentralized solutions tailored to specific needs, as indicated in Chapter 1.
2. **Encourage the formation of tight-knit social networks:** design elements that encourage participants to form a cohesive and closely connected group, leading to a tight-knit social network. This sense of community enhances collaboration and mutual support among participants.
3. **Promote empathy and care**: integrate elements that cultivate a sense of empathy and care among participants, emphasising the importance of considering and supporting one another's well-being and interests. This fosters a supportive and inclusive environment that stimulatse collaboration.
4. **Facilitate personal connections**: include features that facilitate personal connections among participants, beyond professional interactions. Building personal relationships strengthens bonds, enhances communication, and fosters trust, ultimately leading to more effective collaboration and problem-solving.

Before these lessons learned are translated into design cues, first lessons learned in Industrial Symbiosis will be researched in the next section.

LESSONS LEARNED IN **INDUSTRIAL SYMBIOSIS**

As explained in Chapter 1 (page 60), Industrial Symbiosis (IS) shows similar features to e-hubs. Both concepts are socio-technical systems, seek to optimise the use of resources, involve collaboration amongst multiple stakeholders, making them multi-actor systems, both systems are complex and offer similar drivers and barriers to their participants as e-hubs. However, there are more applicable examples of Industrial Symbiotic Networks on Dutch business parks than there are of e-hubs (that are not a pilot). This highlights the relevance of researching lessons learned on managing the Opportunity in the system of IS, in order to translate these into takeaways for the the design of a proposition for the system of e-hubs.

There are multiple examples of IS in the Netherlands. Amongst them are the Port of Rotterdam (Port Of Rotterdam, 2019), Synergiepark Innofase in Duiven (InnoFase, 2021), Biopark Terneuzen in Zeeland (Quist & Korevaar, 2022), Industrial Park Kleefse Waard in Arnhem (Quist & Korevaar, 2022) and Chemelot in Limburg (ECRN, 2021)

The Opportunity was presented to experts on IS in the Netherlands, after which lessons learned on managing this opportunity were discussed. Questions that supported the semi-structured interviews with IS experts can be found in appendix C. Outcomes of these interviews are compared to and triangulated with a report on the lessons learned of IS in the Netherlands. More information en details about the methodological background can be found in Chapter 1 > Research Approach.

Table 10 shows the outcomes of this analysis, translating the lessons learned in IS to actionable takeaways for the design of a new proposition in this master thesis.

Table 10 (part 1/3): Lessons learned from IS, and their takeaways for design

#	Lesson learned	Takeaway for design	Empirical evidence
1	**Self-optimalisation comes before the collaboration:** companies will first focus on themselves, optimising their own processes. Only if this is no longer an option, will synergies be sought.	Prioritize self-optimisation: Before promoting collaboration, ensure that participants have the tools and incentives for self-optimisation, recognizing that this may be the most effective and desired approach in certain situations.	"Companies are not focussed on others. First, they tried lean optimalisation for their processes. Only when they realised they could not handle competition from other continents where the prices were lower, they started to look for other solutions." - P29 "One of the most mentioned constraining factors is that companies focus on their core business and are not aware of what is happening outside their own company. Exchanging streams with other companies is not a priority for company managers." (Valladolid Calderón, 2021, P.111)
2	**The biggest driver is having no other option**: if companies are hit in their core business, they are open to solutions beyond their own boundaries	Necessity drives engagement: Foster participant engagement by creating an environment where collaboration is necessary rather than optional, particularly when self-optimisation is no longer feasible.	"Companies should really stand with their back against the wall in order to look further than their own processes." - P29 "Only when companies have little other options, they will look for solutions outside their own boundaries." – P30
3	**Speaking the same language:** in order to communicate and look for solutions together, all companies must speak the same language, use the same terms and definitions and understand each other.	Establish a common language: Facilitate effective communication by ensuring that all participants speak the same language, both figuratively and literally, to enhance understanding and collaboration.	"People need to have the same understanding of what the problems are, what terms and definitions are used and what the possible solutions are." – P30 "The different companies were all in the same industry, therefore they all knew what the problems and possibilities were, and they knew what they could expect from each other." – P29 "Communication problems may arise between companies with a technical mindset and park management with a business mindset. Also, problems in the mindset may arise between governmental actors and entrepreneurial companies. Establishing clearer requirements and more communication may help to solve this." - (Valladolid Calderón, 2021, p.126)
4	**Collaboratively creating a common vision**: by creating a vision that is accepted and supported by all participants, all noses are in the same direction. This stimulates reaching this vision, and creates a form of peer-pressure in working towards this vision.	Co-create a shared vision: Promote collaboration by facilitating the co-creation of a shared vision among participants, stimulating alignment and commitment during the orientation phase.	"First we created a common vision. This was essential in order to get all the noses pointed in the same direction, keep everyone motivated to fill in their part of the puzzle and also to keep each other in the game." – P30 "The vision has functioned as a guide for their following actions ... All parks were ambitious with their goals ... this led to successful results. (Valladolid Calderón, 2021, p.110) "Portraying the vision in a graphical future map showing the utopian scenario ... works as a guide for every actor involved" (Valladolid Calderón, 2021, p.125)

Table 10 (part 2/3): Lessons learned from IS, and their takeaways for design

#	Lesson learned	Takeaway for design	Empirical evidence
5	**Taking into account individual interests:** it is important to understand individual interests, goals, motivations, and needs of every participating company.	Consider individual interests: Account for the diverse interests of all participants, recognising that addressing individual needs causes a more inclusive and effective collaborative environment.	"This way, companies know for themselves why they join and why they investigate money and effort into the emergence of the hub" – P. 28 "Before you can start collaborating, you need to discuss goals (what does everybody want to achieve?), motivations (why do people want to achieve these goals? when are they satisfied?), Coordination (how are the collaborations organised?) and decision-making (how are decisions decided on?). This creates transparency and right expectations in the group." – P.27 "The vision of two out of the three parks was developed collaboratively ... With this, all involved actors' interests and opinions were considered, motivating them to participate in the project." (Valladolid Calderón, 2021, p. 110)
6	**Transparency**: in order to build trust, it is essential to ensure that all participants are well-informed about each other's activities, plans and expectations.	Promote transparency: Ensure transparency by openly discussing plans and expectations of all individual participants, fostering trust and alignment.	"... a facilitator that motivates companies to look at their surroundings and realise the benefits of collaborating with their neighbours by exchanging streams ... companies share with each other information about their current projects. Therefore, all the companies know what other companies do." (Valladolid Calderón, 2021, p. 111-112) "Companies must be aware of what other companies are doing and in what projects they are involved" (Valladolid Calderón, 2021, P.126)
7	**Steering on relationships, not on contents:** focussing on the relationships before focussing on the contents increases the success rate. Creating a common vision helps in this process.	Prioritize relationship building: Emphasize relationship building over content development and technical design exploration, recognising that strong relationships are the foundation for effective collaboration.	"Leading based on content did not work; companies shouldn't immediately be bothered with the technical story. The relationship should come first; companies should know each other and be willing to do things for each other. For this purpose, a common vision was established. This was documented and signed by all companies, it was the beacon on the horizon that they wanted to reach." – P.28 "It is important to name the group, so people can identify with the group. You could also for instance make a group picture." – P.28
8	**Availability of data:** data should be available, else no technical solution can be designed.	Ensure data availability: Provide access to relevant data to enable informed decision-making and facilitate collaborative efforts.	"Without data, you do not know who you can collaborate with, and in what way" – P.28
9	**Examples**: trust in the process can be enhanced by having examples of successful e-hubs.	Leverage examples for motivation: Enhance participant motivation and trust in the process by showcasing examples of successful collaborations and outcomes.	"Relationships were strengthened by having many discussions, seeing good examples and making field-trips to these examples" – P.28 "This suggests that visiting an EIP (Eco-Industrial Park) in other areas motivates actors to copy the concept of IS after seeing the possible benefits" (Valladolid Calderón, 2021, p.110)

Table 10 (part 2/3): Lessons learned from IS, and their takeaways for design

#	Lesson learned	Takeaway for design	Empirical evidence
9	**People with the right mindset**: people with the right mindset are the ones that are willing to put effort and resources into the formation of the collective solution. This mindset includes taking risks, having a long horizon, prioritizing innovation and sustainability.	Encourage an entrepreneurial mindset: Cultivate an entrepreneurial mindset among participants, encouraging openness to investments with a long horizon that lead to sustainable improvements and innovation.	"There was mainly a difference between older and younger employees. Older employees still thought very individually, according to Porter's 5 forces; 'we don't do anything unless we get better and/or the competition gets worse.' Younger people had a different mindset – towards sustainability, towards a sense of community. They were more willing to take risks and realised that they did not have to compete with their immediate neighbours, but that they could compete together with their neighbours against the rest of the world." -P. 27 "You need visionaries with risk acceptance and long-term vision. You must be comfortable with short-term losses to build relationships so that you can achieve profits in the long term. You need to have horizon." – P.27 "An entrepreneurial mind is one of the most important characteristics of actors that engage in synergies. At [all cases studied], companies have an entrepreneurial mindset and are looking for new opportunities to innovate and participate in synergies with neighbours." (Valladolid Calderón, 2021, P.114) "Companies need ... having an open mind and be willing to collaborate with other companies. This can be incentivized with interactions" (Valladolid Calderón, 2021, P.126)
10	**An independent facilitator**: an independent facilitator can create neutral ground, and ensure solutions are in the middle of all different interests.	Utilize independent facilitation: Engage an independent facilitator during the orientation phase to ensure objectivity and effective coordination of collaborative efforts.	"You need a role that stands above other roles. This is essential. Else, everyone will try to achieve their own goals. You need someone that pulls everyone out of their boundaries, and creates a common context in which different companies can share and collaborate, and come up with out-of-the-box solutions." – P.28 "Facilitators played an important role in enabling interaction and getting companies to know each other for the collaborative sharing culture to emerge." (Valladolid Calderón, 2021, p.113)
11	**Ownership:** companies should have a feeling of ownership on the project; as if they are personally responsible for its success.	Foster a sense of ownership: Stimulate a sense of ownership among participants, empowering them to actively contribute and innovate, leading to more collaborative behavior and generation of new solutions.	"Companies should have the feeling as if they came up with the solutions. Then, they will also feel obliged to collaborate and propose new projects." – P.28 "Companies have to feel co-ownership about problems of others in order to come up with collective solutions" – P.28 "Ownership can be stimulated with collaboratively creating a shared vision." - P.28
13	**Small successes**: a vision towards a holistic solution cannot be reached directly. Realising and celebrating small successes keeps everybody on track for the bigger vision.	Celebrate small wins: Recognize and celebrate small successes along the way, boosting morale and reinforcing the group's commitment and motivation.	"At first, the common vision did not come together as a whole. The beacon on the horizon was too far away. So, we first looked for smaller, achievable solutions. Through trial and error, the entire group was brought together. Now, we are doing very well in reaching for the main vision." – P.28

In conclusion, key design takeaways derived from lessons learned about the Opportunity in Industrial Symbiosis include:

1. **Prioritize self-optimisation:** Before promoting collaboration, ensure that participants have the tools and incentives for self-optimisation, recognizing that this may be the most effective and desired approach in certain situations.
2. **Necessity drives engagement:** Foster participant engagement by creating an environment where collaboration is necessary rather than optional, particularly when self-optimisation is no longer feasible.
3. **Establish a common language**: Facilitate effective communication by ensuring that all participants speak the same language, both figuratively and literally, to enhance understanding and collaboration.
4. **Co-create a shared vision:** Promote collaboration by facilitating the co-creation of a shared vision among participants, stimulating alignment and commitment during the orientation phase.
5. **Consider individual interests:** Account for the diverse interests of all participants, recognising that addressing individual needs causes a more inclusive and effective collaborative environment.
6. **Promote transparency:** Ensure transparency by openly discussing plans and expectations of all individual participants, fostering trust and alignment.
7. **Prioritize relationship building:** Emphasize relationship building over content development and technical design exploration, recognising that strong relationships are the foundation for effective collaboration.
8. **Ensure data availability**: Provide access to relevant data to enable informed decision-making and facilitate collaborative efforts.
9. **Leverage examples for motivation:** Enhance participant motivation and trust in the process by showcasing examples of successful collaborations and outcomes.
10. **Encourage an entrepreneurial mindset:** Cultivate an entrepreneurial mindset among participants, encouraging openness to investments with a long horizon that lead to sustainable improvements and innovation.
11. **Utilize independent facilitation:** Engage an independent facilitator during the orientation phase to ensure objectivity and effective coordination of collaborative efforts.
12. **Foster a sense of ownership:** Stimulate a sense of ownership among participants, empowering them to actively contribute and innovate, leading to more collaborative behavior and generation of new solutions.
13. **Celebrate small wins**: Recognize and celebrate small successes along the way, boosting morale and reinforcing the group's commitment and motivation.

Figure 62: Clustering takeaways for design from e-hub pilots and IS into actionable design cues (Author's image)

DISCOVERING **DESIGN CUES**

The takeaways for design resulting from both the success factors of succesful e-hub pilots as well as from the lessons learned in IS are translated into design cues by clustering them as visualised in figure 62. This leads to the identification of seven design cues:

- **Identify front-runners**: the proposition should include a clear strategy to identify and engage early participants who will form the front-runners group.
- **Foster connections and empathy**: the proposition should include activities and processes that foster a sense of connectedness and empathy among participants, facilitating the formation of a cohesive and caring group. **This includes the collaborative creation of a shared vision** that integrates personal interests and values transparency.
- **Cultivate ownership**: Create opportunities for participants to feel a sense of ownership and empowerment in the collaborative process, encouraging active engagement and commitment to seeking solutions.
- **Maintain motivation**: Implement strategies to keep all participants motivated and engaged throughout the orientation phase, ensuring a smooth and efficient progression towards shared goals and outcomes.
- **Facilitate data collection:** the proposition should include a data collection mechanism that allows to gather relevant and accurate information necessary for informed decision-making and problem-solving throughout the orientation phase.
- **Offer diverse solutions**: the proposition should provide alternative options for situations where an e-hub may not be the optimal solution at the moment.
- **Standardise information**: the proposition should establish standardised communication protocols on knowledge about energy, the electricity grid and e-hubs.
- **Appoint a facilitator**: the proposition should include a dedicated facilitator to ensure consistent and clear communication among all participants, promoting alignment and cohesion.

CHAPTER 5 - EXPLORING THE POSSIBILITY SPACE: **CONCLUSIONS**

This chapter focussed on answering the fifth sub-research question:

What success factors and lessons learned in similar socio-technical, multi-agent complex systems development can inform the design of a new proposition that stimulates the orientation phase of e-hub development?

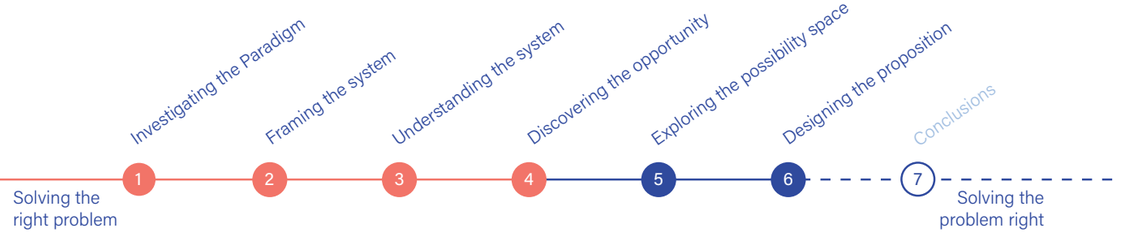
In this chapter, **possible solutions for the Design Statement were explored in similar systems**: e-hub pilots and IS on Dutch Business parks in 2024.

Success factors revolving the Design Statement in e-hubs pilots were investigated, and lessons learned in IS clusters were analysed. These success factors and lessons learned address both the direct management of the Opportunity and the underlying conditions that support it and thus should be included in the design of the new proposition.

Both the success factors from e-hub pilots and lessons learned from IS were translated into actionable takeaways for the design of a proposition that stimulates e-hub development, as stated in the thesis goal. These takeaways for design were clustered and translated into practical **design cues**, that form the basis for the design of the proposition in Chapter 6 - Design of the Proposition. The design cues represent **what** should be included in the new proposition, Chapter 6 focuses on **how** these should be included.

The design cue 'Foster connections and empathy' reflects the largest cluster of takeaways from e-hub pilots and IS, indicating the importance of this design cue. This specific design cue is therefore emphasised in Chapter 6.

A remarkable outcome of this chapter is the inclusion of a facilitator in the new proposition, while the Gap in Current Practices (Chapter 1) states inefficiencies in the function of the facilitator and a lack of availability of facilitators for all business parks in the Netherlands. The role of the facilitator will be further explored in Chapter 6 and the ambiguity in its functioning will be further discussed in Chapter 7 - Conclusions.



6

DESIGNING THE PROPOSITION

INTRODUCTION

In this chapter, the sixth sub-research question will be answered:

How can the success factors and lessons learned in similar systems be included in a new proposition that stimulates the orientation phase of e-hub development on Dutch business parks in 2024?

The Design Cues developed in Chapter 5 state **what** should be included in the design of the new proposition, this chapter focuses on **how** these should be included. The Design Cues are used as a foundation for participatory innovation. This entails **continuously involving end-users, stakeholders and experts** in the proposition's design process to tailor it, enhance its practicality and relevance, and increase its adoption among end-users (figure 63). For more information about this open participatory innovation approach, please visit Chapter 1 > Research Approach.

The design cues, are initially transformed into brainstorming questions, which are then presented to end-users of the proposition, along with other stakeholders and experts. The results of this brainstorming session inform subsequent design efforts, which involve co-creation with experts focusing on specific topics derived from the brainstorm outcomes. Continuous validation and improvement are ensured by actively engaging domain experts and stakeholders throughout the process.

The final proposition design comprises four interventions in at the orientation phase of e-hub development on business parks in the Netherlands in 2024. These interventions are presented, their mechanisms and impacts on system behaviour are clarified, and their alignment with the research conducted in this thesis project is discussed.

Figure 63: Participatory innovation building on the Design Cues (Author's image)

COLLECTING IDEAS: ASKING THE RIGHT PEOPLE

Three main sources of input were used for participatory design, collaborative brainstorming, idea generation, problem-solving and co-creating solutions.

The first source includes the key role (the early participant). This role has to be stimulated by managing the Opportunity in order to stimulate the orientation phase of e-hub development, as discussed in Chapter 2 - Framing the System. In order to stimulate this key role efficiently, the proposition should be tailored to the needs and wishes of this role.

The second source includes supporting roles (discussed in Chapter 2 - Framing the system). As e-hubs remain an multi-actor system, supporting actors will inherently influence and be influenced by the adoption and execution of the proposition. The proposition should therefore consider their capabilities.

As discussed in the conclusion of Chapter 5 - Exploring the Possibility Space, one specific design cue is based on a large amount of takeaways and should therefore be emphasised in the design of the proposition. This design cue is 'Foster connections and empathy', and is supported by the design takeaways from IS and e-hub pilots as shown in figure 64. Therefore, the third source of input includes four experts on creative facilitation, co-creation and social cohesion (appendix A, P31-34).

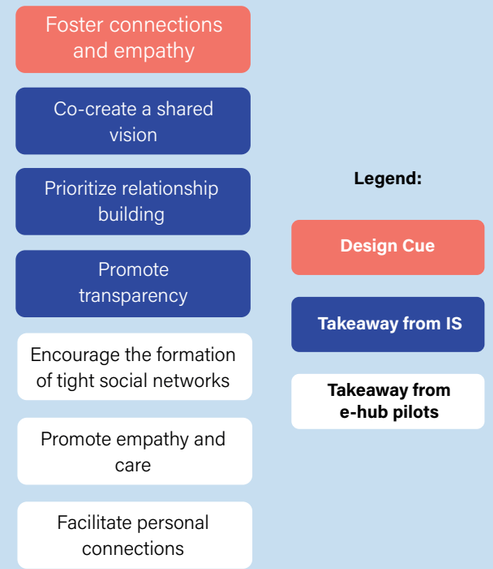


Figure 64: Repetition of the design cue that needs to be emphasised in the proposition design, as previously discussed in Chapter 5 (Author's image)

COLLECTING IDEAS: ASKING THE RIGHT QUESTIONS

In order to be able to collaboratively brainstorm and co-create solutions with both the first source (early participants) and the second source (supporting roles) of input, first the design cues resulting from Chapter 5 are translated into questions. Please refer to Chapter 1 > Research Approach for more information on this translation step. The questions resulting from the design cues are visualised in figure 65. More information on the collaborative brainstorming session can be found in Chapter 1 > Research Approach, and the unprocessed results of this session can be found in appendix H. The accumulated outcomes of this session are presented in table 11 on the next page.

For more information on the co-creation on the design cue 'Foster connections and empathy' with experts on creative facilitation, co-creation and social cohesion, please refer to Chapter 1 > Research Approach.

Design cues used for brainstorming with experts on co-creation, creative facilitation and social cohesion:

Foster connections and empathy	Appoint a facilitator	Offer diverse solutions	Maintain motivation	Cultivate ownership

Design cues used for brainstorming with the early participant and supporting roles:

Design cue:	Foster connections and empathy	Identify front-runners	Facilitate data collection	Standardise information
Goal of the brainstorm - information needed:	What context, values and stimulation early participants need to form connections and a group-feeling	In what ways the right people can effectively be identified and addressed	The prerequisites for early participants to share their data	What early participants need to know before they can speak about their problems and solutions in the same language
Questions asked:	What shared goals als values are important for successful collaboration with another company? How should the contact with other companies look like to collaborate effectively? (e.g. frequency, medium, location, circumstances, etc.) What would the ideal collaboration in an e-hub look like for you?	Who within the company should take responsibility for establishing the e-hub?	What conditions are necessary for you for sharing your energy data with potential partners reliably?	What questions, uncertainties, and/or ideas are currently on your mind regarding the transition towards e-hubs?

Figure 65: The design cues used per input source, translated into questions to brainstorm with early participants and supporting roles (Author's image)

Table 11 (part 1/2): Ideas generated from the brainstorm session with early participants and supporting roles

#	Idea	Relevance	Empirical evidence
1	Basic education for all entrepreneurs	Most entrepreneurs, being potential participants, know very little about energy, let alone e-hubs. They should first be educated on basic principles and characteristics of e-hubs (and other solutions) in order to start communicating about their problems and possible solutions.	"I know nothing about the basic terms of energy. This is not my domain." "I do not know when an e-hub would be a solution for me." "I barely understand what is in my energy contract." Attendees do not know what low voltage is, how the energy grid works, what possible solutions there are for grid congestion and what an e-hub actually is. These are people that are already attending an event about e-hubs, indicating that people who do not attend such events know assumingly even less about these topics. – Researchers observations from presentations and questions asked during the event

Table 11 (part 2/2): Ideas generated from the brainstorm session with early participants and supporting roles

#	Idea	Relevance	Empirical evidence
2	The representative from the participant should be the owner or a board-member	Negotiations and decisions within the hub development have an effect on the long-term strategy of the participants. Therefore someone on the board should be involved in the development of the e-hub.	"It should be the owner, so that the company strategy can be adjusted accordingly." "It should be the owner, but only if this is a person that is not afraid to take risks."
3	Facilitator for introduction, confidence and trust	Participants do not know how to find each other. They prefer being contacted by a facilitator over finding each other by themselves (as long as the facilitator takes a 'supporter' role, leaving the participants in control). A facilitator should provide confidence and trust into the process. Being someone with knowledge and possibly experience, it can take away insecurities of participants.	"I cannot fix my problems myself. The municipality and DSO should help me." "The DSO has conducted pilots for other e-hubs, they should apply the lessons learned from these pilots to help us. We cannot do this by ourselves." "I am unsure how to start an e-hub and when this would be a good solution for me. The DSO should tell me so."
4	Meeting regularly and physically	Participants are willing and find it important to meet regularly and physically	"Off course I want to invest time and money into the process, as else I cannot continue my companies processes" "I find it important to speak to my co-participants in person if I have to trust them"
5	Trust and security in the sharing of data	Participants need to have faith in the success of the hub, trust in other participants and contractual agreements in order to share their data	"I need to be sure that there would be a win-win situation, where we are all dependent on the collaboration to work. I want everyone to sign a letter of intent" "I need to personally know and trust the others" "I want everyone to have signed letters of intent and NDAs, so that I can trust them with my data"
6	Stimulation of the entrepreneurial mindset and potential for collaborative growth on a local level	Participants value growth for all in the creation of synergies. They also value locality, creating synergies and win-win situations with their neighbours.	"Every company wants to grow. I want all participants to value growth and growing together." "A good entrepreneurial mindset to create win-win situations and growth for all." "The 'support your local' mentality, looking for synergies on a local level."
7	An equal degree of motivation amongst the participants is important to create just collaborations	Participants want everyone in the collaboration to actively support the development of the e-hub. For this, a similar amount of motivation amongst all participants is necessary.	"A missing degree of presence, enthusiasm and contribution from other participants could stand in the way of creating synergies." "If other companies are not motivated enough to make the hub work, collaborations could become conflicted."
8	Leaders of the development	The collaboration should be led by a delegation or representative, which can consist out of representatives from the participants who are willing to invest more time and efforts, and/or an independent facilitator.	"A well-managed energy cooperative is important to lead the collaborations and development" "There should be an overarching organisation that is responsible for tasks such as energy exchange as part of daily management and ensuring collaboration between participants, also on other topics as safety and circularity."

IDENTIFYING **THEMES** OF IDEAS THAT NEED TO BE INCLUDED IN THE PROPOSITION

Based on the participatory design approach by Casali, 2013 (please refer to Chapter 1 > Research Approach), collected ideas are synthesised and prioritised into four themes that need to be included in the design of the proposition (figure 66).

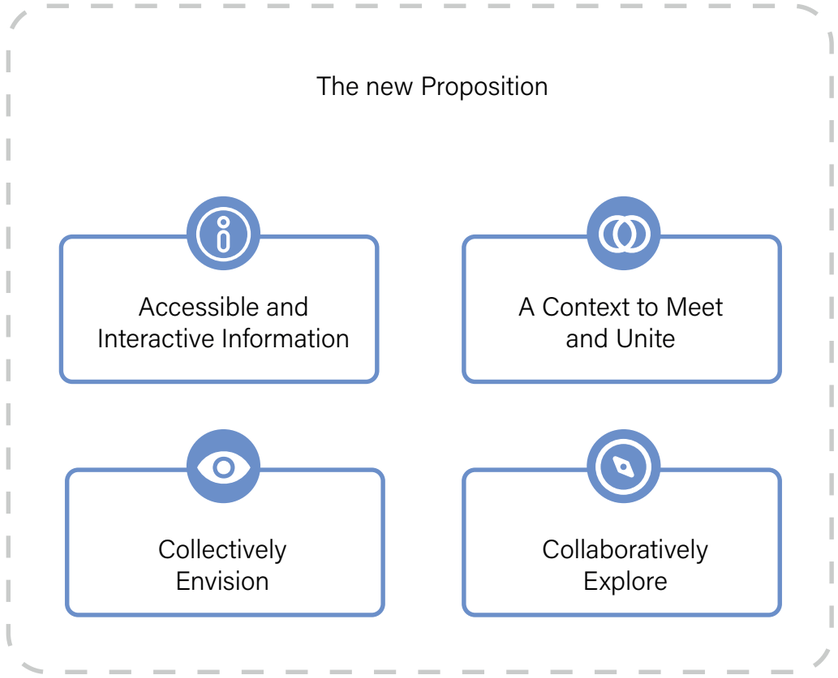


Figure 66: The four themes of ideas resulting from participatory innovation, forming the foundation for the design of the new Proposition (Author's image)

PERSONAS OF THE **INTENDED USERS**

Based on the collective brainstorming and prior research, the new proposition will focus on two main end-users:

1. The early participant: as identified in Chapter 2 - Framing the System, the early participant is the key role of the orientation phase of e-hub development and therefore is one of the end-users of the new proposition.
2. The facilitator: as explained in Chapter 5 - Exploring the Possibility Space and based on the collective brainstorming conducted in this current chapter, the addition of a facilitator is needed for objectivity and strategic direction. Therefore, the facilitator is one of the end-users of the newly designed proposition.
    - As concluded in Chapter 5, the Gap in Current Practices describes a lack of availability of facilitators. This ambiguity will be further discussed in Chapter 7: Conclusions.

The characteristics of the two end-users are elaborated in two personas depicted in figure 67. This portrayal aims to provide a comprehensive understanding of these users, influencing and contextualising the design of the proposition.

Early Participant

Age: Mostly 35-67

Sex: Mostly men

Goals or objectives: Prevent and/or circumvent net congestion, pursue affordable energy security for now and the future

Motivations: Maintaining and possibly expanding on their core business, settling a new company, reaching sustainability targets

Biggest challenges: Little available time and knowledge about energy/e-hubs, are not by default open to very out-of-the-box ideas, are not used to being dependent on other companies

Gain information by: searching online, contacting the DSO, municipality, province, VNO-NCW, attending events on e-hubs

Role within their company: mostly the CEO or another board-member with an open mindset for new, collaborative and sustainable solutions

Size of group engaging in the proposition:
1, sometimes 2 representatives per company
10 - 20 companies per park

Facilitator

Age: Mostly 25-67

Sex: All

Goals or objectives: Aid companies in the formation of a new e-hub

Motivations: To preserve the health of businesses within the Dutch economy

Biggest challenges: Little available time, little experience from earlier examples, having to 'convince' companies to join, having no personal relationships with companies

Gain information by: speaking to companies directly to gain information on their attitudes, problems and possible solutions, speaking to facilitators of other hubs, the DSO and the province to gain information about the (technical) possibilities

Role: Can vary, will most likely be an advisor appointed by the province, a representative of Programma Verduurzaming Bedrijventerreinen (PVB) or a representative from VNO-NCW (branche organisation)

Size of group facilitating the proposition: 1

Figure 67: Personas of the two end-users of the proposition (Author's image)

OUTLINE OF THE PROPOSITION

The proposition comprises four interventions in the orientation phase of e-hub development, all rooted in the preceding research of this master thesis. These four interventions are somewhat sequential, including an energy knowledge hub, a participant procurement protocol, a series of energy-coalition building workshops and a forum for facilitators of e-hubs.

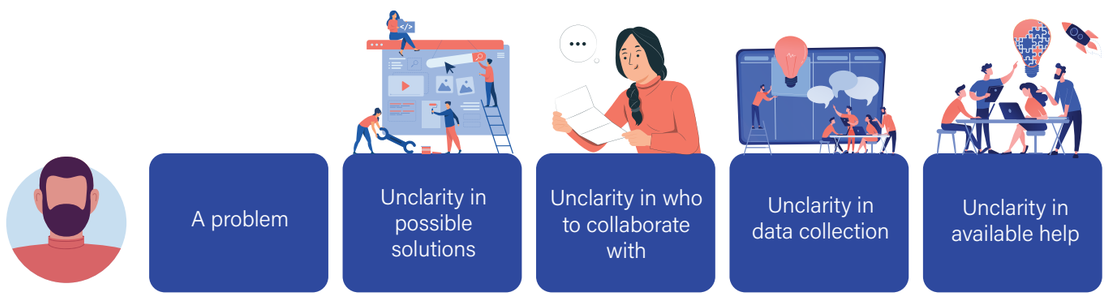
Figure 69 visualises the outline of the proposition, including the themes delineated from the collaborative brainstorm associated with each intervention where applicable. Figure 68 illustrates the placement of the proposition within the orientation phase of e-hub development as currently experienced by the key role (please refer to Chapter 2 and Chapter 3 for more details), showing the specific steps in this phase that are addressed by the four interventions and demonstrates how these steps are improved.

The four interventions will be explained in the following four sections. Per intervention, the following details are discussed:

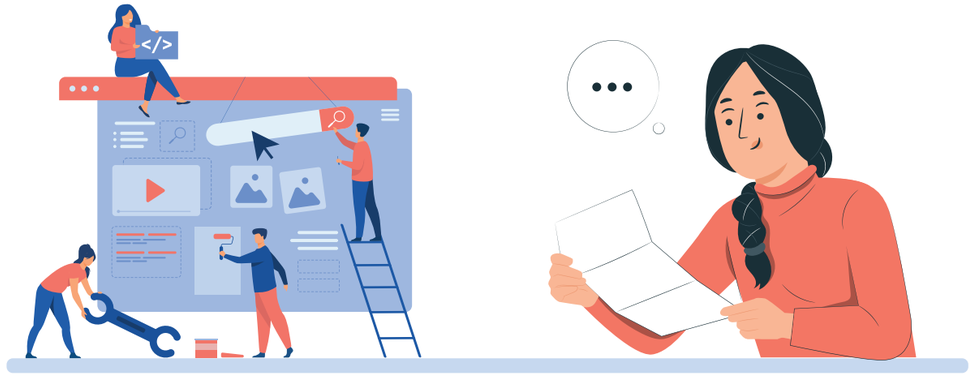
- The placement of the intervention in the orientation phase
- The intended use of the intervention
- The role within the multi-actor system of e-hubs that is responsible for the implementation of the intervention
- Key findings from the research conducted in this thesis which informed the design of this intervention, underscoring its purpose and relevance
- Validation of the intervention by the end-users

For more information about the collaborative and iterative design process of the proposition, as well as the validation of the interventions, please see Chapter 1 > Research Approach.

Further discussion on the proposition, including its societal impact is addressed in Chapter 7: Conclusions.



Top: figure 68: Placement of the interventions within the current experience of the orientation phase by the key role as explained in Chapter 3 (Author's



INTERVENTION 1
Energy Knowledge Hub

INTERVENTION 2
Participant Procurement Protocol

INTERVENTION 3
Energy Coalition Building Workshops

INTERVENTION 4
E-hub Facilitator Forum

Themes of ideas:

- Accessible and Interactive Information
- A Context to Meet and Unite
- Collaboratively Explore
- Collectively Envision

Right: figure 69: Outline of the four interventions of the Proposition, including their covered idea themes (Author's image)

INTERVENTION 1:
ENERGY KNOWLEDGE HUB

Figure 70: The Energy Knowledge Hub (Author's image)

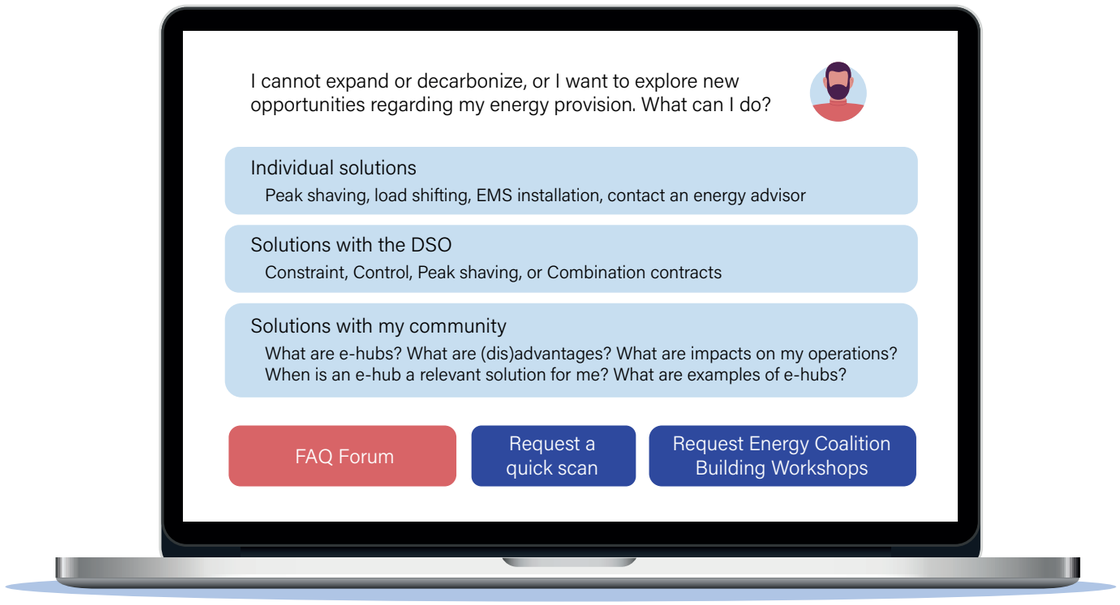


Figure 71: Example Interface of The Energy Knowledge Hub (Author's image)

DESCRIPTION OF THE INTERVENTION

The Energy Knowledge Hub serves as an engaging online platform for entrepreneurs, providing comprehensive insights into energy fundamentals, the electricity grid, and associated challenges (figure 70). It offers a spectrum of possible solutions tailored for entrepreneurs, starting from individual solutions to collaborative solutions with the DSO and community-based solutions (e-hubs). All information is entrepreneur-centric, offering clear guidance on possible actions to take, including examples, and outlining the potential benefits and drawbacks associated with each solution. Additionally, entrepreneurs can request a quick scan to analyse the feasibility of potential solutions and participation to Intervention 3: Energy Coalition Building Workshops can be requested (explained later in this chapter). Lastly, the Energy Knowledge Hub features an interactive FAQ forum similar to platforms such as Reddit, fostering dynamic engagement and knowledge sharing.

More detailed information that could be included in the Energy Knowledge Hub can be found in appendix J

INTENDED USE OF THE INTERVENTION

Entrepreneurs can freely access the Energy Knowledge Hub online when they experience challenges due to grid congestion or want to explore opportunities to optimise their energy usage (figure 71). Here, they find a repository on energy knowledge, including relevant terms and definitions, the mechanisms of the Dutch energy system, its challenges and possible solutions. After navigating through individual solutions and exploring these opportunities, if the entrepreneur still experiences challenges or wants to explore further possibilities it can look at the different potential contractual agreements with the DSO, or investigate the explanations and examples on the community-based solutions, the e-hubs.

If the entrepreneur wants to review whether an e-hub would be a feasible and potentially viable solution for its challenges or future plans, it can request a quick-scan. After receiving a positive result on this scan, it can start motivating other companies on its business park, and/or request the Energy Coalition Building Workshops (explained later in this chapter) to jumpstart the development of a new e-hub on its business park.

If the entrepreneur experiences any confusion or further questions on the information and possible solutions provided, it can turn to the FAQ forum for clarification. As a dynamic platform, the FAQ forum enables entrepreneurs to both ask questions and respond to questions and comments placed by other businesses. The DSO oversees this platform, ensuring accuracy and relevance of the knowledge presented. This fosters a collaborative learning environment where entrepreneurs and DSOs exchange knowledge.

Through the FAQ forum, the DSO collects valuable insights into entrepreneur's inquiries, enabling them to provide accurate responses and address common challenges by adding information and adapt future innovations in the energy system to better meet entrepreneurs' needs.

THE ROLE RESPONSIBLE FOR IMPLEMENTATION OF THE INTERVENTION

The **DSO** is responsible for the implementation of this intervention (figure 72), because:

- The DSO possesses the most comprehensive and accurate **understanding of relevant terms, issues, and potential solutions**
- The DSO has the most complete and precise **overview of emerging innovations** and solutions, including pilot projects
- As a trustworthy and neutral institution with a broad reach, the DSO provides information that is both **representative and reliable**
- It is **in the DSO's interest** to inform all businesses in a structured manner, preserving their already limited human resources needed to explain information to each business individually.

Figure 72: The DSO (Author's image)

IMPACT OF THE INTERVENTION IN THE ORIENTATION PHASE

Figure 73 visuaslises the impact of the intervention in the orientation phase of e-hub development as experienced by the key role.

KEY RESEARCH FINDINGS HIGHLIGHTING THE PURPOSE AND RELEVANCE OF THE INTERVENTION

The Energy Knowledge Hub stimulates the Opportunity by answering to the design cues of 'Standardise information', 'Offer diverse solutions', and 'Identify front-runners' (figure 74).

This intervention answers the design cue 'Standardise Information' by creating a common language. All entrepreneurs in the Netherlands can access the platform, meaning they all have the same opportunity to learn about energy terminology, addressing experienced challenges and exploring new opportunities. The concept is grounded in the results from the collaborative brainstorm with early participants (idea 1; 'Basic education for all entrepreneurs', see table 11). This underscores its necessity, significance and purpose.

Next to this, the design cue of 'Offer diverse solutions' is answered, by providing information on self-optimalisation and multiple possible contractual agreements with the DSO, before explainging the possibilities and advantages of e-hubs.

At the same time, the intervention answers to the design cue of 'Identify Front-Runners.' Entrepreneurs requesting a workshop are identified by the facilitator. If multiple entrepreneurs on the same business park request a workshop, this indicates the relevance of focussing on this business park by the facilitator. The facilitator can compare the amount of requrests to the amount of grid congestion experienced on business parks, idifying parks where 'Necessity drives engagement' (Lessons learned from IS, Chapter 5) and an 'entrepreneurial mindset' can be encouraged (Lessons learned from IS, Chapter 5).

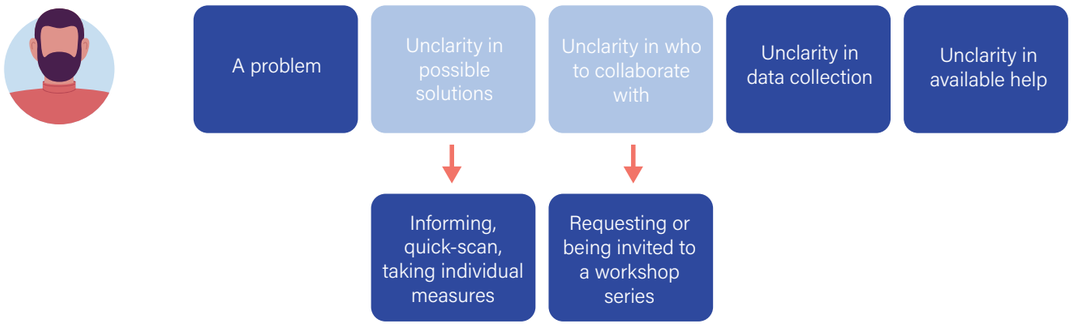


Figure 73: Impact of Intervention 1 on the orientation phase as experienced by the key role (Author's image)

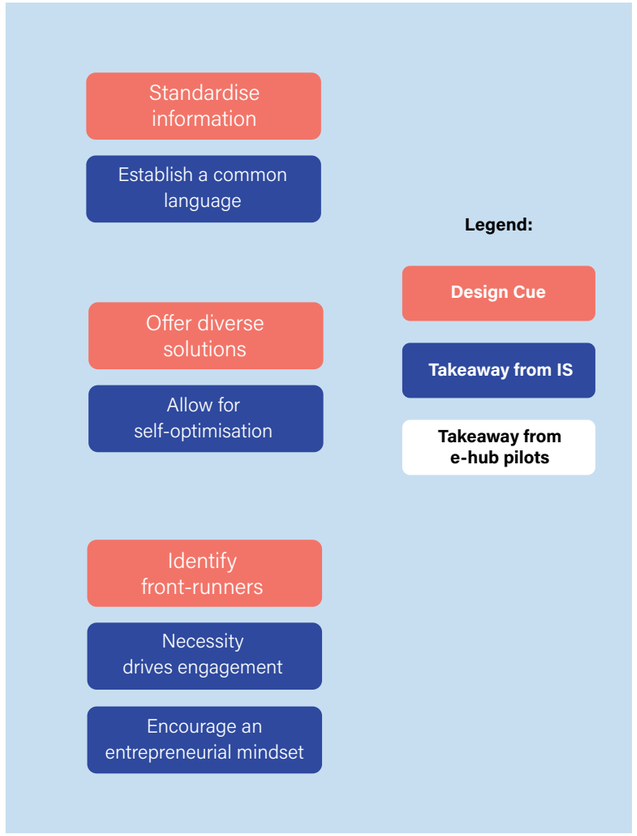


Figure 74: Design cues implemented in Intervention 1 (Author's image)

VALIDATION OF THE FUNCTIONING AND PURPOSE

- Participants comment that it is important to facilitate information from the perspective of the entrepreneur. Currently, most information from the DSO (e.g. the website) is written from the perspective of the DSO. The FAQ forum is a valuable addition, as the participants currently feel unheard by the DSO and facilitators.
- Facilitators have no direct confirmation on this intervention, other than already implemented into its design.
- Multiple supporting roles indicated developing a quick-scan during validation rounds (appendix I)

CASCADING EFFECTS EXPECTED OF INTERVENTION 1

Referring back to the outcomes of Chapter 3 - Understanding the System, cascading effects in the complex system of drivers and barriers experienced by the key role include:

- Mitigation of B7; increasing public knowledge, causing mitigation of B5; entrepreneurs having more realistic expectations of what an e-hub can mean for them
- Mitigation of B15; showing entrepreneurs possibilities and possible advantages of expanding their solution-seeking boundaries to account for the community, pushing leverage point 3 and stimulating early participants to develop an e-hub.
- Drivers D8 and D9 are stimulated, including the realisation there is a shared problem and it is possible to collaborate in overcoming this problem and find new opportunities. Diver D4 is also stimulated, increasing the knowledge on lessons learned in other e-hubs.

Referring back to the outcomes of Chapter 2 - Framing the System, cascading effects in the multi-actor system of the orientation phase of e-hub development include:

- Stimulation of the key role, which takes a central position in the orientation phase of e-hub development, stimulating supporting roles to join efforts and move towards an energy system with integrated e-hubs.

Referring back to the outcomes of Chapter 1 - Investigating the Paradigm, cascading effects in the socio-technical energy system include:

- Entrepreneurs being aware of and understanding the technical and legal dimensions, leading to implementation of technology (both individually and collectively) as well as being able to engage in new contractual agreements (both with the DSO and collectively in e-hubs).

INTERVENTION 2:
PARTICIPANT PROCUREMENT PROTOCOL

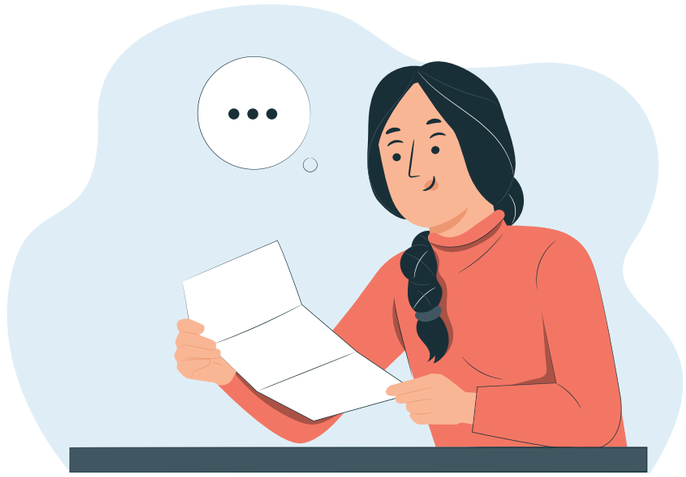


Figure 75: Intervention 2: Participant Procurement Protocol (Author's image)

DESCRIPTION OF THE INTERVENTION

The Participant Procurement Protocol focuses on the acquisition of motivated early participants on relevant business parks. This intervention functions as the gateway between intervention 1 and intervention 3 by analysing the businesses that requested the Enenergy Coalition Building Workshops (intervention 3) within the Energy Knowledge Hub (intervention 1), and selecting business parks where an e-hub proves a viable and needed option. Consequently, the appointed facilitator (further explained in next sections) invites the businesses on the selected parks for the workshops of intervention 3, after which the invited businesses can decide whether they want to accept this invitation (figure 75).

INTENDED USE OF THE INTERVENTION

The DSO monitors the workshop requests resulting from Intervention 1 and compares this to the grid congestion maps (Netbeheer Nederland, 2024). This way business parks where an e-hub is a desirable and needed solution can be highlighted, after which the DSO sends out invitations for Interventinon 3 to all businesses on the same cable or substation, ensuring inclusivity of all business that are technically able to form an e-hub. An example of such invitation is shown in figure 77. The invitation contains precice information, written from the perspective of the entrepreneur in order to prevent an information-overflow.

The entrepreneurs receiving the invitation can decide whether joining the workshops of Intervention 3 is a relevant option for them, by following the flow chart in the invitation. The invitation contains a disclaimer; if the entrepreneur joins the workshops, it will see what other entrepreneurs are on the same cable, as will these others see this information about itself.

Meanwhile, facilitators are appointed by a neutral, trustworthy institute such as the province, branch organisation VNO-NCW (defending the interests of the entrepreneurs in the Netherlands) and/or governmental consortium PVB (focussing on the sustainable development of business parks). More information and reasoning behind this is provided in next sections. The facilitator assesses the amount and type of businesses reacting to the invitation, and prepares the workshops of Intervention 3.

Expected is an average of 10 businesses per park reacting to the invitation, based on current experiences of facilitators.

IMPACT OF THE INTERVENTION ON THE ORIENTATION PHASE

Figure 76 visuaslises the impact of the intervention in the orientation phase of e-hub development as experienced by the key role and the facilitator.

THE ROLE RESPONSIBLE FOR IMPLEMENTATION OF THE INTERVENTION

The province, VNO-NCW and/or PVB are mainly responsible for the implementation of this intervention, supported by the DSO, because:

- The province, VNO-NCW and/or PVB have the financial capacity to appoint a facilitator, having access to subsidies and financing from the government.
- They have an overview of multiple hubs within their area which allows them to connect different e-hubs to each other for knowledge-sharing, which for example the municipality does not.
- They are trusted intermediaries, responsible for providing complete and accurate information while preventing a lock-in of the facilitator in the exploitation of the e-hub, which for example consultancies are not.
- The DSO supports this intervention as the DSO possesses the necessary data, without having to share this data directly with the facilitator or potential participants.

Figure 77 (right): The Province, Consortium, Branche Organisation and DSO (Author's image)

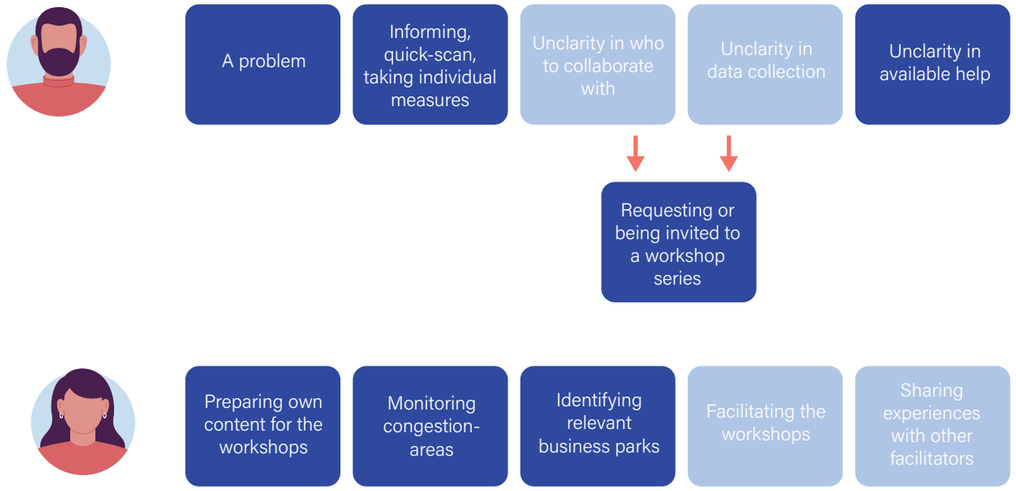


Figure 76: Impact of Intervention 2 on the the orientation phase as experienced by the key role (top) and facilitator (bottom) (Author's image)

Dear entrepreneur,

You are receiving this invitation as your region has been selected to explore possibilities for an e-hub. Companies within your area have received this invitation to explore the possibilities together for establishing a new e-hub.

What is an e-hub?

- As you may increasingly see in the news, our power grids are becoming overloaded. An e-hub is one of the solutions to address this issue. It involves collaboration among various companies within a geographical area to optimize the generation, storage, and consumption of electricity in sync with the available energy infrastructure. The aim is to avoid overloaded power grids and to efficiently align energy demand and supply at a local level.

What does this workshop series entail?

- The workshop series consists of multiple sessions. During these sessions, you will gain more knowledge about e-hubs and collectively form a vision with other companies in your area. Ultimately, the possibilities for forming an e-hub will be explored.

Is this workshop series relevant for my company?

- Review the flowchart to determine if this workshop series is relevant for your company, and/or what other steps you can take.

What is expected of me?

- The workshop series consists of three sessions, and your attendance is expected. During these workshops, we will explore with other interested companies in your area the possibilities for forming e-hubs. The three sessions are described below, including the requirements from your company.

Workshop	Goal	Needed preparation by you
1	Meet and Inform	Explore the Energy Knowledge Hub
2	Collectively Envison cooperation and energy capacity	Discuss expected growth with your board, prepare expectations and plans for your future energy demand and supply.
3	Collaboratively Explore technical possibilities	Approve the safe retrieval of your energy data from the DSO by signing an authorisation (more information will follow)

I am interested, what now?

- You can sign up for the workshop series via the link below. For further questions or remarks, please refer to our online information page.

Disclaimer

- By participating in the workshop, you will have the opportunity to discover which other companies share the cable with you, while they, in return, will gain insight into your connection.

Figure 77 (part 1/2): Example of the invitation (Author's image)

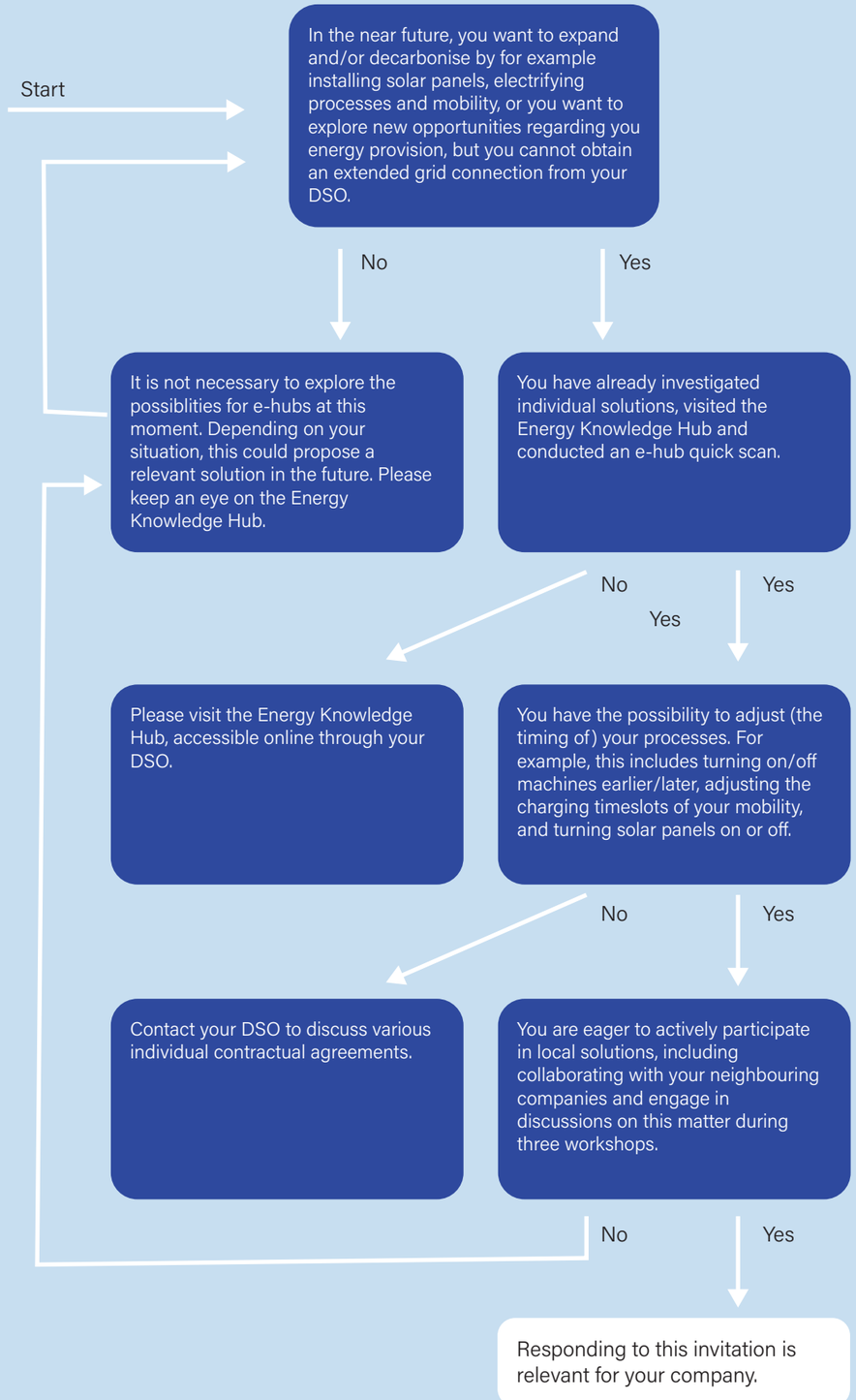


Figure 77 (part 2/2): example of the invitation (Author's image)

KEY RESEARCH FINDINGS HIGHLIGHTING THE PURPOSE AND RELEVANCE OF THE INTERVENTION

The Participant Procurement Protocol stimulates the Opportunity (Chapter 4) by answering to the design cues (Chapter 5) of 'Identify front-runners', 'Cultivate ownership', 'Facilitate data collection' and 'Appoint a facilitator' (figure 78).

- Frontrunners are identified by first including all businesses that are technically able to form an e-hub, after which the entrepreneurs with necessity and an entrepreneurial mindset will answer to the invitation. This filters out the frontrunners.
- Ownership is cultivated as entrepreneurs actively choose to join the workshop of Intervention 3, agreeiing to the condition of 'You are eager to actively participate' mentioned in the inviation flowchart.
- Data collection is facilitated by circumventing the issue of privacy-sensitive data by letting the DSO send out the invitations for the workshop. This way, the DSO does not have to share this data while reaching the same target.
- As discussed, an independent and neutral facilitator is appointed, blending top-down with bottom-up development of the e-hub.

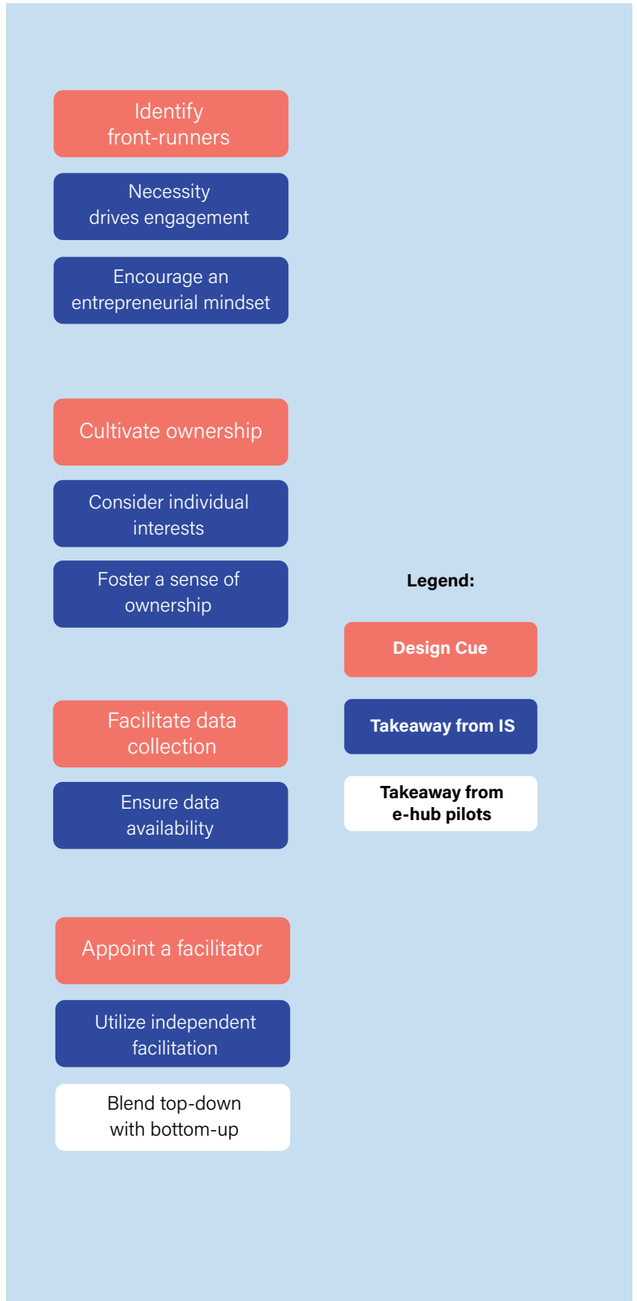


Figure 78: Design cues implemented in Intervention 2 (Author's image)

CASCADING EFFECTS EXPECTED OF INTERVENTION 2

Referring back to the outcomes of Chapter 3 - Understanding the System, cascading effects in the complex system of drivers and barriers experienced by the key role include:

- Mitigation of barrier B5 (entrepreneurs have false expectations) is achieved by clearly outlining both what the workshops will deliver and what is expected from the entrepreneurs.
- Barrier B15 (companies are primarily self-focused) is mitigated by having the facilitator manage the process, eliminating the need for companies to independently consider or find their neighbours. This partly pushes leverage point 3 (Chapter 3); the Opportunity.
- Barrier B17, where entrepreneurs are unsure whom to collaborate with, is mitigated by this Intervention. Instead of having to search for peers and initiate relationships on their own, participants will connect with other motivated and relevant companies who responded to the invitation during the workshops of Intervention 3. This pushes Leverage point 4 (Chapter 3, the chicken-and-egg dilemma of data collection and group formation). By having the DSO send out invitations, it is immediately evident that all participating entrepreneurs are technically capable of collaborating in an e-hub, ensuring that group formation efforts are worthwhile.
- By addressing B5, B15 and B17, cascading effects within the system of drivers and barriers causes early participants start the development process of a new e-hub.
- However, this intervention exacerbates barrier B1: the lack of capacity in supporting roles, as it increases the amount of facilitators needed. This issue will be further discussed in Chapter 7.

Referring back to the outcomes of Chapter 2 - Framing the System, cascading effects in the multi-actor system of the orientation phase of e-hub development include:

- Stimulation of the key role, which takes a central position in the orientation phase of e-hub development, stimulating supporting roles to join efforts and move towards an energy system with integrated e-hubs.
- By stimulating and guiding the facilitator, less effort is required from the facilitator and supporting roles to identify relevant business parks and initiate the formation of an e-hub. This approach saves both time and resources for the facilitator.

Referring back to the outcomes of Chapter 1 - Investigating the Paradigm, cascading effects in the socio-technical energy system include:

- Entrepreneurs start finding each other, which will eventually lead to starting group formation (Intervention 3), includig the technical design and legal agreements of the new e-hub.

VALIDATION OF THE FUNCTIONING AND PURPOSE

- Participants comment that the invitation is clear and share a positive remark on its length. The flow chart is an easy and quick way to understand if attending the workshop is relevant for the participant. However, participants used for this validation already had knowledge on e-hubs, indicating the importance for more research towards the effectiveness of the design of the invitation for participants that do not have any knowledge yet about e-hubs.
- Facilitators comment that the invitation is an effective way to circumvent the chicken-and-egg dillema of leverage point 4 (Chapter 3), involving group formation and data collection.

INTERVENTION 3:
ENERGY COALITION BUILDING WORKSHOPS

Figure 79: Intervention 3: Energy Coalition Building Workshops (Author's image)

DESCRIPTION OF THE INTERVENTION

The Energy Coalition Building Workshops offer a context for potential participants of a yet-to-be-established e-hub to connect, exchange frustrations and interests, form coalitions, unite into a group, establish a shared vision, and initiate exploration of technical possibilities (figure 79). Serving as a catalyst for e-hub development, these workshops facilitate the initial essential steps during the orientation phase. They comprise three workshop-sessions:

1. Meet and Inform
2. Creating a Collective Vision
3. Explore Possibilities

Within these sessions, top-down guidance and direction is combined with bottom-up self-organisation and democratic decision-making, by connecting potential participants and facilitators.

INTENDED USE OF THE INTERVENTION

In order to understand the intended use of the Energy Coalition Building Workshops, first the roles of the participants and the facilitator are explained.

- The participants have all accepted the invitation of Intervention 2, meaning they are motivated to actively participate and are technically able to collaborate. Between 3 and 50 companies are situated on the same cable (Senja Boom, personal communication, april 2024), an average of 10 participants is expected to join the workshop (P16, appendix A), varying between 3 and 20 attendees.
- The facilitator's role is to ensure the completeness and accuracy of the information provided, serving as a neutral and objective centerpiece for all discussions and decisions during the workshops.

The intended use of this intervention will be elaborated upon in the following sections, delving into the three workshop sessions.

INTENDED USE OF WORKSHOP 1: MEET AND INFORM

1. Participants introduce themselves and the companies they represent to each other (figure 80). This allows them to create personal connections which are essential for forming a connected and caring group.
2. Participants express their wishes/needs regarding their business operations and energy supply/demand, and voice their frustrations about the situation. This makes clear what personal interests all participants have. Also, sharing frustrations will create a group-feeling, as every participant assumingly struggles with the same frustrations. An example for facilitators on executing this step is provided below.
3. A (standard) presentation explaining the energy system, the problems, and possible solutions (from individual to e-hub) is provided. This presentation is similarly constructed as the information in the Energy Knowledge Hub of Intervention 1. An example of included information can be found in appendix J. This allows the participants to be on the same page and speak the same language while discussing problems, creating a vision and looking for a solution.
4. The facilitator asks the participants specifically who wants to continue to the next workshop. This way, only relevant and motivated participants join the succeeding workshops and development of the e-hub.

An example for facilitators on executing the second step:

- Distribute a worksheet to all participants. Initially, allocate a few minutes for individual completion of the worksheet. Subsequently, encourage participants to share their filled worksheets with one another. A designated note-taker summarises all expressed wishes, needs, and frustrations, creating a reference for following workshop discussions. This practice increases motivation of the participants, as it forms a reminder of 'why we are here'. For an example of this worksheet, see figure 81.

What is bothering you?

- Frustrations:
- Obstacles:
- Fears:

What motivates you?

- Needs:
- Wishes:
- Goals:

Figure 81: Example worksheet for Workshop 1 (Author's image)

Figure 80: Workshop 1: Meet and Inform (Author's image)

INTENDED USE OF **WORKSHOP 2: COLLECTIVELY ENVISION**

1. Participants reflect on and add to the wishes/needs and frustrations from the previous workshop. This way, all participants are again on the same page on what they want to overcome and what they want to reach. Participants share their interests and motivations for joining the e-hub, fostering transparency and oppenness.
2. Participants brainstorm on multiple ideas for a long-term goal, envisioning both their ideal way of collaboration amongst the group, and their ideal energy supply. Ideas are voted on, reflected upon, and iterated to determine the best one (figure 82). An example for facilitators on executing this step is provided below.
3. Group cohesion can be fostered by brainstorming a name for the hub and taking a group photo.
4. A letter of intent is signed, after which quarter-hour data can be requested from the grid operator by the facilitator.

An example for facilitators on executing the second step:

- A worksheet that can be used to formulate a shared vision (figure 83). Depending on the speed of the vision-creation of the participants, sub-goals can be added. First let all participants fill in the worksheet individually for a couple of minutes. Later, let participants present their worksheets with visions. Let the group vote on different ideas, and reflect and iterate on the proposed vision.

Figure 82: Workshop 2: Collectively Envision (Author's image)

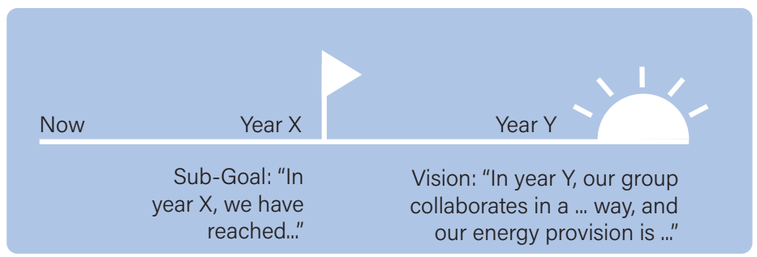


Figure 83: Example worksheet for Workshop 2: Collectively Envision (Author's image)

Figure 84: Workshop 3: Collaboratively Explore (Author's image)

INTENDED USE OF **WORKSHOP 3: COLLABORATIVELY EXPLORE**

1. Tangible examples of successful e-hubs are shown, with a focus on operational aspects.
2. Together, the technical possibilities are explored, for example, using the Zenmo tool or the calculation tool developed by the Province of Utrecht (under development) (figure 84).
3. A project group is formed to further elaborate on the technical possibilities.
4. A hub board is appointed to oversee the development and operation of the e-hub from the participants' perspective.

TIPS FOR FACILITATORS FOLLOWING THE INTENDED USE OF THE WORKSHOPS

Based on the interviews and collective brainstorming with experts on creative facilitation, co-creation and social cohesion (please refer to Chapter 1 > Research Methods for more information), the following tips for facilitators for facilitating the workshops are drafted:

- Before each workshop, clearly outline the purpose of the workshop and what is expected from the participants. Emphasise active participation; participants should come up with ideas and solutions, not the facilitator. The facilitator is there only to support where necessary.
- Schedule sufficient breaks before, during, and after the workshops. It is advisable to provide meals, snacks, and beverages during these breaks, allowing participants to form personal connections and feel comfortable with each other and build a sense of group-feeling and trust.
- It is recommended to distinguish between collective and individual parts for each workshop component. Sometimes, it works better to allow everyone five minutes to think individually about a topic before presenting ideas to each other. This way, input is gathered from all participants.
- Ensure that a note-taker is always present to make notes. This is necessary during the session to keep all participants engaged and to clarify what has been discussed. At the end of each session, these notes should be reflected upon so that everyone knows what has been discussed and what the conclusions were. It is also essential to send a summary to all participants after each workshop, so everyone stays on the same page. At the beginning of the next workshop, reflections on the summaries are made again.
- It is recommended to do a collective energiser for workshop 2. There are a lot of energisers to be found online. This helps participants feel comfortable and generate better ideas. However, pay attention to the group; in some groups, an energiser may not be taken seriously. In such cases, it is better to skip this step to prevent resistance against the workshop.
- Advised is making use of an idea repository. At any point during, before or after the workshops, ideas may emerge from the participants or facilitator. These ideas may not always be immediately applicable, but could prove valuable at a later time. Therefore, it is advised to always have an idea repository in place, where ideas can be recorded to ensure they are not lost.

THE ROLE RESPONSIBLE FOR IMPLEMENTATION OF THE INTERVENTION

The facilitator is responsible for the implementation of this intervention. As explained in Intervention 2, the province, VNO-NCW and/or PVB appoint the facilitator, therefore they are final responsible for the implementation of this intervention (figure 85).

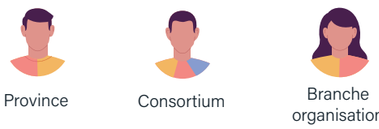


Figure 85: Province, Consortium Brance Organisation (Author's image)

KEY RESEARCH FINDINGS HIGHLIGHTING THE PURPOSE AND RELEVANCE OF THE INTERVENTION

The Energy Coalition Building Workshops stimulate the Opportunity (Chapter 4) by answering to the design cues (Chapter 5) of 'Foster connections and empathy', 'Cultivate ownership', 'Maintain motivation', 'Facilitate data collection', 'Standardise information' and 'Appoint a facilitator' (figure 86).

- Connections are fostered as the workshops provide a context for early participants to meet and form new relationships and coalitions. As outlined in the Tips for Facilitators, frequent breaks are recommended to facilitate personal connections. Empathy is cultivated through participants sharing their frustrations and goals. It is expected that many entrepreneurs will have similar frustrations and objectives, leading them to recognize themselves in each other and develop empathy for one another. Also, a collective vision is co-ceated, leading to a group-feeling.
- Ownership is cultivated by repeatedly emphasizing, both in the invitation for Intervention 2 and during the workshops, that participants are both the problem-owners and solution-owners. The facilitator's role is merely to support the process during the orientation phase, while the participants take the lead in forming coalitions. Additionally, individual interests are considered during Workshops 1 and 2. Next to this, the collectively created vision is shaped by all entrepreneurs, thereby fostering a feeling of ownership in realising this vision.
- Motivation is maintained by providing clear information and examples in Workshop 1, as well as having clear goals for the outcomes of each workshop. With small stimulants like the group name and picture, motivation is increased. Next to this, this intervention addresses participants that are already experiencing motivation, as explained in Intervention 2.
- Data collection is stimulated as the attending participants are already positioned on the same cable and/or substation as stated in Intervention 2, and the process of quarterly-hour data collection is standardised and managed by the facilitator as described at the end of Workshop 2.
- Information is standardised as the facilitator presents a standardised presentation, containing similar information as to Intervention 1.
- A facilitator supports and guides the workshops, combining top-down neutrality and direction with bottom-up grassroot innovation and emergence of

IMPACT OF THE INTERVENTION ON THE ORIENTATION PHASE

Figure 87 visuaslises the impact of the intervention on the orientation phase of e-hub development as experienced by the key role and the facilitator.

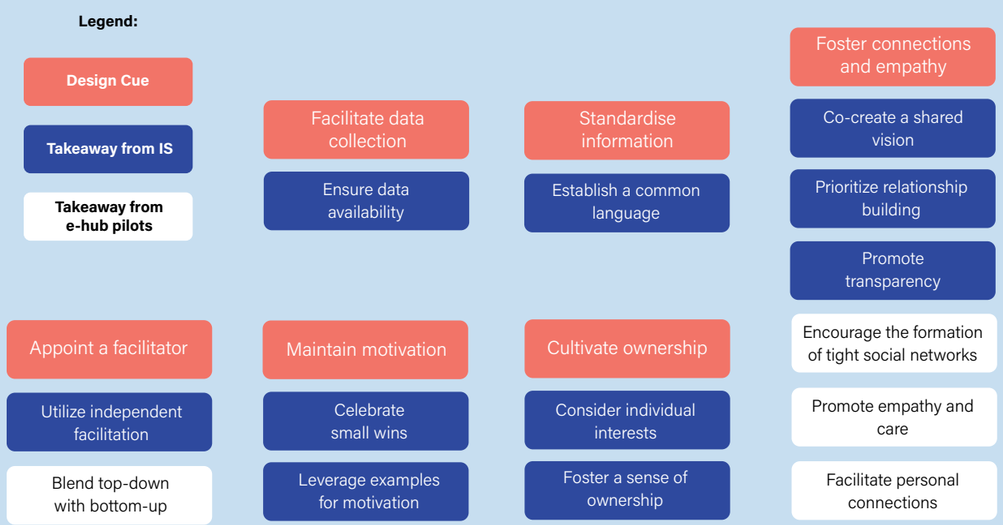


Figure 86: Design Cues implemented in Intervention 3 (Author's image)

VALIDATION OF THE FUNCTIONING AND PURPOSE

- Participants appreciate the collaborative nature of the initiative, noting the shared involvement of both participants and facilitators. They find it particularly valuable to have a structured context in which they can connect with each other and generate ideas. This fosters effective collaboration, solution-seeking and decision-making. They also enjoy the direct interaction, allowing all issues to be openly addressed.
- Facilitators express enthusiasm regarding the incorporation of the second workshop, where a shared vision is created. This addition is not yet integrated in current practices, even for experienced facilitators who are already hosting workshops for e-hub formation. One facilitator emphasizes the importance of vision creation to stimulate cohesion amongst the group. This facilitator mentions an instance in which it became apparent that one potential participant of a developing e-hub might not directly benefit from the collaboration, however this participant still had valuable contributions to offer the other participants. Thanks to the already cohesive group dynamics, this participant remained open to collaborate in the e-hub to support its peers. The facilitator highlights that the creation of a shared vision greatly stimulates the establishment of cohesive group dynamics.

CASCADING EFFECTS EXPECTED OF INTERVENTION 3

Referring back to the outcomes of Chapter 3 - Understanding the System, cascading effects in the complex system of drivers and barriers experienced by the key role include:

- Pushing the key leverage point defined as the Opportunity by mitigating barriers B9 (companies do not have existing relationships on the park) and B10 (there is a lack of communicaton between businesses on the park), by offering a context for participants to meet, start communicating and build relationships.
- B13 (companies do not trust each other) is also addressed, as companies start to trust each other as a result of the shared frustrations, shared goals and transparency in individual interests.
- D2 (having a small group of enthusiastic companies that are willing to put time and effort into the e-hub development) is directly stimulated as this intervention creates a group by attracting enthusiastic companies as explained in Intervention 2.
- By addressing the Opportunity, B13 and B2, cascading effects within the system of drivers and barriers causes early participants start the development process of a new e-hub.
- However, this intervention exacerbates barrier B1: the lack of capacity in supporting roles, as it increases the amount of facilitators needed. This issue will be further discussed in Chapter 7.

Referring back to the outcomes of Chapter 2 - Framing the System, cascading effects in the multi-actor system of the orientation phase of e-hub development include:

- Stimulation of the key role by mitigating barriers and stimulating drivers, which takes a central position in the orientation phase of e-hub development, stimulating supporting roles to join efforts and move towards an energy system with integrated e-hubs.

Referring back to the outcomes of Chapter 1 - Investigating the Paradigm, cascading effects in the socio-technical energy system include:

- Starting to form coalitions and explore opportunities for collaboration will eventually lead to engaging in new group contracts with the DSO and technical design, implementation and exploitation of the e-hub, the technical design and implementation, and thereby stimulation of new energy technology innovations.

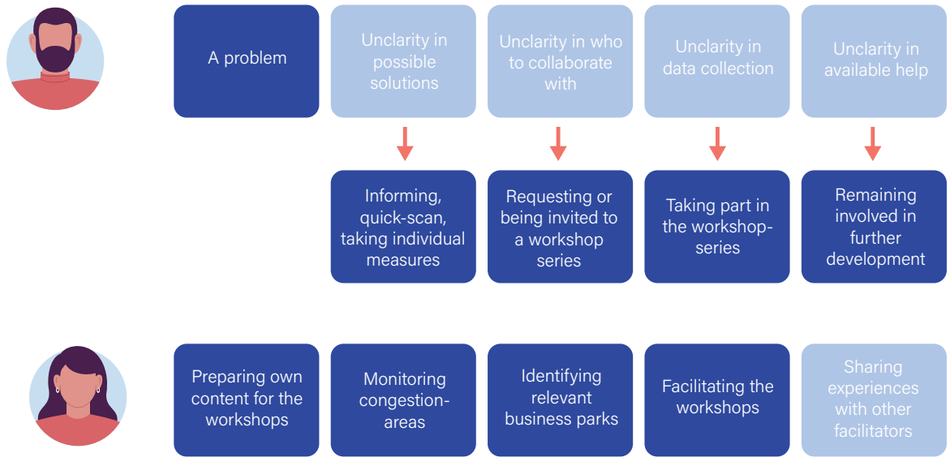


Figure 87: Impact of Intervention 3 on the orientation phase as experienced by the key role (top) and the facilitator (bottom) (Author's image)

INTERVENTION 4:
E-HUB FACILITATOR FORUM

DESCRIPTION OF THE INTERVENTION

The E-hub Facilitator Forum entails a context and/or platform where facilitators come together in order to discuss experiences, challenges, lessons learned, and new innovations (figure 88).

INTENDED USE OF THE INTERVENTION

The following points are important to address in the Forum:

- An overview of business parks in congestion areas and requested workshops as described in Intervention 2, or in other words what business parks are in need of a facilitator to guide the workshops of Intervention 3.
- An overview of e-hubs: which ones exist, their current phase of development, which facilitator assists them.
- Challenges in the facilitation of the e-hubs they facilitate, and exchange lessons learned and best practices in addressing these challenges
- New tools, frameworks, developments and information that are being or need to be developed.

The embodiment of the Facilitator Forum is preferably a monthly meeting moment, supported with an online overview similar as to Intervention 1 to ensure accessibility, and a central database for collected knowledge.

IMPACT OF THE INTERVENTION ON THE ORIENTATION PHASE

Figure 90 visuaslises the placement of the intervention in the orientation phase of e-hub development as experienced by the key role.

KEY RESEARCH FINDINGS HIGHLIGHTING THE PURPOSE AND RELEVANCE OF THE INTERVENTION

The E-hub Facilitator Forum is not directly focused on the Opportunity or Design Statement, as it is not directed to the key role. However, this intervention assures continuous improvement of all other interventions, and therefore indirectly supports all Design Cues.

Figure 88: Intervention 4: E-hub Facilitator Forum (Author's image)

THE ROLE RESPONSIBLE FOR IMPLEMENTATION OF THE INTERVENTION

The responsible role is preferably a neutral, unifying role, such as a consortium (figure 89). Examples of specific actors are PVB (similar to Intervention 2), or the NGO Energy Scale-Up. This NGO aims to accelerate the energy transition by supporting innovative companies and improving the ecosystem of e-hubs on business parks. Energy Scale-Up already facilitates a reporting point for experienced grid congestion, an online knowledge base and maintain a list of e-hubs in the Netherlands. It identifies problems experienced by entrepreneurs, and alerts governments on these. Therefore, Energy Scale-Up proves a neutral and unifying role in connecting and uniting facilitators.

Facilitators are connected, but not appointed by Energy Scale-Up foundation, as appointing facilitators (as discussed in Intervention 2) requires governmental funding and subsidies, for which the provinces, VNO-NCW and PVB have closer connections and capacity available for grant application. However, Energy Scale-Up could play a supporting role in this process.

Consortium

Figure 89: Consortium (Author's image)

VALIDATION OF THE FUNCTIONING AND PURPOSE

- Participants do not have any relevant validation on this intervention, as it is not focused on them.
- Facilitators underscore the importance of regular meetings, and agree that a monthly meeting is an efficient way to do so. A monthly facilitator-frontrunner meeting is already established (appendix I), this can be further enhanced by expanding and integrating the mentioned topics, as well as complementing it with the (online) knowledge platform.

CASCADING EFFECTSEXPECTED OF INTERVENTION 4

Referring back to the outcomes of Chapter 3 - Understanding the System, cascading effects in the complex system of drivers and barriers experienced by the key role include the mitigation of B16 (a lack in communication between supporting roles). This partly pushes leverage point 2 as described in Chapter 3, involving a lack of communication between supporting roles. However, in order to fully push this leverage point, communication between all connected roles as described in the Multi-Actor analysis of Chapter 2 is needed.

Referring back to the outcomes of Chapter 2 - Framing the System, the cascading effects in the multi-actor system during the orientation phase of e-hub include the key role being supported by the collective of facilitators, leading to a larger voice and impact on the outcomes of the multi-actor system towards its common goal of e-hub establishment.

Referring back to the outcomes of Chapter 1 - Investigating the Paradigm, cascading effects in the socio-technical energy system caused by Intervention 4 include a systematic and synchronised stimulation of the organisational dimension, leading to new coalitions and collaborations within groups of entrepreneurs that engage in contractual agreements with each other and the DSO, and consequently the technical design and implementation, and thereby stimulation of new energy technology innovations.

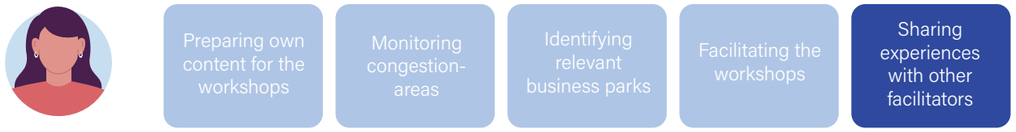


Figure 90: Impact of Intervention 3 on the orientation phase as experienced by the facilitator (Author's image)

Figure 91: The orientation phase after implementation of the Proposition, as experienced by the key role (top) and the facilitator (bottom) (Author's image)

CHAPTER 6 - DESIGNING THE PROPOSITION: CONCLUSIONS

The Design Cues resulting from Chapter 5 state **what** should be included in the design of the new proposition. This chapter focuses on **how** these Design Cues should be included into the proposition by answering the following sub-research question:

How can the success factors and lessons learned in similar systems be included in a new proposition that stimulates the orientation phase of e-hub development on Dutch business parks in 2024?

Through Participatory Innovation, a collaborative brainstorm involving the key role and supporting roles, combined with continuous and iterative validation and feedback from stakeholders and experts, multiple ideas were generated in order to translate the success factors and lessons learned in similar systems towards possible design inputs for the new proposition that stimulates e-hub development in its orientation phase on Dutch business parks in 2024. These ideas were clustered into four main themes, reflecting **how** stakeholders and experts would translate the Design Cues into the new proposition:

- Accessible and Interactive Information
- A Context to Meet and Unite
- Collectively Envision
- Collaboratively Explore

These themes, along with all their underlying ideas and research outcomes, have been transformed into the design of a proposition.

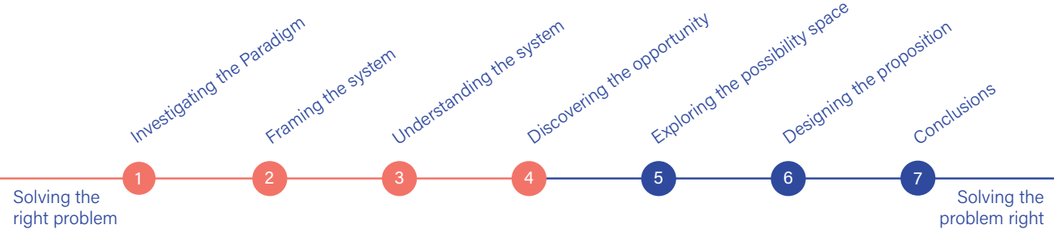
The proposition comprises four interventions during the orientation phase of e-hub development on Dutch business parks in 2024:

1. Energy Knowledge Hub
2. Participant Procurement Protocol
3. Energy Coalition Building Workshops
4. Forum for Facilitators

These interventions intervene in the organisational dimension of e-hub development as experienced by the key role as well as by the facilitator, depicted in figure 91.

The Proposition stimulates the orientation phase by intervening in the complex systems of drivers and barriers experienced by the early participant and thereby stimulating the key role, result in cascading effects and changing behaviour of the multi-actor system, resulting in cascading effects and changing behaviour of the socio-technical system.

More discussion on these cascading effects and the societial impact caused by the Proposition is provided in Chapter 7 - Conclusions.



7

CONCLUSIONS

INTRODUCTION

It can be concluded that e-hubs are an essential part of the solution for preventing and mitigating the effects of grid congestion, and thereby allow for the energy transition in the Netherlands. E-hubs provide multiple benefits for different stakeholders. Therefore, the development of e-hubs on business parks should be stimulated.

As most bottlenecks in e-hub development on Dutch business parks in 2024 emerge from the organisational dimension in the orientation phase, this is the system of focus of this thesis research.

The systemic design approach taken included ethnographically researching the caracteristics of this system, identifying leverage points and discover an Opportunity to intervene, and consequently use open participatory innovation to answer on the Opportunity and causing cascading effects on the system's behaviour.

Therefore, this thesis researche focused on stimulating e-hub development from bottom-up by introducing a new Proposition, in order to prevent grid congestion and allow for the energy transition in the Netherlands.

The conclusions of this research are explained in this chapter. First, all sub-research questions will be repeated and answered. This leads to answering the main research question of this thesis research. Consequently, the societal impact, validations, limitations and recommendations for future research are discussed. Finally, the contribution to the academic debate is discussed, both by the produced knowledge and by the innovative research approach and methods conducted.

ANSWERING THE SUB-RESEARCH QUESTIONS

Before answering the main research question, the conclusions drawn from the six sub-research questions that are answered in the six chapters of this thesis are reviewed.

CHAPTER 1 INVESTIGATING THE PARADIGM

In the first chapter of this thesis, the first sub-research question is answered:

What problems are experienced in the development of e-hubs on the large scale in the Netherlands in 2024, and what knowledge gap on overcoming these problems remains in existing literature?

E-hubs require a fundamentally different design compared to the traditional energy system, including new technologies, new contractual agreements and new organisational structues. **The development of e-hubs involves a shift from a top-down, centrally managed system to a decentralized, bottom-up approach.** This transition demands active participation and collaboration among actors who produce, consume, and/or store energy. It requires them not only to seek out new technologies but also to engage in new contractual agreements with the DSO and each other, and organize themselves in innovative ways.

This identifies e-hubs socio-technical systems. While the technical, legal and institutional dimensions of e-hubs are moving towards becoming standardised products, the organisational dimension shows bottlenecks. With 90% of business parks being currently inadequately organised and 80% not being organised at all, the **organisational dimension of e-hubs should be researched and stimulated**.

The orientation phase of e-hub development is where most uncertainties and inertia within the organisational dimension, as this is the phase were new coalitions are established. This phase therefore forms the foundation of the multi-actor and complex nature of the organisational dimension, making it the **main focus of this thesis research.**

Current practices propose solutions that involve a top-down approach, where facilitators initiate new e-hubs. However, this creates resistance in grassroot innovation and energy democracy, and due to a lack in (human) resources of facilitating roles it is desirable for e-hubs to have a self-organising character. Furthermore, while current practices promote linear frameworks for e-hub development, e-hubs are actually multi-actor and complex systems that involve unpredictable changes and evolution over time. While providing a backbone for e-hub development, **this indicates that the current solutions aren't effective or suitable for stimulating e-hub development on the large scale**.

Because of these reasons, **a new proposition is needed to stimulate and guide potential participants to organise themselves into new e-hubs, focussing on the orientation phase of their development process.**

In current academic literature, a **knowledge gap** on the design of such proposition remains on the following three aspects:

- Most research primarily focuses on describing processes and phenomena, rather than concluding their organisational implications that stimulate and activate e-hub development. Therefore, a knowledge gap remains in **actionability of research outcomes**.
- The **multi-actor and complex systems nature** of e-hubs, incorporating their caracteristics of emergence, adaptation and evolution is underresearched.
- There is a notable lack of academic understanding regarding the **drivers and barriers experienced by actors** of e-hub development, particularly within the scope of the Netherlands in 2024.

In addition to this remaining knowledge gap in the findings of current academic research (the 'what'), there also exists a gap concerning the approaches and methods used to study e-hub development (the 'how'). This **methodological gap** exists out of three aspects:

- Integrating research with the **design of an intervention** in order to not only describe but also actively promote e-hub development based on the research findings.
- The lack of **action-based empirical** qualitative data collection and analysis in order to create an understanding of the multi-actor, complex systems characteristics and dynamics of e-hub development.
- The lack of focus on the **research scope** of the organisational dimension within the orientation phase of e-hub development on business parks in the Netherlands in 2024

Therefore, the **goal of this thesis** is to research the dynamics of the multi-actor, complex system of the organisational dimension during the orientation phase of e-hub development, in order to find an intervention opportunity within this system (the first phase of this thesis: 'Solving the Right Problem'), with the objective to design a new proposition that actively stimulates this system (the second phase of this thesis: 'Solving the Problem Right'). In order to reach this goal, a systemic design approach is followed, including ethnography, systems analysis, open and participatory innovation.

CHAPTER 2 FRAMING THE SYSTEM

The 'system' resulting from Chapter 1 involves the organisational dimension during the orientation phase of e-hub development. In order to research and intervene in this system, the complexity of the multi-actor system is reduced by narrowing down the system boundaries and identifying one key role that has most influence on this multi-actor system. This key role therefore functions as the leverage point within the multi-actor system; stimulating this role results into cascading effects that activate the entire system.

Therefore this chapter focussed on answering the second sub-research question:

What is the key role that needs to be stimulated in the orientation phase of e-hub development?

The key role is defined by mapping all involved roles and evaluating their characteristics, as well as assessing their engagement within the organisational dimension of e-hub development. In order to holistically understand the dynamics of the multi-actor system, first the engagement of actors in the entire development process of e-hubs is assessed, after which focus is redirected on the orientation phase in order to assess the power and involvement each role has in the targeted system of this thesis research.

This leads to the identification of the early participant as the key role (figure 92).

Early Participant

- Be the first companies on the park to join the hub. Investing time and money, sharing data, taking the risk to start. When the hub succeeds, this role acts as an ambassador of the possibilities for other companies on the park (see the role 'late patricipants') and to potential hubs on other parks
- Mostly a group of 4 - 15 companies on the park, who experience the most drivers
- Can be multiple, see: Chapter 3 Understanding the System
- Can be multiple, see: Chapter 3 Understanding the System

Figure 92: The key role of the system (Author's image)

CHAPTER 3 UNDERSTANDING THE SYSTEM

In order to stimulate the key role identified in Chapter 2, this chapter focuses on answering the third sub-research question:

What are drivers and barriers experienced by the key role in the orientation phase of e-hub development, and what drivers and barriers serve as strategic points for intervention (leverage points) to stimulate this phase?

First, the experiences and accompanying thoughts of the key role within the system of focus are mapped, based on 28 semi-structured interviews and 9 attended knowledge-sharing events. In order to discover the cause of these experiences and thoughts, the drivers and barriers of the key role are investigated, leading to the identification of 16 drivers and 18 barriers within the system boundaries. 7 barriers were identified outside the system boundaries, these are shown in appendix F.

In order to find an intervention opportunity, which strategically stimulates drivers and mitigates barriers, the causality between as well as rootedness of these drivers and barriers are analysed, all eventually leading to the effect of early participants starting to form coalitions and starting the orientation phase of e-hub development. A combined Causal Loop Diagram (CLD) and Iceberg Model (IM) analysis led to the identification of four leverage points:

1. A lack of examples
2. A lack in communication around the e-hub
3. A lack in communication within business parks
4. A chichen-and-egg situation in group formation and data collection

CHAPTER 4 DISCOVERING THE OPPORTUNITY

Aiming to selecting one key leverage point that serves as the Opportunity for design, this chapter focuses on answering the fourth sub-research question:

What key leverage point represents the most relevant and effective opportunity for intervention to stimulate e-hub development?

The Opportunity is discovered by comparing the four leverage points resulting from Chapter 3 based on three criteria:

1. To what extent the leverage point is not yet touched by other currently evolving tools, frameworks and developments
2. The feasibility to design interventions to push the leverage point within the timeframe of the thesis project (based on the rootedness of the leverage point)
3. The impact of pushing the leverage point on the system behaviour, and therefore the effectiveness of the to-be-designed interventions on stimulating e-hub development

The Opportunity is defined as the third leverage point: A lack of communication within business parks.

This Opportunity is translated into a Design Statement that describes the goal and marks the beginning of the second phase of the thesis ('Solving the Problem Right'):

"Design a new proposition to stimulate the organisational dimension during the orientation phase of e-hub development on Dutch business parks in 2024 by encouraging early participants to consider their surrounding community in their decisions and solutions, fostering communication and relationships among businesses."

CHAPTER 5 EXPLORING THE POSSIBILITY SPACE

The Design Statement resulting from Chapter 4 is used as a starting point in this chapter in order to answer the fifth sub-research question:

What success factors and lessons learned in similar socio-technical, multi-agent complex systems development can inform the design of a new proposition that stimulates the orientation phase of e-hub development?

Elements of the Design Statement were researched and possible solutions were explored in similar contexts by means of Open Innovation. This included analysing success factors of e-hub pilots on business parks in the Netherlands in 2024, as well as gathering lessons learned on the Design Statement in Industrial Symbiosis.

These success factors and lessons learned were translated into Design Cues, that form an actionable basis for the design of the new proposition.

Eight Design Cues were identified, including:

1. Foster connections and empathy
2. Identify front-runners
3. Cultivate ownership
4. Maintain motivation
5. Offer diverse solutions
6. Facilitate data collection
7. Standardise information
8. Appoint a facilitator

CHAPTER 6 DESIGNING THE PROPOSITION

The Design Cues resulting from Chapter 5 state **what** should be included in the design of the new proposition. This chapter focuses on **how** these Design Cues should be included into the proposition by answering the following sub-research question:

How can the success factors and lessons learned in similar systems be included in a new proposition that stimulates the orientation phase of e-hub development on Dutch business parks in 2024?

Through Participatory Innovation, a collaborative brainstorm involving the key role and supporting roles, combined with continuous and iterative validation and feedback from stakeholders and experts, multiple ideas were generated in order to translate the success factors and lessons learned in similar systems towards possible design inputs for the new proposition that stimulates e-hub development in its orientation phase on Dutch business parks in 2024. These ideas were clustered into four main themes, reflecting **how** stakeholders and experts would translate the Design Cues into the new proposition:

- Accessible and Interactive Information
- A Context to Meet and Unite
- Collectively Envision
- Collaboratively Explore

These themes, along with all their underlying ideas and research outcomes, have been transformed into the design of a proposition.

The proposition comprises four interventions during the orientation phase of e-hub development on Dutch business parks in 2024:

1. Energy Knowledge Hub
2. Participant Procurement Protocol
3. Energy Coalition Building Workshops
4. Forum for Facilitators

ANSWERING THE MAIN RESEARCH QUESTION

The six sub-research questions led to the answer to the main research question:

How can the organisational dimension during the orientation phase of energy hub development on business parks in the Netherlands in 2024 be stimulated?

In conclusion, the orientation phase of e-hub development in business parks in the Netherlands in 2024 can be stimulated by implementing the newly designed proposition comprising of four interventions.

By defining, perceiving and researching the orientation phase of e-hub development as being a socio-technical, multi-actor complex system, leverage points within this system could be discovered. Leverage points are places within the system where a small change in input leads to cascading effects and large shifts in system behaviour. This allows relatively small design efforts to be both **effective** and **impactful** in the stimulation of the organisational dimension during the orientation phase of e-hub development.

In order to discover a key leverage point, or Opportunity for design, complexity of the system should be navigated. By continuously prioritising and zooming in, the system boundaries and therewith solution area were narrowed. First, complexity of the socio-technical dynamics was navigated by prioritising the organisational dimension, showing the most bottlenecks in e-hub development. Second, complexity of the multi-actor dynamics was navigated by prioritising the early participant as the key role, having the most power and involvement in the organisational dimension during the orientation phase of e-hub development. Third, the complex system of drivers and barriers experienced by the key role is navigated by analysing causal relationships between and rootedess of these drivers and barriers. This led to the identification of the Opportunity for intervention that is not yet touched by current developments, feasible within the timeframe of the thesis research and impactful on the system behaviour. This Opportunity is to encourage early participants to consider their surrounding community in their decisions and solutions, fostering communication and relationships between businesses.

This Opportunity is seized with a new Proposition that comprises four interventions during the orientation phase of e-hub development on Dutch business parks in 2024:

1. Energy Knowledge Hub
2. Participant Procurement Protocol
3. Energy Coalition Building Workshops
4. Forum for Facilitators

These interventions aim to merge a bottom-up approach, which promotes energy democracy and grassroots innovation, with a top-down approach that ensures balance and direction. This is achieved by uniting the early participants and the facilitator.

The Proposition is built on lessons learnt in similar systems, being e-hub pilots and Industrial Symbiotic clusters on business parks in the Netherlands in 2024.

As the interventions are designed in collaboration with the intended users, surrounding stakeholders and experts, they represent **feasible** and **viable** solutions for businesses on Dutch business parks in 2024 to seize the Opportunity.

By capitalising on the Opportunity, cascading effects stemming from the causal relationships between drivers and barriers will stimulate early participants to start developing e-hubs, by mitigating barriers and stimulating drivers. As early participants have the most power and involvement in the orientation phase of e-hub development, their initial actions will trigger cascading effects, drawing supporting roles into the development process and stimulating the organisational dimension of e-hub development in its orientation phase. This will trigger cascading effects on the socio-technical system, as the coalitions, collaborations and agreements established in the organisational dimension will lead to new contractual agreements and, eventually, the technical design and implementation of e-hubs on business parks across the Netherlands in 2024.

HIGHLIGHTS OF THE RESAERCH OUTCOMES - THE PROPOSITION

IMPACT ON THE SYSTEM: PUSHING LEVERAGE POINTS

The four interventions that make up the Proposition are mainly revolving about Intervention 3; the Energy Coalition Building Workshops. In this intervention, the Design Statement is answered and the key leverage point that represents the Opportunity for intervention (leverage point 3; A lack in communication between businesses, Chapter 3) is pushed, by mitigating drivers B15 (a lack of comunity consideration), B9 (companies do not have existing relationships on the park) and B10 (lacking communication between businesses on business parks), as well as fostering trust between companies (B13).

While Intervention 1, 2 and 4 focus on the practical support of Intervention 3, they also mitigate barriers and stimulate drivers, such as increasing public knowledge on energy and e-hubs (B7), providing realistic expectations (B5), facilitating connections among motivated companies (B17) and partially improving communication between supporting roles (B16). The Proposition directly stimulates the drivers of having knowledge on lessons learned in other e-hubs (D4), The realisation there is a shared problem (D8), the realisation it is possible to collaborate (D9), and most importantly the Proposition addresses and stimulates a small group of motivated companies that are willing to put time and effort into the development of the e-hub (D2)

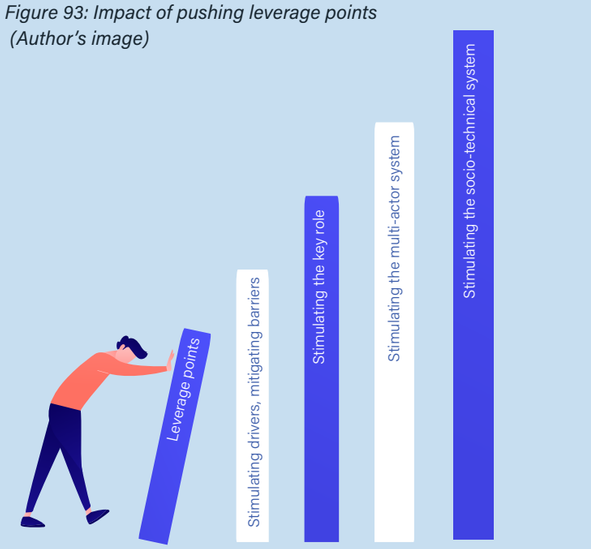
By mitigating these drivers and stimulating these barriers, the Proposition does not only push Leverage point 3; a lack in communication between businesses, but simultaneously pushes Leverage point 4; a chicken-and-egg situation in data collection and group formation. Leverage point 1; a lack of practical examples is not directly pushed by the Proposition, but will be indirectly addressed resulting from the cascading effects of the system; as implementation of the Proposition will lead to two reinforcing loops revolving 'the ambassador-effect', with which e-hubs on business parks will grow, as well as the amount of e-hubs on different business parks, and thus the amount of examples, addressing Leverage point 1. Leverage point 2 is not yet completely pushed by the implementation of the Proposition. While Interventions 2 and 4 require collaborations between facilitators, the province, the DSO, branch organisations and consortia, which will expectedly stimulate the multi-actor system in moving towards its goal of e-hub development. However, the Proposition does not specifically address the collaborations between all different roles. This will be further discussed in the sections 'Limitations of the proposition' and 'Recommendations for practitioners.'

Pushing the key leverage point and addressing additional drivers and barriers, cascading effects within the complex system of drivers and barriers as experienced by the key role will lead to the effect of early participants initiating the orientation pase of e-hub development. By stimulating the early participant, who has the most power over and involvement into the orientation phase of e-hub development, the ball starts rolling in the orientation phase and consequently cascading effects will stimulate supporting roles, who all experience drivers and thus have an interest in e-hub development as described in Chapter 2.

These cascading effects in the complex system of drivers and barriers of the early participant and thereby stimulating the multi-actor system will result into ripple effects on the legal and institutional and technical dimensions of the socio-technical system of e-hub development, by engaging in new contractual agreements, pressuring policy, law and regulation, and technical design and implementation of assets and software and thereby stimulating new energy technology innovations (figure 93).

Finally, the implementation of the Propisition will stimulate e-hub development and thereby the large-scale establishment of new e-hubs on business parks in the Netherlands in 2024, thereby preventing and circumventing grid congestion and allowing for the energy transition. More about these societal effects will be discussed in the section 'Societal implications of the Proposition'

Figure 93: Impact of pushing leverage points (Author's image)



FILLING THE GAP IN CURRENT PRACTICES AND THE ROLE OF THE FACILITATOR

As stated in Chapter 1 (page 30), current practices show two main limitations, including:

1. Their linear, one-size-fits-all approach for stimulating a complex, multi-actor socio-technical system involving unpredictable emergence, adaptation and evolution
2. Their reliance on the facilitator in a top-down approach, causing inefficiency, resistance in grassroot innovation, and deficiencies in the availability of facilitators.

The Proposition concluding this thesis research is not a replacement of, but rather an addition to these current practices, overcoming their limitations.

Overcoming the first limitation of current practices, the Proposition does not aim to fit a complex, multi-actor, emerging system into a linear, one-size-fits-all approach. Rather, the Proposition provides a launch pad for e-hub development, offering a context to emerge as well as initial guidance, after which the complex multi-actor socio-technical system can evolve and adapt to unpredictable local conditions.

In addressing the second limitation, the Proposition involves a remarkable outcome as **it still relies on the presence of a facilitator.** However, a significant difference between the intended role of the facilitator exists between current practices and the Proposition. This discrepancy is explained by distinguishing **three main differences within the intended role of the facilitator:**

1. In current practices, the facilitator is dependent on, or has to simultaneously bear the role of 'Connector' having to win the trust of the participants (further explained in Chapter 2, repeated in figure 94). In the top-down approach of current practices, the facilitator has to introduce itself, as well as all early participants to one another.
    1. In the Proposition, the participants are not approached one by one, but meet each other all at the same time, having the same goal and basic background information, being motivated to collaborate. This saves a vast amount of time for the facilitator.
2. As explained in the quotes in Chapter 1 (page 30), the top-down approach and the facilitator initiating e-hub development creates resistance by early participants and causes inertia in the development process.
    2. In the Proposition, the role of 'initiator' (Chapter 2) is beared by the early participant instead of the facilitator, mitigating this resistance. Next to this, early participants are clearly informed that they are the problem-owners, as well as the solution-owners. The facilitator is not the solver of their problems, but guides the process of self-organisation by early participants.
3. As described in the quotes by current facilitators in Chapter 1 (page 30), the current facilitator role includes constantly keep all participants informed, focussed and motivated. This causes an inefficient use of the limited available time of facilitators.
    3. In the Proposition, attending early participants are all experiencing large drivers for the development of an e-hub, which they are aware of before taking part in the development process. This makes them motivated to stay informed and collaborate throughout the orientation phase, or decide to leave if the e-hub appears not a relevant solution for them. By introducing this bottom-up element instead of only taking a top-down focus, this limitation of current practices is overcome.

However, current practices provide a relevant backbone that serves as an example, and highlights certain necessary steps like legal requirements. **Therefore, the Proposition is not intended as a replacement of, but rather an addition to current practices, mitigating their limitations.**

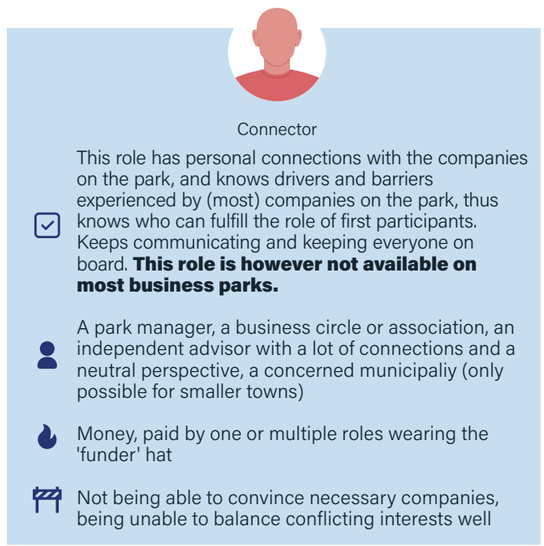


Figure 94: Repetition of the 'Connector' role, as explained in Chapter 2. (Author's image)

LIMITATIONS OF THE PROPOSITION:

Limitations of the proposition include:

- The Proposition **mainly addresses highly motivated potential early participants**. However, businesses that are less motivated could offer benefits to the e-hub, for example if they can offer a lot of flexibility in their processes. Nonetheless, it can be argued that while the inclusion of all companies on the park would possibly result in a large resilience and flexibility in collaborations, the organisational dimension of the orientation phase is dependent on the motivation and forthcoming active participation of early participants, and is experiencing less barriers when developed in a small group of early participants in order to foster communication and close relationships, as discussed in Chapter 3.
  By adopting this limited focus in the Proposition, more e-hubs can be kickstarted, leading to the ambassador-effect, after which the late participants can join the hub and offer their flexibility and other benefits.
- The Proposition **does not fully push leverage point 2**: a lack in communication in supporting roles. Communication between supporting roles (except between the facilitators in Intervention 4) is not stimulated within the Proposition. In next section, recommendations to practitioners are provided in order to overcome this limitation.
- As discussed in last section, the Proposition is dependent on the **limited amount of available facilitators**. However the Proposition streamlines and optimises the available time of the facilitators, this limited availability could still impose barriers for the development of e-hubs after implementation of the Proposition. In next section, recommendations to practitioners are provided in order to overcome this limitation.
- The Proposition does **not include specific tools and/or methods in order to map, visualise and discuss the quarterly-hour energy data** of participants and consequently exploring possible collaborations. While some currently developing tools are recommended (see Intervention 3 > Workshop 3). In next section, recommendations to practitioners are provided in order to overcome this limitation.
- Due to the system boundaries and assumptions of this thesis research (Chapter 2 > System Boundaries and Assumptions), some experienced **barriers fell outside of the research scope**. However, these barriers were mentioned a vast amount of times by multiple roles, indicating their importance of e-hub development. These barriers, as well as their impact on the system of drivers and barriers, can be found in appendix F. In next section, recommendations to practitioners are provided in order to overcome this limitation.

RECOMMENDATIONS FOR PRACTITIONERS

Recommendations following the outcomes of this master thesis research start with general recommendations for practitioners, followed by dividing role-specific recommendations.

ALL PRACTITIONERS:

- As described in last section, **leverage point 2** involving a lack in communication between supporting roles is not fully addressed in this thesis research project. Recommended is future research by practitioners into **effective ways to share knowledge, unite efforts, and efficiently and effectively collaborate** on stimulating e-hub development. An example of such collaboration is the VrouwenPower Whatsapp-group, in which around 60 highly motivated women from all different roles within the energy transition share news, projects, new knowledge and their experienced challenges. This allows for quick communication between different roles, fostering collaboration, innovation and impact. Next to this, regular meeting moments, or a platform / context similar to Intervention 4 - Forum For Facilitators could overcome this limitation.
- As described in last section, the Proposition is still dependent on the limitedly available facilitators. While Intervention 2 - Participant Procurement Protocol describes the Province, PVB and/or VNO-NCW to be the responsible roles for assigning facilitators, it is highly recommended for **all supporting roles to stimulate (the assignment of) facilitators and lobby** at governmental institutions in order to collect funding in order to increase the amount of facilitators.
- As described in last section the Proposition does not address barriers out of scope of this thesis research, while these barriers cause large effects on the system's behaviour. Appendix F shows these barriers and their effects on the system's behaviour. In order to mitigate these barriers, recommended is all practitioners **researching these barriers out of scope** and possible solutions they could propose in order to mitigate these barriers.
- The Proposition is not a plug-and-play product, but is intended as a disruption in current practices and an example of doing so. The specific roles mentioned as being responsible for each intervention have to take responsibility in **further design, embodiment and implementation of each intervention**.
- Assume each intervention is never optimised nor complete. As described in the limitations of the Proposition, the experienced drivers and barriers, the multi-actor system and the socio-technical system are constantly evolving. This underscores the necessity of **constant improvement and iteration** of all interventions.

- Assume that you never know the complete answer to existing problems within e-hub development. During the course of my thesis research project, I, as a neutral researcher, had the privilege to speaking with a wide variety of stakeholders and experts. What stood out during these conversations was that different stakeholders and expert had different views on the development of e-hubs. In itself, this is not a problem, as e-hubs are such complex systems it would be almost impossible to find completely similar perspectives from different actors within the system. However, what caused limitations within the development of e-hubs was multiple actors were convinced of their own perception of 'the solution,' making them less prone to listen to other actors and be open to the complexity of the system. As explained before, e-hubs are multi-actor, complex systems, constantly need new ideas, collaborations and solutions. Remember that you, as a practitioner, are part of this system, not its manager. This includes constantly **doubting your own perspective, listening to the system, placing yourself in this system and adapting your input accordingly**.

DSOs:

- As described in Intervention 1 - Energy Knowledge Hub, you are the central player on energy knowledge, and thereby the key to all data, holistic and accurate knowledge on energy innovations in the Netherlands. As the transition towards a decentralised energy system (Chapter 1) shifts your role from top-down manager of energy transportation towards the facilitator of bottom-up energy exchange and thereby the energy market facilitator, it is essential that you provide correct, current and clear information to all that want to enter this market (by for example establishing an e-hub). It is therefore highly recommended to conduct additional research to and put efforts in **streamlining your information and data provision** to consumers, producers and prosumers. In order to do so, it is important to empathise with these consumers, producers and prosumers, in order to understand what they need to know, what they want to know, and how they want to gain this knowledge.

PROVINCE, PVB, VNO-NCW:

- As described in last section (limitations), the Proposition does not include a standardised tool and/or method for data mapping and visualisation, to serve as a basis for discussion on possible collaborations by participants in Intervention 3 - Workshop 3. It is therefore recommended to conduct future research towards the **development of a (nationally) standardised tool in order to facilitate this step**. Recommended is to **collaborate with other supporting roles** on a national scale, in order to increase the speed of development and implementation of this data visualisation tool.
- To build on last recommendation, future research could be conducted towards the development of such data visualisation tool that shows **aggregated data of multiple businesses on the park, that could be implemented in a quick scan** (Intervention 1). This way, participants can explore possible collaborations and thereby their relevance of joining the Energy Coalition Building Workshops of Intervention 3. Examples of data technologies that could be utilised for anonymised aggregated data visualisation include Secure Multi-Parti Computation, Differential Privacy, Homomorphic Encryption, Data Anonymisation and Aggregation, Zero-Knowledge Proofs, Blockchain and Smart Contracts (based on personal informal communication with a data-science expert, March 16, 2024).
- As you play a central role in connecting participants, facilitators and supporting roles, recommended is the **organisation of regular meetings, presentations, knowledge-sharing sessions and other events** that are attendable for all interested parties in order to inform themselves and others, connect, and boost the development of e-hubs.

PARTIES THAT DEVELOP HOLISTIC FRAMEWORKS, SUCH AS MOOI EIGEN, PROVINCIE UTRECHT, FIRAN:

- As mentioned in recommendations to 'all practitioners,' solutions are never finished and need to constantly evolve, adapt and answer to the rapidly changing landscape of e-hub development. It is therefore recommended to **add the possibility for interaction into your frameworks**.
- E-hub development is a complex process and includes a large amount of steps, conditions and information. It is therefore recommended to **clearly visualise your framework** and all its steps, in order to allow for easy navigation and understanding by the intended users.

BUSINESSES:

- Acknowledge that you are the key role. You have the power to involve supporting roles and decide on the direction, pace and process of the development of an e-hub on your business park. Recommended is active participation in both e-hub development on your business park, as well as in the large-scale societal development of e-hubs by **clearly communicating your experiences, needs, challenges, and recommendations for supporting roles.**

THE SOCIETAL IMPLICATIONS

The following sections explain the societal implications of the research outcomes. First, the urgency of the societal problem and the expected growth of e-hub development are discussed, after which the societal relevance and implications are validated and put to action.

URGENCY OF SOLUTIONS FOR THE SOCIETAL PROBLEM

E-hub development is necessary, e-hubs are needed now. As explained in Chapter 1, due to grid congestion new companies cannot obtain a grid connection, existing companies cannot expand nor decarbonise. On most events attended during this thesis research project, experts warned that grid congestion will become one of the biggest national problems in the coming years (appendix B). It poses a very significant obstacle to the energy transition, some participants of this research spoken to during events even mentioned having a diesel generator at their facilities, because they have no other option. Grid congestion will leave many businesses, residential areas and public facilities in dire straits. As explained in Chapter 1, e-hubs are an essential part of the solution of overcoming grid congestion, and have to be stimulated.

Given the urgency posed by grid congestion and the energy transition, solutions must be implemented rapidly. There is **no time to wait for political decisions, policy adjustments or technological advancements such as reinforcement of the grid**. By addressing responsible roles for every intervention of the Proposition resulting this tesis research project, solutions can be implemented promptly, and the development of e-hubs will be directly stimulated.

EXPECTED GROWTH OF E-HUB DEVELOPMENT

Implementing the Proposition in current practices will **stimulate the growth of e-hub development, both within and beyond the scope of this research**.

Within the scope, the expected implications of the solutions suggested by this master thesis research can be explained by means of referring back to the Combined Causal Loop Diagram and Iceberg Model (CLD/MLA) Analaysis of Chapter 3. By pushing the leverage point and overcoming additional barriers and stimulating additional drivers when implementing the proposition, the effects on the system include:

- An **ambassador-effect within the hub**: a small group of early participants will develop some small successes. These successes are noticed by other companies on the business park, who will join the e-hub as well. This means the hub expands, providing advantages for more companies. Additional advantages of growing e-hubs include enhanced resilience and reliability, due to a larger diversity of energy sources and services available within the hub. Also, increased participations fosters economies of scale, leading to cost effectiveness in shared assets and infrastructure development.
- An **ambassador-effect on the larger scale**: as some hubs will start showing successes in their development, other business parks in the Netherlands will pick up the possibility and advantages of developing an e-hub. This leads to a vicious cycle of the growth of e-hubs on Dutch business parks and later residential areas, and an increasing knowledge base on their development processes.

Beyond the scope of this research, the ambassador-effect will cause an increasing amount of public knowledge on energy and e-hubs. During the events attended in this research project (appendix B), experts and stakeholders highlighted the increasing demand for e-hubs in residential areas, such as neighbourhoods and high-rise residential buildings. The increased amount of public knowledge, together with other outcomes and research methods of this thesis research can serve as a foundation for **research and design of e-hub development in residential areas**.

VALIDATION OF SOCIETAL RELEVANCE AND ADDITION TO CURRENT PRACTICES

This societal relevance was validated after the results were presented to a front-runners group of e-hubs in the Netherlands. Attendees of this group included key players in the development of e-hubs on business parks, representing both participants and supporting roles. More information and minutes of this session can be found in appendix I. Quotes of feedback include:

"A first and very interesting research incorporating the social view of participants. Normally research to e-hubs focuses on policy-advise or technical possibilities."

– Attendee of front-runners meeting

"The first time that a workshop is proposed – all earlier propositions focus on digitalisation and data flows. This is important for the change-management that is needed for e-hubs."

– Attendee of front-runners meeting

"Interesting and complete view of the viewpoint of the participants. This increases the understanding of the problems experienced in the field by facilitators who are not in direct contact with participants, such as policymakers or decision-makers in provinces, municipalities, DSOs, etc."

– Attendee of front-runners meeting

PUTTING OUTCOMES TO **ACTION**

After this thesis research is concluded, **possibilities will be invested to apply for MOOI subsidies to implement its outcomes**, in collaboration with the EnergyScale-Up foundation. MOOI subsidies are subsidies provided by the government of the Netherlands as part of the Mission-Driven Research, Development and Innovation program (in Dutch: Missiegedreven Onderzoek, Ontwikkeling en Innovatie). These subsidies are intended to support innovative projects that contribute to the energy transition and the achievement of climate goals.

FILLING THE **KNOWLEDGE GAP IN ACADEMIC LITERATURE**

In current academic literature, a **knowledge gap** on the design of such proposition remains on the following three aspects:

- Most research primarily focuses on describing processes and phenomena, rather than concluding their organisational implications that stimulate and activate e-hub development. Therefore, a knowledge gap remains in **actionability of research outcomes**.
- The **multi-actor and complex systems nature** of e-hubs, incorporating their caracteristics of emergence, adaptation and evolution is underresearched.
- There is a notable lack of academic understanding regarding the **drivers and barriers experienced by actors** of e-hub development, particularly within the scope of the Netherlands in 2024.

This section examines how the research outcomes address these three aspects of the knowledge gap and highlights differences and similarities with the outcomes of existing academic literature.

ADDRESSING **ACTIONABILITY**

Only one reviewed research does not only focus on describing phenomena and processes, but actually desings an intervention to actively stimulate the development of e-hubs or similar community energy initatives (Revesz et al., 2022). Other literature does not go into detail on organisational and managerial implications of the research outcomes, limiting the actionability of the research outcomes.

In this master thesis, not only are phenomena and processes described (Chapter 1, 2, 3), also an **active alteration into the system is proposed** (Chapter 5, 6). Next to this, this thesis research offers **clear guidelines on managerial implications**, by specifying the roles that need to implement the proposed interventions and providing clear recommendations to practitioners.

ADDRESSING **MULTI-ACTOR AND COMPLEX SYSTEMS**

While current academic literature does perceive e-hubs as multi-actor systems, there is little knowledge on their characteristics of emergence, adaptation and evolution that accompany the multi-actor and complex nature of e-hubs.

This research does not empirically observe these characteristics and their development over time. However, by **perceiving e-hubs as having these characteristics**, systems dynamics and causality between system elements (such as drivers, barriers, actors, legal, institutional and technological aspects) are researched, mapped, and taken as a starting point for design. This shapes a knowledge base conductive to the emergence, adaptation and evolution of the system over time. Consequently, this adds relevant insights to current academic literature by diverging from simplifying e-hub development into linear or standardised processes.

ADDRESSING **DRIVERS AND BARRIERS**

In current academic literature, drivers and barriers that **result from** the interactions within the multi-actor system are concluded, while knowledge on drivers and barriers **experienced by** specific actors are missing.

This thesis research adds relevant insights to existing literature by empirically researching, mapping and concluding drivers and barriers experienced by the key role (the early participant), as well as drivers experienced by supporting roles within the multi-actor system and the barriers these roles can impose to the system (Chapter 2).

Next to this, these drivers and barriers are researched **within the scope of the Netherlands in 2024**. Knowledge within this specific scope is important due to the fast pace of the energy transition and its varying implications on different geographical locations due to policy and regulations as explained in Chapter 1, causing differences in experienced drivers and barriers in varying geographical or temporal scopes.

REMARKABLE **SIMILARITIES** WITH EXISTING ACADEMIC KNOWLEDGE

Warbroek et al. (2019) state that a large sucess factor for the organisational dimension of e-hub development is having 'project champions.' These are the driving volunteers and starters of the initiative. This is similar to the identification of two different roles that businesses can bear; the early participant and the late participant. The early participant functions as the described project champions, as highly motivated entrepreneurs initiate the development of the e-hub. Showing their successes to other entrepreneurs on the park, causing the 'ambassador-effect' as described in Chapter 3, causes the motivated early participants to indeed pose a large success factor for e-hub development.

Van de Grift & Cuppen (2022) describe that actors of new energy technologies respond to public concerns by using public engagement and by educating the public. Based on this thesis research, the importance of this observation is underscored, confirming the importance of public engagement and accessible education on energy and e-hubs in e-hub development.

Only the research of Chilvers et al. (2018) describe the multi-actor, complex characteristics of emergence, adaptation and the complex nature in their 'ecologies of participation', combining the 'who' (actors and stakeholders), the 'what' (technology, infrastructure, data) and the 'how' (structures and tools to facilitate the participation). However, this research remains descriptive and conceptual, not introducing actionable knowledge.

This research does not specifically focuses on the 'what', however arguments that the 'how' will have cascading effects on the 'who' and consequently on the 'what.' **It can therefore be concluded that e-hubs indeed exist out of 'ecologies of participation' as described by Chilvers et al. (2018),** in which different dimensions are greatly dependent on one another, and shifts in one aspect of the system can cause ripple effects significantly alterating other aspects in different dimensions, triggering shifts in system behaviour.

REMARKABLE **DIFFERENCES** WITH EXISTING ACADEMIC KNOWLEDGE

A difference between the outcomes of this thesis research and existing academic knowledge of Rodhouse et al. (2023) exists. They describe the importance of the timing in, the timing of, and the actor positions within expectation management in the co-creation process of e-hubs. While the expectations actors have of the system are addressed in the drivers and barriers of Chapter 3 as well as designed for in the Proposition, **no specific attention was provided to the timing in, the timing of and the actor positions within managing these expectations in this research**.

Also, while drivers and barriers **experienced by actors** of e-hubs in the Netherlands in 2024 were missing in current academic knowledge, this thesis research does not investigate the drivers and barriers **resulting from actor interactions**. These can provide relevant knowledge for the stimulation of e-hub development, as they can be used to study the in-depth multi-actor dynamics. Where this thesis research simplifies the multi-actor dynamics by selecting one key role, these in-depth multi-actor dynamics could have significant influence on the behaviour of the system.

Only the research of Chilvers et al. (2018) describe the multi-actor, complex characteristics of emergence, adaptation and the complex nature. However, this research remains descriptive and conceptual, not introducing actionable knowledge. This thesis research combines the aspects of the ecologies of participation as described by Chilvers et al. (2018), by focusing on the dynamics within the 'who' (the multi-actor system) and actively stimulating these dynamics with, as well as researching the current 'how' (researching current practices and designing the Proposition), and consequently **producing actionable knowledge** on the stimulation of these ecologies.

RECOMMENDATIONS FOR **ACADEMIA** FOLLOWING THE **RESEARCH OUTCOMES**

In conclusion, the academic knowledge gap that exists in the combination of actionability, perception of e-hubs as socio-technical, multi-actor complex systems, and experienced drivers and barriers by actors of e-hubs in the Netherlands in 2024 is addressed in this thesis research.

However, some recommendations for further research to build on this knowledge, and to overcome its limitations, include:

- As described in 'Addressing multi-actor and complex systems', **this thesis research does not empirically observe the multi-actor complex characteristics of emergence, adaptation and evolution over time.** In order to identify reoccuring patterns in the systemic dynamics between drivers and barriers, actor interactions and socio-technical elements over time, a longitudinal research to these phenomena is recommended.
- As described in 'Addressing drivers and barriers', experienced drivers and barriers are scope-dependent. As the energy transition moves in a rapid pace, a **longitudinal research on the experienced drivers and barriers is recommended to ensure the relevance** of the research outcomes.
- As described in 'Remarkable differences with existing academic knowledge', in this thesis research the (timing in, timing of, and actor positions in) **expectation management in co-creating e-hubs is not addressed.** Recommended is an empirical, action-based research to these phenomena within e-hubs on business parks in the Netherlands in 2024, and consequently how interventions can be designed optimising these aspects and therefore stimulating e-hub development.
- As described in 'Remarkable differences with existing academic knowledge', this research focuses on the drivers and barriers experienced by actors. Recommended is a **empirical research to the drivers and barriers resulting from actor interactions**, in order to research how these influence the system behaviour of e-hub development, and identify inefficiencies in the current definitions of roles, positions of roles and dynamics between roles. Consequently, these inefficiencies can be solved by researching and designing an actionable intervention in order to stimulate e-hub development.
- Further than researching the drivers and barriers for e-hub development resulting from the multi-actor dynamics as described in last recommendation, a **longitudinal study to their forthcoming and evolution** could provide relevant knowledge on reoccuring patterns, identifying new opportunities for intervention within the system in order to stimulate e-hub development.
- Next to focusing on multi-actor dynamics with the goal of stimulating e-hub development, future research should investigate the **interactions between the actors themselves rather than their interactions (including experienced drivers and proposed barriers) in relation to the system goal**. This approach would allow for a deeper understanding of how and why they collaborate, what they offer to each other, and what they need from one another. Additionally, conducting a longitudinal study over time would provide inisights to the emergent behaviour of this system and possibly identify patterns in these behaviours over time, creating a deep understanding of the multi-actor dynamics of e-hubs.
- Also, the 'early participant' is assumed to be one homogeneous role in this thesis research in order to simplify the system, allowing research and design. However in reality, various differences exist between multiple the characteristics of, and drivers and barriers experienced by early participants. **Chapter 3 shows this simplification by grouping B18. Dynamics between different actors within the role of 'early participant' and their effects on the system behaviour should be further researched**. These dynamics could for example include the difference between renters and owners of facilities, different sizes of companies, different processes of companies, etc., and their forthcoming interactions, drivers and barriers.
- Building on last recommendation, on top of researching system dynamics between different companies within an e-hub, recommended is further research **focussing on system dynamics and effects caused by different types of entrepreneurs within these companies**. As described in Chapters 2, 3, and 5, personal human characteristics like age, entrepreneurial mindset, sustainability-focus, religion, could all influence the behaviour of the entrepreneur, and thus of the company, within business parks. Success factors, pitfalls and according opportunities for interventions caused by these personal characteristics should be studied, in order to investigate what their relationship is to the success of e-hub development.
- The produced knowledge is a result of the conducted research methods constructing this thesis research. As described in Chapter 1 > Research Approach, these methods limit the knowledge produced by imposing a **sample bias** within the ethnographic research, as well as a temporal constraint as the retreived data represents a specific moment in time. Therefore, recommended is continuous future research, randomly selecting developing e-hubs from all parts of the Netherlands.
- Lastly, the research methods of this thesis research limit the knowledge produced by taking only a **small sample of interviewed experts on Industriel Symbiosis**. While results from these interviews were triangulated with a report on the success factors of IS in the Netherlands, additional research to lessons learned in IS clusters on Dutch business parks is recommended.

HIGHLIGHTS OF THE RESEARCH PROCESS - SYSTEMIC DESIGN

ADDRESSING THE METHODOLOGICAL GAP IN CURRENT ACADEMIC LITERATURE

While the outcomes of this research, mainly the Proposition, are an important addition to current practices, the **true addition to the academic debate cause by this master thesis lies in not the outcomes, but the research approach** and according methods conducted in this research project. In this section, first the methodological gap in current literature is reviewed and the contribution of this research in relation to the gap is discussed. Specific methodological highlights will be discussed, after which the relevance of the taken research approach at large to the academic debate is discussed.

In existing academic literature, a methodological gap remains in researching e-hubs by combining the following approaches:

- **Action-based empirical qualitative data collection and analysis** in order to create an understanding of the multi-actor, complex systems characteristic of e-hubs.
- Focussing on the **organisational dimension** in the orientation phase of e-hub development on business parks in the Netherlands in 2024
- Combining this research with the **design of an intervention** to stimulate the development of e-hubs.

This thesis research addresses this gap by implementing **ethnography** into the research approach, providing a deep and accurate understanding of multi-actor mechanisms such as engagement, power and involvement, as well as of the complex dynamics of drivers and barriers experienced by the early participant. This approach **emphasises the organisational dimension** in the orientation phase of e-hub development on business parks in the Netherlands in 2024. In addition to researching these phenomena, this thesis research takes a **systemic design approach** in order to leverage the systemic research (Solving the Right Problem) by the design of interventions (Solving the Problem Right), actively stimulating the system rather than merely describing observed phenomena.

Highlights of addressing the methodological gap and the contribution to academia are discussed in next sections.

METHODOLOGICAL HIGHLIGHTS AND THEIR CONTRIBUTION TO ACADEMIA

As discussed in Chapter 1 > Research Approach, systemic design is a young discipline, not yet containing any restricted guidelines or research methodologies. Therefore, this master thesis focused on filling the methodological gap in current academic literature by composing a new **medley of methodologies**, focussing on both efficiently and effectively mapping and scoping system dynamics as well as efficiently and effectively pushing leverage points. Exact details on the interaction between the methodologies and accompanying methods conducted are described in Chapter 1 > Research Approach. In this section, highlights and significant additions to current academia caused by the medley of methodologies and research methods are discussed. Three main highlights are discussed; designing interventions within multi-actor complexity, combining causality and rootedness in systemic design by the combined CLD and IM analysis, and the use of open participatory innovation in fast-moving transitions.

DESIGNING INTERVENTIONS WITHIN MULTI-ACTOR COMPLEXITY

Designing interventions within multi-actor complexity calls for a significantly different approach than analysis of multi-actor systems. In Industrial Ecology and the broader faculty of Technology, Policy and Management (TPM), multi-actor systems form an important basis for analysing various societal problems and concepts. This mostly involves researching, mapping and analysing such systems. However, systemic design requires a significantly different approach. Outcomes of systemic design do not involve a top-down implementation of policies or other incentives and recommendations in order to change the system's behaviour, as commonly used in Industrial Ecology and TPM. Rather, it focuses on the identification of leverage points, opportunities to intervene in the multi-actor system and cause bottom-up cascading effects that have a large and rapid effect of the system's behaviour while making use of a relatively small problem solving force. This however requires significantly different research approaches in researching, mapping and analysing these multi-actor systems. For example, in the book 'Policy Analysis of Multi-Actor Systems' (Enserink, 2022), commonly used at the faculty of TPM, the word 'leverage point' cannot be found once.

This led to the design of new research methods for analysing multi-actor systems used in this thesis research, which find their foundation in the fields of both Industrial Design Engineering (IDE) and TPM.

As described in Chapter 1 > Theoretical Background, multi-actor systems comprise multiple self-optimising actors, their interactions and relationships while reaching for a common goal of the system. Within the system of focus in this research, the large-scale establishment of e-hubs can be defined as the goal of the system. In order to find leverage points within the multi-actor system, focus was put on identifying the role that has the most effect on the behaviour of the system and thus on reaching the system's goal.

After empirically identifying and classifying all involved roles, an **engagement map** showed at what points in the e-hub development process these roles had significant influence on the behaviour of the system. This led to the identification of a 'step owner' per step of current development processes, being the role with the most influence over the system's behaviour within that step, as well as the 'touchpoints', being the supporting roles of significance per step. This created a deep understanding of the dynamics between roles as well as their effect on the system's behaviour for each step. This research method is based on a customer journey, commonly used in IDE. A customer journey is the complete experience a customer has when interacting with a company or product, from initial awareness and consideration through to purchase and post-purchase, for each step identifying the activities, experiences and touchpoint the customer has with the company or product of focus (Tueanrat et al., 2021). In this research, the 'customer' was replaced with 'the system of e-hub development.' The touchpoints between the customer and the product or company were replaced with the touchpoints between the system's behaviour and the engaged roles for each step, clarifying the multi-actor dynamics per step of e-hub development. This provided a stystematic approach of identifying the relationships between the system's behaviour of each step and the engaged roles that influence this behaviour. While the engagement map provided a deep understanding of actor dynamics and contribution to the system goal, in order to identify a leverage to intervene focus was put on the orientation phase of e-hub development, as explained in Chapter 1, by means of mapping and analysing the engagement of all roles within this specific phase by means of a power-involvement grid.

A **power-involvement grid** represents an effective method for concluding one key leverage point for intervention within the multi-actor system. This analysis is based on a power-interest grid, commonly used in the field of TPM. Instead of mapping the interests different roles have in the success of the system, in order to identify leverage points more relevant knowledge included the involvement these roles have in the system. This includes a focus on actors' actual engagement levels rather than just their interests providing a clearer picture of their active participation and influence in the system's behaviour. Correlating the level of involvement to the power each role has on actually altering the system's behaviour, this allowed the identification of a key role; the leverage point within the multi-actor system.

In conclusion, by distillating, altering and combining research methods from both the fields of IDE and TPM (including Industrial Ecology), multi-actor systems can not only be analysed and altered from top-down, but can be stimulated and disrupted from bottom-up.

COMBINING CAUSALITY AND ROOTEDNESS IN SYSTEMIC DESIGN

The combined CLD and IM analysis plays a pivotal role in defining the Opportunity for intervention, that forms the gateway between the ethnographic systemic analysis of the system ('Solving the Right Problem') and the open, participatory innovation process towards the design of the Proposition ('Solving the Problem Right').
While CLD and IM are both tools to map and navigate complex systems, **the two have not yet been combined in current academic literature. Nonetheless, this combination offers large advantages for academia and systemic design**. While the CLD illustrates system dynamics and behaviour, the IM illustrates how deep these dynamics are embedded in the behaviour of the system. It increases the comprehensive understanding of the complexity of the system, and allows to gain a holistic view of this system. In systemic design, this results into two important insights for selecting the right point of intervention (leverage point) within the system:

1. **Feasibility** of the intervention design within the research timeframe: if leverage points are situated in the top layer of the IM, this will lead to only designing for the symptoms of the system, decreasing the effectiveness of the designed interventions. If leverage points are situated in the lowest layer of the IM, the leverage point is too deeply embedded into the system, making it very difficult to push this leverage point. However, if leverage points are situated in the middle layers of the iceberg model, and/or encompass a combination of multiple layers, designing relevant and effective interventions will be feasible within the timeframe of the research.
2. **Impact** of the interventions on the system's behaviour: by means of analysing causal

relationships that connect leverage points to the system, it can be analysed what the impact of pushing the leverage point will have on the behaviour of the system. This enables researchers to pinpoint leverage points for designing interventions that will have significant impacts on system behaviour.

In conclusion, combining CLD with IM analysis provides insight into the feasibility, effectiveness and impact of multiple leverage points. Combining this analysis with a Multi-Criteria Decision Analysis, weighing the effectiveness and feasibility of each leverage point, allows the identification of a key leverage point that functions as the Opportunity to intervene in the system within the research project. This combination of research methods shows therefore a relevant contribution to systemic design and academia.

OPEN PARTICIPATORY INNOVATION IN FAST-MOVING TRANSITIONS

Open participatory innovation offers an efficient approach in research and design for fast-moving transitions. The rapid pace of the energy transition and e-hub development should be stimulated instead of slowed down by the tempo of innovation within these systems. This means there is no time to keep reinventing the wheel in research and design. Efficient innovation methods should be implemented in systemic design within fast-moving transitions. Open innovation shows a relevant, efficient and effective approach for such transitions. By defining and exploring similar systems, lessons learned can almost directly be implemented within the system of research. Combining this approach with participatory innovation within the system of focus, tailoring the lessons learned in similar context, research outcomes are both efficient and effective.

Next to this, as mentioned in most research methods in Chapter 1 > Research Approach, a **temporal constraint** is a frequent limitation of this research. Some data retrieved at the beginning of the research project was already out-dated at the end of the research project. Participatory innovation mitigated this limitation. By constantly collecting input and validation from diverse stakeholders and experts, agility, flexibility and inclusivity of the innovation process were intended. This collaborative approach enabled rapid iteration, experimentation and adaptation, empowering stakeholders and experts to co-create solutions that are responsive to evolving needs and trends.

METHODOLOGICAL **LIMITATIONS** OF THIS RESEARCH AND **RECOMMENDATIONS**

A large methodological limitation of this thesis research is caused by **navigating complexity**. Due to the largely interconnected and wide variety of socio-technical, multi-actor complex systems elements and dynamics, a true understanding of this complexity is not possible (Meadows, 2008). This thesis research navigated complexity by constantly **prioritising, simplifying and scoping the system boundaries**. Recommended is future research focussing on a different sequence and focus of the conducted scoping cycles (Chapter 1 > Research Approach), and **compare outcomes** and identified leverage points to the ones resulting from this thesis research. For example, the system boundaries could focus on the facilitator as being the 'key role', or putting a technological aspect as a central player within the system. Differences in the results could provide insights into the effect of system boundaries, as well as sequence of systems analysis methods used.

However, in accordance with the TU Delft HREC protocol all raw **data will be deleted after the thesis research project**, **limiting further research on different combinations and sequences of systems analysis methods** used as described in last recommendation. Therefore, recommended is collecting accessible and continuoulsy available data in order to experiment with different combinations and sequences of systems analysis methods, in order to see what differences in outputs they produce while using the same data.

Building on last recommendation, a methodological limitation of this thesis research results from the colossal amount of data resulting from the ethnographic research approach. Including 41 hours of recorded interviews and researchers' voice notes on observations during events, resulting into 645 quotations and 178 different codes in the Atlas.ti software, which result in a large network of code co-occurence (figure 95). In order to narrow down towards the identification of leverage points, **a lot of raw data, potentially providing insightful knowledge about e-hub development, is lost.**

While the approach of this research is **action-based**, including the researcher collaborating with research participants to identify system elements and dynamcis as well as possible designs for interventions, this approach does not include **action research**, where the interventions are implemented, reflecting on their outcomes in order to inform future actions. Where action based research includes the steps of planning, acting, observing and reflecting (Johnson, 2008), the action-based approach of this thesis research only includes planning. Implementing the Proposition in real-life scenarios and observing its effects on the system behaviour could provide valuable insight into the methodological assumptions made in this research.

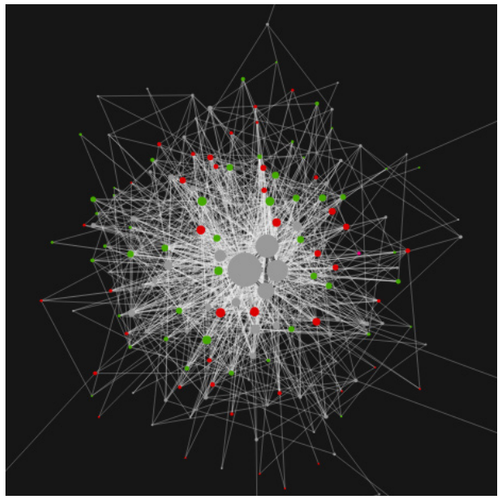


Figure 95: Large amount of codes and code co-occurence

SYSTEMIC DESIGN AND ITS CONTRIBUTION TO THE **ACADEMIC DEBATE**

In today's society, systems become more and more complex, interconnected and unpredictable. This could be explained by technological advancements and the explosion of available data due to digitalisation, however this also includes factors like globalisation, economic pressures, environmental challenges, and socio-cultural changes. Almost no fabrication, product, service, job, or other elements are not dependent on and influencing system dynamics and consequently system behaviour.

This does not have to be a bad thing. However, due to societal challenges, like climate change with all its effects, society needs to manage complexity, influencing all systems' behaviour towards decreasing cascading effects that could eventually lead to tipping points.

In current practices, similar to the development of e-hubs in this thesis research, this complexity is often managed from top-down. Consumers being dependent on the supply of producers, producers answering to the demand of consumers, and the governments that try to intervene in this balancing loop by implementing policies and regulations.

However, this has shown large inefficiencies in influencing systems' behaviour and preventing further negatively cascading effects on the environmental, or other systems. Not only do governmental institutions experience bureaucracy and long implementation time of policies and regulations, these institutions are also ambiguous in their influence due to regular elections and constant re-positioning of functions, actors and perceptions.

Therefore, a **bottom-up approach in influencing systems' behaviour**, like the systemic design approach conducted in this thesis research, could provide a significant addition to current practices and the academic debate.

Offcourse, this approach will not directly lead to a sustainable world, nor will they assure positive cascading effects on systems' behaviour. However, perceiving societal problems as being interconnected systems, and **compounding complexity** including socio-technical, multi-actor and complex systems characteristics, not only mapping and describing their dynamics but also looking for opportunities to intervene and cause cascading effects, provides a pivotal starting point for further research. **Systemic design, including perceiving, researching and mapping compounding complexity of societal problems, as well as designing efficient and effective interventions that will change large-scale system behaviour, shows a material addition to the academic debate.**

Future research and development of systemic design approaches, tools and methods that support **navigating and designing for complexity** should gain attention in the academic debate.

SYSTEMIC DESIGN AND ITS CONTRIBUTION TO **INDUSTRIAL ECOLOGY**

Industrial Ecology (IE) is a relatively new field of science. One of its first mentions in academic literature was by Frosch and Gallopoulos (1989). They envision a new model of industrial activity: an industrial ecosystem.

"In such a system the consumption of energy and materials is optimised, waste generation is minimised and the effluents of one process... serve as the raw material for another process. The industrial ecosystem would function as an analogue of biological ecosystems."

- Frosh and Gallopoulos (1989, p.1)

Ever since, the scientific field of Industrial Ecology has grown, introducing The Journal of Industrial Ecology in 1997, the International Society for Industrial Ecology in 2001 and the journal Progress in Industrial Ecology in 2004 (International Society for Industrial Ecology, n.d.; Yale Center of Industrial Ecology, n.d.) The IE-toolkit has expanded including methods and approaches such as Material Flow Analysis (MFA), Life Cycle Analysis (LCA), Environmentally Extended Input-Output Analysis (EEIOA) and Systems Thinking (International Society for Industrial Ecology, n.d.). Using this toolkit, IE analyses societal issues through an holistic view of combining the biosphere and the Technosphere. In doing so, ecology is used as a metaphor for the use of similar principles as natural systems in industrial systems to reduce their impact on the natural environment, such as closing resource loops and symbiosis.

When I, as a student, joined the field of IE in 2021, it was a time where there was an unquestionable need for the approaches and findings of IE, including its life cycle perspective, focus on close-loop systems, design for the environment, and industrial symbiosis. In my time studying IE, I studied multiple quantitative methods and approaches common in the IE-toolkit with the goal to reduce the environmental impact of the industry.

However, Frosh and Gallopoulos predicted:

"An ideal industrial ecosystem may never be attained in practice, but both manufacturers and consumers must change their habits to approach it more closely if the industrialised world is to maintain its standard of living and the developing nations are to raise theirs to a similar level without adversely affecting the environment."

- (Frosh and Gallopoulos, 1989, p.1)

Habit change forms an essential foundation of all sustainability transitions. While IE-methods like MFA, LCA and EEIOA help analysing and reducing environmental impacts, the habits, experiences, culture and beliefs of both manufacturers and consumers play a pivotal role in the demand to and effective implementation of these impact reductions.
Having a BSc. in Industrial Design Engineering (IDE), a field that emphasizes creativity, problem-solving and human-centred design to develop innovative solutions that enhance people's lives and contribute to societal well-being, I recognized an opportunity to unite the strengths of these two fields.

Beginning from the perspective of the human, it can be understood how (technological) impact reductions can be realised. By making use of puzzle of methods, borrowing pieces of IDE and pieces of IE, I had the ambition to create a multidisciplinary research project that focuses on identifying the right problem (which is more focused on the IE perspective, using tools from the IE toolkit), and solving this problem right (which is more focused on the IDE perspective), constantly intertwining the two disciplines.

Before beginning of this thesis research, while looking for a research subject, I spent a lot of time researching the combination of IE and IDE perspectives. My special interest had the field of Systems Thinking, which was ignited after following the course "System Design for Industrial Ecology" by prof. Ramirez Ramirez. I was deeply inspired by Donella Meadows, a pioneering systems thinker and writer of the book 'Thinking in Systems: A Primer.' Having a background in chemistry and biophysics, she introduces a method to explore whole system behaviour using the computer as a tool. This required to break down the system into parts, identifying causal linkages, feedback loops, rates and levels and structural behaviours of the system (Meadows, Lecture on Dartmouth College, 1977).

This is a rather technical approach. However, social, cultural and organisational structures often have the same characteristics as the complex systems described by Meadows and explained in the theoretical background of this master thesis. By implementing the systems thinking methods on social and organisational perspectives, the strengths of IE and IDE are united. Habits, experiences, culture and beliefs of both manufacturers and consumers can be analysed and interventions can be designed, in order to maintain the standard of living of the industrialised world and to help the developing nations to raise theirs to a similar level without adversely affecting the environment.

CONCLUDING REMARK TO ACADEMIA

IE and IDE, both being constantly evolving and highly-interdisciplinary FIELDS, demonstrate significant potential for collaboration and mutual expansion. Using the IE perspective to understand complexity and find actual relevant points to intervene in today's society, and using the IDE perspective to emphasize creativity in and effectiveness of designing solutions that will make a difference. These two perspectives find each other in the field of Systemic Design.

So, dear Industrial Ecologists and Designers who made it all the way to the end of my master thesis, I call to you:
Unite and expand the field of Systemic Design.

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APPENDICES

APPENDIX A INTERVIEW PARTICIPANTS

Participant	Role
P1	DSO
P2	DSO
P2	DSO
P4	DSO
P5	Measuring company
P6	Organisational Process Manager
P7	Organisational Process Manager
P8	Organisational Process Manager
P9	Organisational and Technical Process Manager
P10	Organisational and Technical Process Manager
P11	Organisational and Technical Process manager
P12	Organisational and Technical Process manager
P13	Technical Process Manager
P14	Connector: Park manager
P15	Municipality
P16	Province
P17	Province
P18	Consortium
P19	Consortium
P20	Consortium
P21	Branch Organisation
P22	Early Participant
P23	Early Participant
P24	Early Participant
P25	Early Participant
P27	Early Participant
P28	Early Participant
P29	Researcher Industrial Symbiosis – Rotterdam School of Management
P30	Facilitator of Industrial Symbiosis in NL
P31	Expert on co-creation, working at a consultancy firm on co-creation
P32	Expert on creative facilitation, working an internship at a consultancy firm on creative facilitation
P33	Expert on co-creation and creative facilitation, researching these topics for a MSc. Thesis at TU Delft
P34	Expert on co-creation for social cohesion in neighbourhoods

APPENDIX B ATTENDED EVENTS

#	Event Name	Organisor	Date	Location
E1	Webinar Energy Hubs	Rijkdienst voor ondernemend Nederland (RVO)	20-6-2023	Online
E2	Opening e-hub Tholen	Stakeholders of e-hub Tholen	26-9-2023	Town hall holen, Zeeland
E3	Webinar ‘verduurzaming van bedrijventerreinen, de wereld van tools’	Programma Verduurzaming Bedrijventerreinen - PVB	31-1-24	Online
E4	E-hub meeting Tholen	On-e-Target and Hub Board Tholen	25-1-24	Business Park Tholen, Zeeland
E5	Kick-off e-hub Veenendaal	Organisational Process Manager Veenendaal	1-2-24	Business Park Veenendaal, Utrecht
E6	Synergy Hackathon	Synergy Hackathon Board	1-2-24 to 3 -2-24, attended only 2-2-24	Green Village, Delft
E7	Community of Practice: e-hubs	Province of Utrecht	15-2-24	Space to Create, Utrecht
E8	Kennisbijeenkomst Energy Hubs	Energy Scale-Up, Province of Zuid-Holland	12-04-2024	Provinciehuis Zuid-Holland
E9	Meeting Front-runners energy hubs	Energy Scale-Up, RVO	30-05-2024	Hogeschool Domstad, Utrecht

APPENDIX C INTERVIEW FORMATS

QUESTIONS FOR FACILITATORS

Introduction
- May I record the conversation?
- Consent form

Explanation of the purpose of the thesis:
- I am primarily focusing on the organisational dimension of the orientation phase of e-hub development. This en tails how companies find each other, come together, establish a common vision, and eventually make agreements to form an e-hub.

Who are you, and what is your role in the development of e-hubs?

Outline of the System: Development of E-hubs (with help of the miro board below)
- According to you, what steps are involved in forming an e-hub?
  - Especially in the initial phase; please elaborate further.
- What are essential roles in the formation of e-hubs (and who usually fills these roles)?
- Where does it often go wrong? (What are the barriers/bottlenecks)
  - Why?
  - Can you provide examples?
- What do you use to drive the process (what are the drivers/success factors)?
  - Why?
  - Can you provide examples?
- What trends do you see in the development of e-hubs over time?
  - How do companies' motives for participating change?
  - How do barriers for companies to participate change?
  - How do relationships between companies and between companies and network operators/facilitators change?
  - Do new roles emerge? Do roles disappear?
  - Do new steps emerge? Do steps disappear?
- What values underlie the success of an e-hub?
- How do different perspectives and power structures of various stakeholders influence the formation of the e-hub?
- What assumptions, beliefs, and values do stakeholders have about the system?
- How would the development of an e-hub ideally progress?
  - What steps are taken here?
  - What tools are available?
  - What roles exist? What roles do not exist?
  - How does this ideal scenario differ from the current reality?

Putting Yourself in the System
- If you were a company and had to start, what would your first steps be?
- What tools are available or needed to boost the development of e-hubs, especially the approach for companies?

Closing Questions
- Do you have any further comments or questions?
- I am still in the early stages of my research; may I contact you again in later stages with any follow-up questions?

QUESTIONS FOR PARTICIPANTS

Introduction
- May I record the conversation?
- Consent form

Explanation of the purpose of the thesis:
- I am primarily focusing on the organisational dimension of the orientation phase of e-hub development. This en tails how companies find each other, come together, establish a common vision, and eventually make agreements to form an e-hub.

Who are you, and what is your involvement in the energy hub?

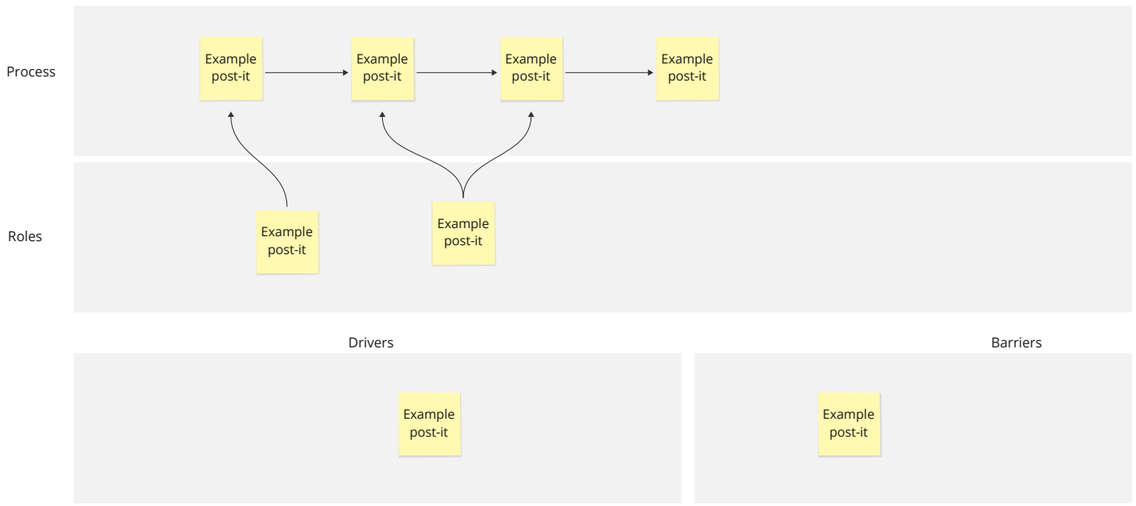
Why did you want to join a hub?
- E.g.: Energy saving, self-generation and storage of energy, sustainable mobility, gas-free heating, reducing energy bill costs, increasing predictability of the bill, sustainability, 'new gadgets', other

Engagement journey (with help of miro board in next sections)
- According to you, what were the steps in the creation of the hub, up until now?
  - How did you experience these steps? where there any drivers or barriers in these steps?
- Who helped you during the process? What other actors did you have contact with?
  - How did this go? did you experience any barriers? did you get motivated by (the actions of) other actors? how?
- What tools did you use?
  - Where there any roadmaps you used?
- If you would do it again, what would your approach be?

Closing Questions
- Do you have any further comments or questions?
- I am still in the early stages of my research; may I contact you again in later stages with any follow-up questions?

MIRO BOARD USED DURING INTERVIEWS

This Miro board was used in collaboration with the interviewee, to make it visible how the evolution process of the e-hub behaved, what role was involved per step, and what drivers and barriers were experienced during this process. By means of letting the interviewee stick post-its on this form, information was gathered.



FOCUS POINTS FOR EVENTS ATTENDED

Focus points during the event:

- Who are attending?
- What are people talking about?
- Who is talking the most?
- What questions are asked?
- What jokes are made / what is the vibe?

Questions during conversations (if possible)

- What is your role in the hub?
  - What kind of company are you working for?
  - How involved are you?
- How do you feel about the process?
  - Wat are your experienced drivers and barriers?
  - What do you think are important solutions and developments for e-hubs?
  - Do you have trust in the process?
- Can I contact you for an interview?

QUESTIONS FOR **EXPERTS OF INDUSTRIAL SYMBIOSIS**

Introduction
- May I record the conversation?
- Consent form

Explanation of the purpose of the thesis:
- I am primarily focusing on the stimulation of the organisational dimension of the orientation phase of e-hub de velopment. This entails how companies find each other, come together, establish a common vision, and eventually make agreements to form an e-hub. I have conducted research to drivers and barriers experienced by the early early participant (the first companies to join the e-hub). In order to stimulate drivers and mitigate barriers of this early participant, and thereby stimulating e-hub development, I have drafted the following design statement:

"Design a new proposition to stimulate the organisational dimension during the orientation phase of e-hub development on Dutch business parks in 2024 by encouraging early participants to consider their surrounding community in their decisions and solutions, fostering communication and relationships among businesses."

Questions on their lessons learned:
- How do IS networks emerge? Where do they start? Who initiates? What key steps do they take?
- How did you encourage early participants to consider their surrounding community in their decisions and solutions?
- How did you foster communication between businesses on the park?
- How did you foster relationships among businesses?
- What were the biggest lessons learned, successes and/or pitfalls in the organisational dimension of the orientation phase of development of your (facilitated / researched) IS clusters?

APPENDIX D INTERVIEW CONSENT FORM

You have been invited to participate in a research study titled "*Stimulating the emergence of energy hubs in Dutch business parks"*. This study is being done by Odile Niers from the TU Delft, in collaboration with Stedin.

The purpose of this research study is to gain insight into drivers and barriers for the emergence of energy hubs as experienced by its stakeholders. I will be asking you for your experiences and opinions on the formation process of energy hubs. This research will take you approximately one hour to complete.

Data will be collected by means of voice-recordings and/or interview-transcripts. This data will have controlled access, only by the study team consisting of the researcher and her two supervisors of the TU Delft. Data will be stored in safeguarded storage solutions provided by the TU Delft in order to mitigate the risk of data breach. Data will be deleted within one month after completion of this research project. The research will be published in the TU Delft repository. However, only anonymized summaries and de-identified quotes of interviews will be used in this publication.

Your participation in this study is entirely voluntary and **you have the right to refuse to answer and withdraw from this research at any time**. You also have the right to request access to and rectify or erase your personal data.

For any further questions, please do not hesitate to reach out to the researcher:
- Odile Niers

Signatures

_____ _____ _____

Name of participant Signature Date

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

__Odile Niers_____ _____ _21-12-23_____

Researcher name Signature Date

APPENDIX E ANALYSIS OF CURRENT DEVELOPMENTS THAT STIMULATE E-HUB DEVELOPMENT

Table E (part 1/2): Developments, methods and tools currently evolving

Development	Explanation	Driver or barrier the development is touching	Source
Network code change (netcodewijziging)	Currently, the law does not allow a participant in an e-hub to trade the 'trasnport right', referring to the legal permission or entitlement granted to a participant to transport energy through the grid infrastructure operated by network operators. This makes it impossible to engage in new contractual agreements with the DSO as a group (a Group Transport Agreement – Groeps Transportovereenkomst or Groeps-TO in Dutch). DSOs are currently working on a proposal for the regulatory authority ACM. ACM will assess the adjustments in the network code.	Law- and regulation makes it impossible to share assets, trade in transport rights and become an energy supplier to a neighbour	RVO, 2024
Standard contract development	DSOs are developing new standard contracts for groups. By means of introducing Group Transport Agreements (Groeps-TO in Dutch) and Capacity Constraining Contracts (Capaciteitsbeperkende contracten or CBC in Dutch), contractual agreements between the group and the DSO are made possible.	There are no standard contracts with the DSO	Netbeheer Nederland, 2023
Consultancy companies that focus on technical designs	Companies like Firan, Resourcefully and Spectral offer data analysis tools and possible designs of e-hubs. Next to this, grid control platforms and analyses of possible business cases are also in development by these consultancies.	There are little standard calculation tools	Firan, 2024; Resourcefully, n.d.; Spectral, n.d.
Gear@SME	Gear@SME is a consortium by research organisations (CIT, TNO, ENEA), that offers a 'trusted partner role' for SMEs who do not have the financial capital to hire consultancies for their energy scans. Gear@SME has launched an online portal offering free support and tools for energy efficiency.	There are little standard calculation tools	Tno, n.d.
Zenmo	Zenmo is a tool that focuses on making digital twins of energy usage on business parks. This facilitates conversation about technical possibilities. The Zenmo tool is presented often during the events attended by the researcher. However, a commonly heard comment is that the Zenmo tool is (currently) hard to introduce, as a lot of data is needed from the business park before the tool can be set up.	It is hard to make a technical design	Zenmo, n.d.
Holon	The Holon tool is a calculation tool to analyse energy communities. It draws inspiration from practical examples, and contains a community where users and experts can find each other and share knowledge and experiences. The Holon tool is in development in collaboration with Topsector Energie.	There are little standard calculation tools, It is hard to make a technical design	Holon, n.d.

Table E (part 2/2): Developments, methods and tools currently evolving

All-in-one packages by measuring companies	Measuring companies like Joulz and Groendus offer smart meters, automised insight into data, and standard calculation tools for e-hubs. An accompanying advantage is that sometimes a lot of companies on the business park already are engaged with one of these measuring companies, easing data collection and calculation.	There are little standard calculation tools	Joulz, n.d. Groendus, n.d.
MOOI EIGEN	MOOI EIGEN is a government-funded consortium that focuses on the development and validation of a blueprint for the development of energy hubs on industrial parks. The blueprint consists of a step-by-step plan that comprises of four phases, as stated in the introduction of this master thesis. The tools presented are modular in nature and can be deployed for the development and implementation of e-hubs on business parks.	There is a lack of public knowledge about e-hubs	MOOI EIGEN, n.d.
Industrial ValueFlex Tool	Tennet is developing a tool that enables industrial users to assess the potential revenues that can be achieved by operating flexibly across different electricity markets.	It is hard to make a business case	Tennet, n.d.
TNO Serious game: energy transition on industrial parks	TNO developed a serious game aiming to advance the conversation about the energy transition on business parks. Using the game, support for the energy transition on the park can be increased, and concrete actions can be linked to it. The local driver of the energy transition on the park, often a park manager or a representative of the business association, is empowered in their dialogue with participants.	There is a lack of communication between companies on park X	TNO, 2024

What is commonly in development are mostly calculation tools, that stimulate data analysis and ease the technical design of e-hubs, as well as possible business models. However, as explained in earlier chapters, this is not the biggest bottleneck in the orientation phase of e-hub development. Little tools and methods also involve the social side of e-hubs. Only the MOOI EIGEN blueprint and the TNO serious game fill this gap. These two will be discussed shortly below.

While the MOOI EIGEN tool gives a good overview of what steps need to be taken in the development of e-hubs, it assumes the starting e-hub already is organised including an appointed process coordinator. Figure 48 shows a quote of the first step of the MOOI EIGEN blueprint. However, as defined in Chapter 1 > Challenges in the development of e-hubs (page 25), 90% of Dutch business parks are inadequately organised to form an e-hub, and 80% of Dutch business parks are not organised at all and have to start from scratch in forming new coalitions and eventually an e-hub, let alone already angaged with a process coordinator.

This means the MOOI EIGEN blueprint is applicable for facilitators that approach a business park from top-down but is not yet helpful for business parks that want to start an e-hub from bottom up. As discussed in Chapter 1 > Gaps in current practices, this bottom-up hub formation is necessary in order to overcome the lack of available facilitators.

The TNO serious game includes the same gap as the MOOI EIGEN tool. On the website of TNO, the goal and target group of the game are stated as: "The local driver of the energy transition on a business park, often a park manager or a board member of the business association, is empowered in their dialogue with entrepreneurs" (TNO, 2024). However, as stated before, 80% of Dutch business parks do not yet have a park manager or a business association.

In conclusion, missing is a development that focusses on the social side of e-hubs, that also stimulate the orientation phase of business parks that are not yet organised (which accounts for 80 to 90% of Dutch business parks, as discussed in Chapter 1).

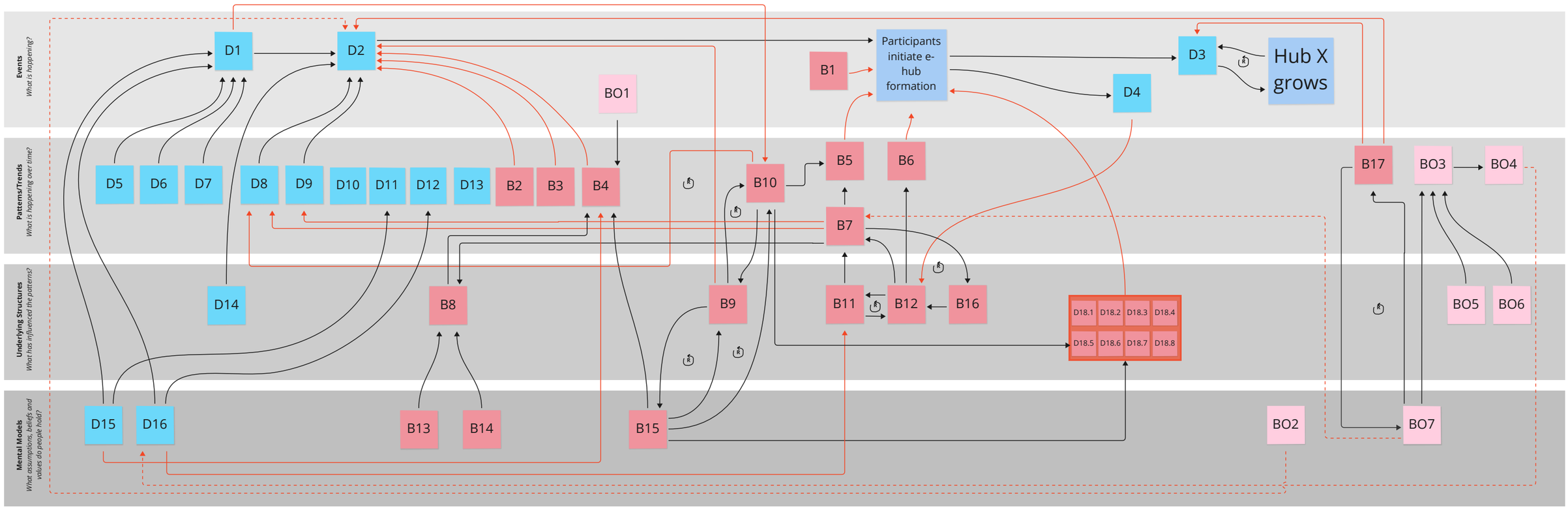
APPENDIX F BARRIERS OUT OF SCOPE, INCLUDING CLD/IM ANALYSIS

Table F (part 1/2): The barriers experienced by the early participant in the orientation phase of e-hub development, that are out of scope of this master thesis research

#	Barrier (out of scope)	Explanation	Empirical evidence
BO1	Companies still have existing contracts	Companies are hesitant to terminate their existing contracts with the DSO and energy suppliers, either due to fear for losing their current position or because it may not be feasible to do so.	10 quotes, a.o.: "Entrepreneurs do not want to let their current contracted capacity go, without knowing the hub will be a success. They might never get their previous contracts back." – P2 "Participants all need to have contracts with the same supplier. If someone in the group still has an existing contract, this participant should wait or the group should buy out this contract." -P10
BO2	Law- and regulation makes it impossible to form an e-hub	Current laws and regulations impose restrictions, requirements and limitations that make it difficult for companies to form an e-hub.	16 quotes, a.o.: "The problem lies mainly in the legislation and regulations, which are 100 years old. The system looked completely different 100 years ago, and we didn't have the same problems as we do now." -P16 "Many initiatives cannot comply with the laws and regulations. These can be implemented as pilots but are not scalable on a large scale." -P4
BO3	It is hard to make a technical design	Making a technical design for e-hubs is not yet a standardised practice, with little parties having expertise in this topic.	9 quotes, a.o.: "There are only a very few people right now who are able to make technical designs for new e-hubs." -P20 "Many plans are being made, but it translates into little implementation because no one knows how to make an actual technical design." -P13

Table F (part 2/2): The barriers experienced by the early participant in the orientation phase of e-hub development, that are out of scope of this master thesis research

BO4	It is hard to make business cases	Because there aren't many examples and there are many steps needed before we can create a business plan, it's tough to make one before investing in the e-hub.	4 quotes, a.o.: "Making business cases is quite trial and error. First entrepreneurs have to form a group, make mutual agreements, install EMS, and then see how everything could work together. Only then the real business case can be determined. Companies want to see business cases and figures before making all these investments; they want to asses their opportunities." -P9 "There are no clear business cases or examples of business cases yet due to a lack of available data. This causes difficulty to apply for loans by banks for example." -P14
BO5	There are no standard contracts	There is no established set of rules or agreements that companies can use as a framework for their interactions within the hub, nor between the hub and the DSO.	3 quotes, a.o.: "People lack clarity on their possibilities due to the absence of standardized contracts." -P6 "There is a need for standardized contracts, so entrepreneurs know what possible collaborations could look like." – P12
BO6	There are little standard calculation tools	Due to a lack of standard calculation tools, entrepreneurs and/or consultancies make innacurate calculations, causing a distorted understanding of what is feasible within the e-hub.	4 quotes, a.o.: "Entrepreneurs make a lot of assumptions and unsubstantiated calculations." – P11 "A very big risks is consultancies who start making calculations without knowing the full picture of e-hubs. Standard calculation tools are essential." – P3
BO7	It is hard to gain insight into net topology and data from DSOs due to law and regulation	Legal constraints make it challenging to access and understand information about the network structure and data on supply and demand of energy, which are essential for planning and implementing e-hubs.	22 quotes, a.o.: "If it is not possible to map flexible capacity due to a lack of data, an e-hub is not feasible." – P10 "The DSO keeps all the cards close to their chest. They have all the data but don't share it, which means we don't know who to collaborate with or how to set up a hub." – P25



#	Barrier (out of scope)
BO1	Companies still have existing contracts
BO2	Law- and regulation makes it impossible to form an e-hub
BO3	It is hard to make a technical design
BO4	It is hard to make business cases
BO5	There are no standard contracts
BO6	There are little standard calculation tools
BO7	It is hard to gain insight into net topology and data from DSOs due to law and regulation

#	Driver
D1	Grid congestion – not having another option
D2	Having a small group of enthusiastic companies that are willing to put time and effort into the hub
D3	Ambassador-effect: first movers pull more companies into the hub
D4	Having knowledge on lessons learned in other e-hubs
D5	Existing companies want to expand
D6	New companies want to settle
D7	Companies want to become more sustainable and therefore want to electrify
D8	The realisation there is a shared problem; other companies have the same problem
D9	Realising it is possible to work together to overcome problems
D10	Motivations of company X: Finding new technology / new things interesting / sexy
D11	Motivations of company X: Save on costs by sharing assets and saving on grid fees
D12	Motivations of company X: Group independency
D13	Motivations of company X: Wanting to be future-proof
D14	A change in attitudes is happening; people are more open to new technologies and solutions
D15	Companies want to earn money
D16	Companies always want to have energy, energy is the basis of business operations

Figure F: Combined CLD/IM Analysis of the drivers and barriers experienced by the key role (Author's image)

#	Barrier
B1	There is a lack of capacity in supporting roles
B2	Companies hold a grudge to DSOs and think someone else has to fix their problems
B3	Companies do not want to or cannot invest time and effort into the hub next to their core business
B4	Companies do not want to take risks
B5	Companies have false expectations about what a hub can mean for them
B6	It is hard to find financing
B7	There is a lack of public knowledge about energy, net congestion and e-hubs.
B8	Companies do not trust the innovation of e-hubs
B9	Companies do not have existing relationships on the park
B10	There is a lack of communication between companies on park X
B11	There is a lack of communication between e-hubs
B12	There are limited examples from successful hubs
B13	Companies do not trust each other
B14	Companies do not trust changing policies
B15	Companies are primarily self-focused
B16	There is a lack of communication between supporting roles
B17	It is hard to know who company X can collaborate with
B18	Different companies have different interests (for more information, please refer to table 7)

Positive effect

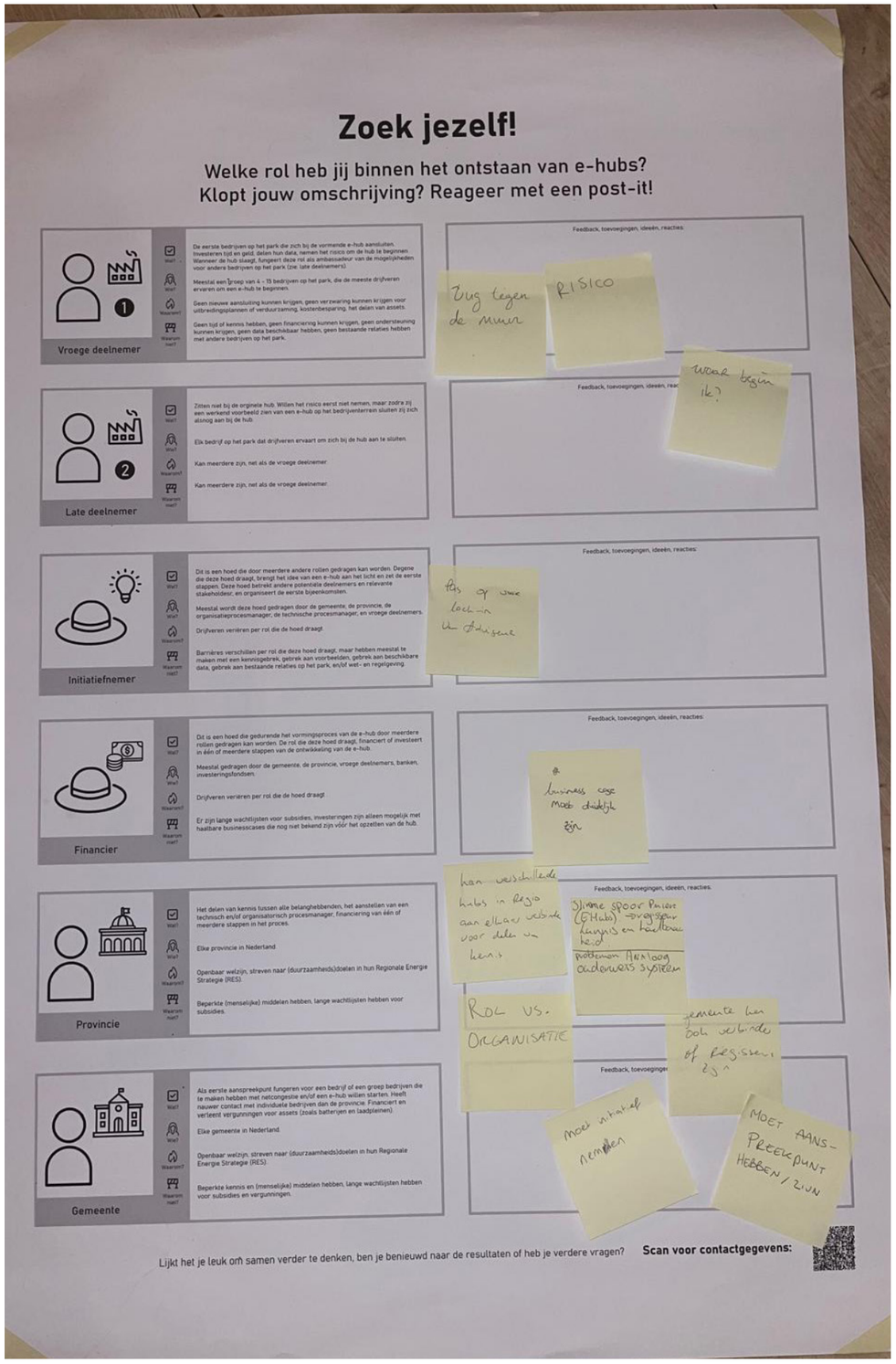
Negative effect

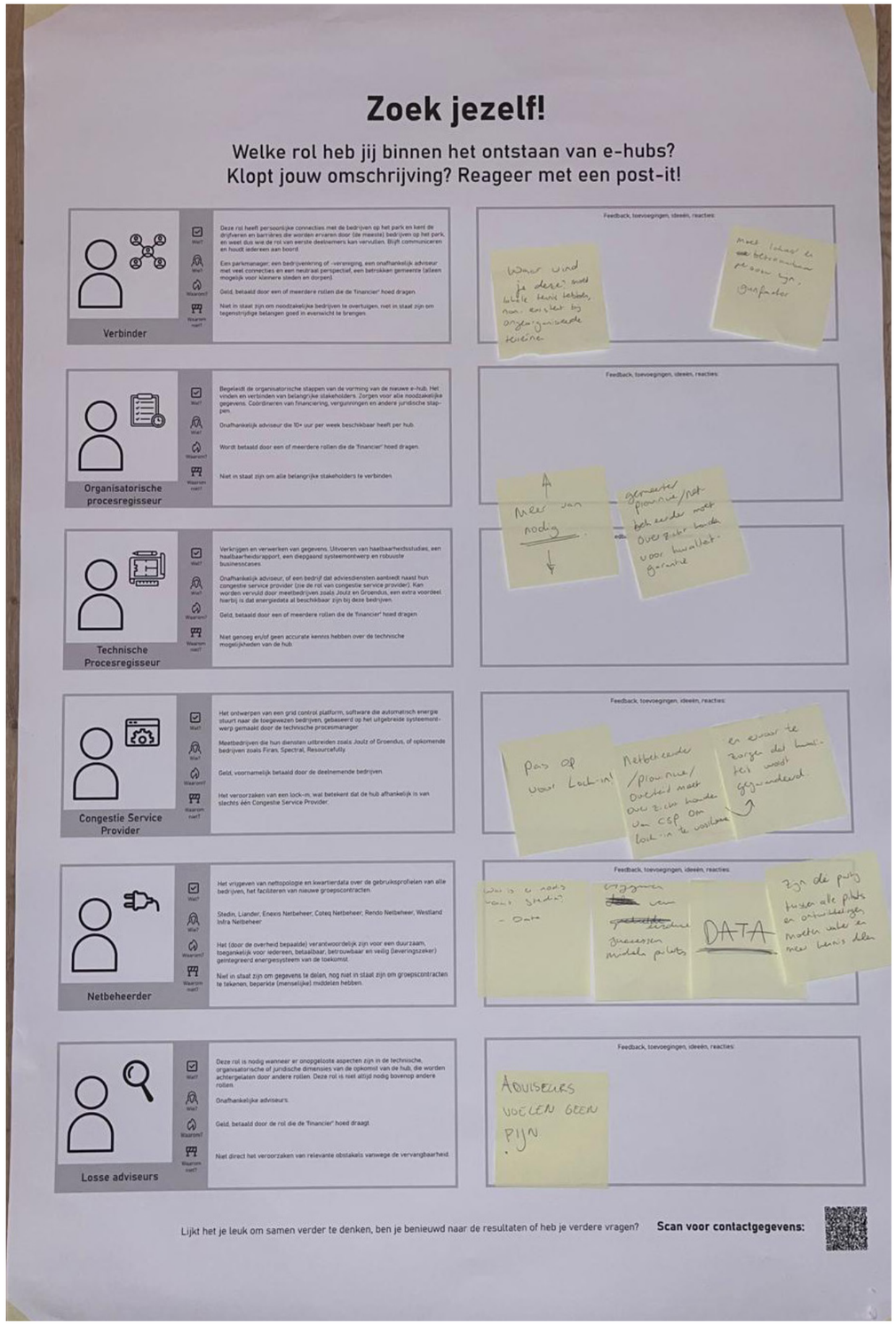
Negative effect out of scope

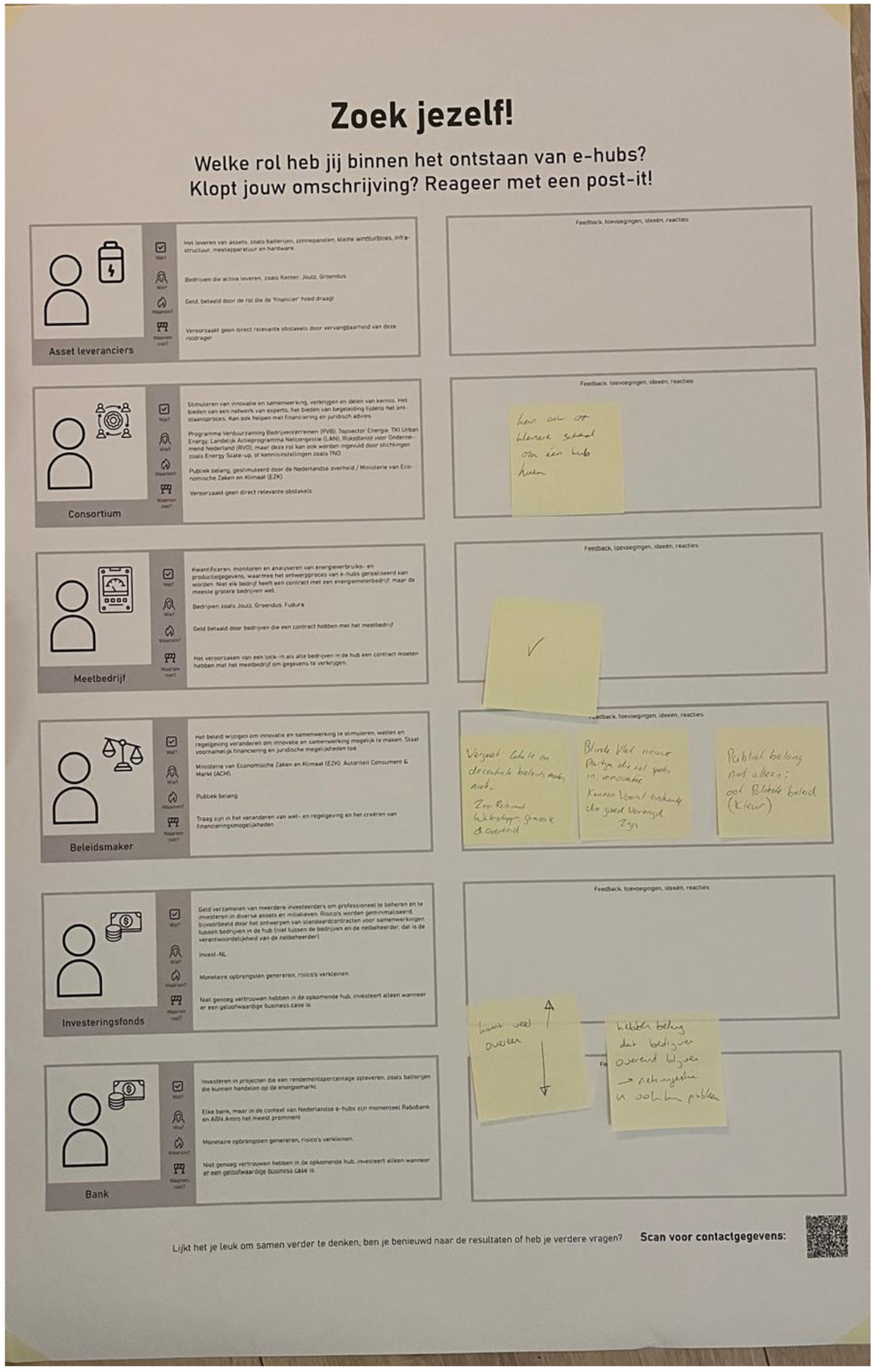
R

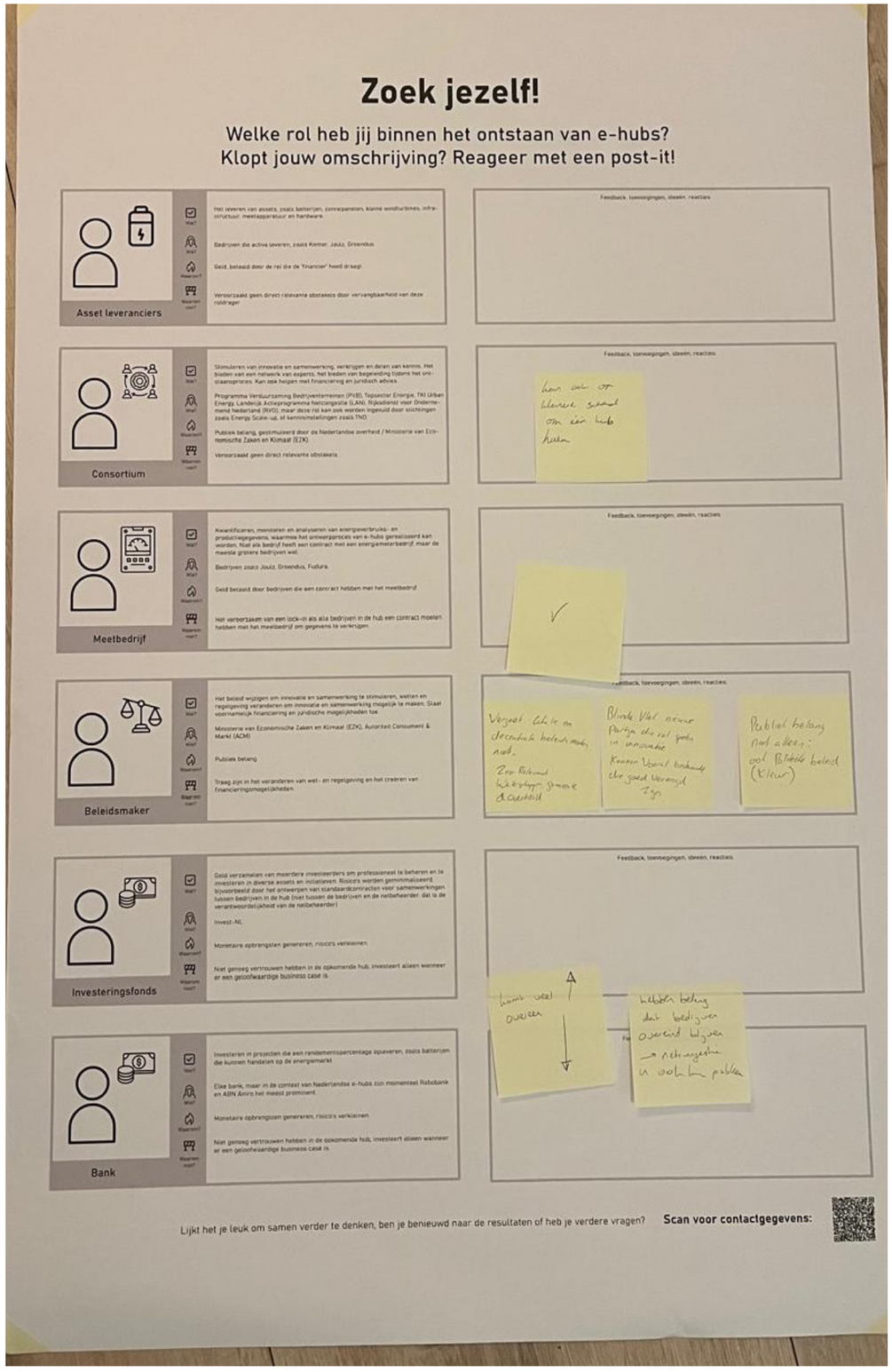
Reinforcing loop

APPENDIX G VALIDATION OF ROLES

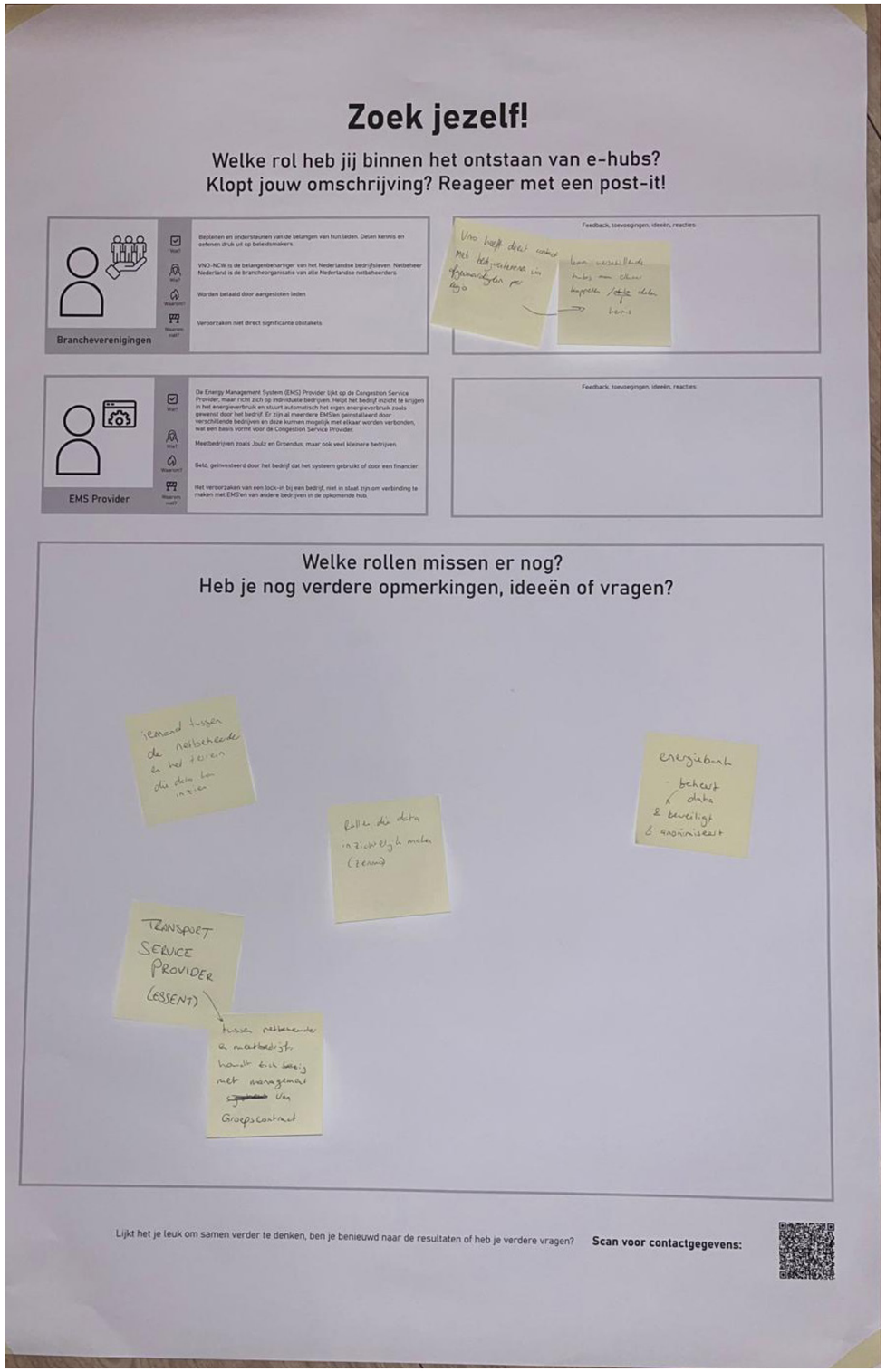


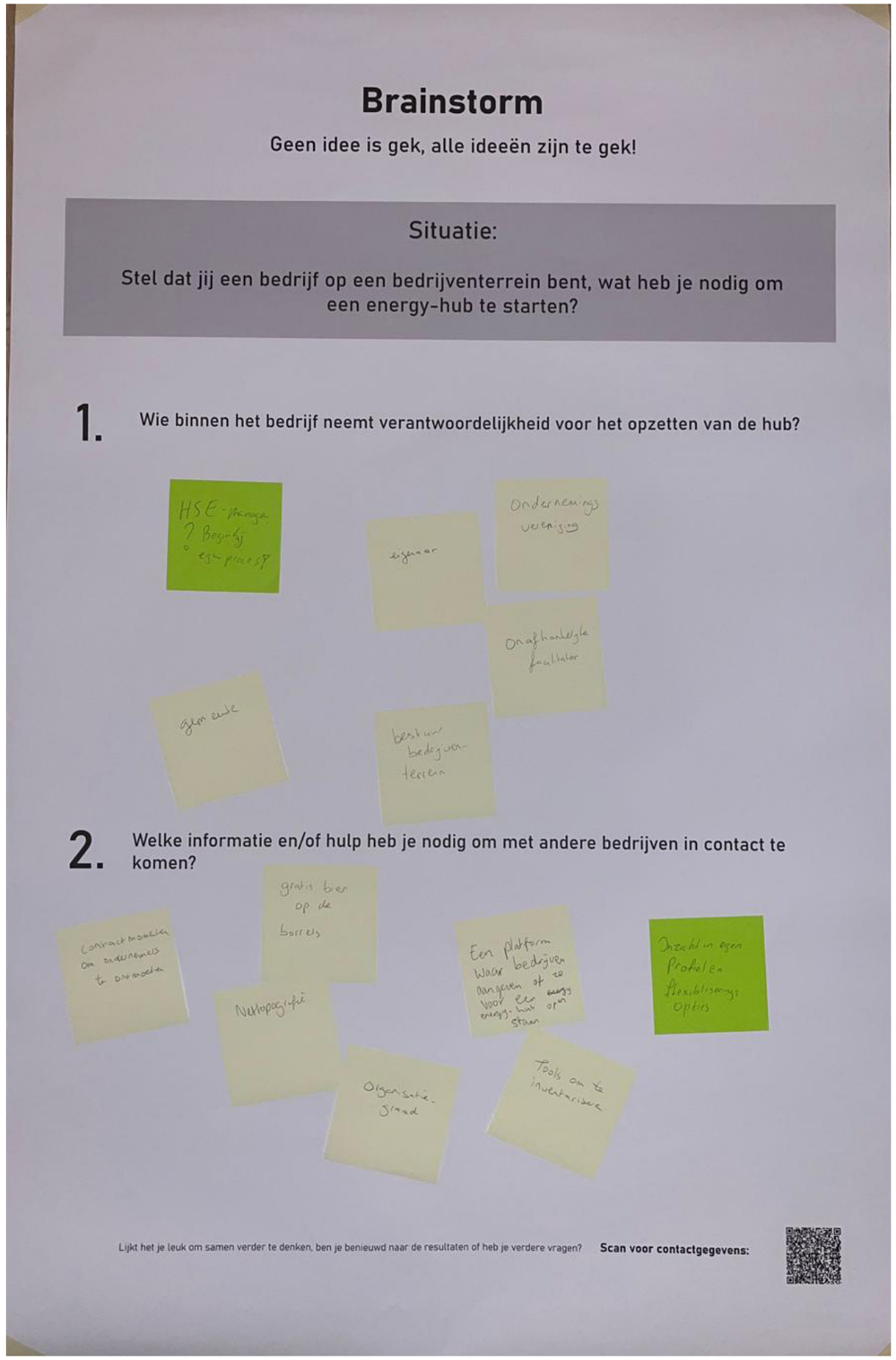



Zoek jezelf!
Welke rol heb jij binnen het ontstaan van e-hubs?
Klopt jouw omschrijving? Reageer met een post-it!
Asset leveranciers
Het leveren van assets, zoals batterijen, zonnepanelen, kleine windturbines, infrastructuur, meetapparatuur en hardware.
Bedrijven die activa leveren, zoals Kenter, Jouliz, Groendus.
Geld, betaald door de rol die de 'financier' hoed draagt
Veroorzaakt geen direct relevante obstakels door vervangbaarheid van deze roldrager
Feedback, toevoegingen, ideeën, reacties
Consortium
Stimuleren van innovatie en samenwerking, verkrijgen en delen van kennis. Het bieden van een netwerk van experts, het bieden van begeleiding tijdens het ontstaansproces. Kan ook helpen met financiering en juridisch advies
Programma Verduurzaming Bedrijventerreinen (PVB), Topsector Energie, TKI Urban Energy, Landelijk Actieprogramma Netcongestie (LAN), Rijksdienst voor Ondernemend Nederland (RVO), maar deze rol kan ook worden ingevuld door stichtingen zoals Energy Scale-up, of kennisinstellingen zoals TNO
Publiek belang, gestimuleerd door de Nederlandse overheid / Ministerie van Economische Zaken en Klimaat (EZK)
Veroorzaakt geen direct relevante obstakels
Feedback, toevoegingen, ideeën, reacties
Meetbedrijf
Kwantificeren, monitoren en analyseren van energieverbruiks- en productiegegevens, waarmee het ontwerpproces van e-hubs gerealiseerd kan worden. Niet elk bedrijf heeft een contract met een energiemeterbedrijf, maar de meeste grotere bedrijven wel.
Bedrijven zoals Jouliz, Groendus, Fudura
Geld betaald door bedrijven die een contract hebben met het meetbedrijf
Het veroorzaken van een lock-in als alle bedrijven in de hub een contract moeten hebben met het meetbedrijf om gegevens te verkrijgen
Feedback, toevoegingen, ideeën, reacties
Beleidsmaker
Het beleid wijzigen om innovatie en samenwerking te stimuleren, wetten en regelgeving veranderen om innovatie en samenwerking mogelijk te maken. Staat voornamelijk financiering en juridische mogelijkheden toe.
Ministerie van Economische Zaken en Klimaat (EZK), Autoriteit Consument & Markt (ACM).
Publiek belang
Traag zijn in het veranderen van wet- en regelgeving en het creëren van financieringsmogelijkheden.
Feedback, toevoegingen, ideeën, reacties
Investeringsfonds
Geld verzamelen van meerdere investeerders om professioneel te beheren en te investeren in diverse assets en initiatieven. Risico's worden gemminimaliseerd, bijvoorbeeld door het ontwerpen van standaardcontracten voor samenwerkingen tussen bedrijven in de hub (niet tussen de bedrijven en de netbeheerder; dat is de verantwoordelijkheid van de netbeheerder)
Invest-NL
Monetaire opbrengsten genereren, risico's verkleinen
Niet genoeg vertrouwen hebben in de opkomende hub, investeert alleen wanneer er een geloofwaardige business case is.
Feedback, toevoegingen, ideeën, reacties
Bank
Investeren in projecten die een rendementspercentage opleveren, zoals batterijen die kunnen handelen op de energiemarkt
Elke bank, maar in de context van Nederlandse e-hubs zijn momenteel Rabobank en ABN Amro het meest prominent
Monetaire opbrengsten genereren, risico's verkleinen.
Niet genoeg vertrouwen hebben in de opkomende hub, investeert alleen wanneer er een geloofwaardige business case is.
Feedback, toevoegingen, ideeën, reacties
Lijkt het je leuk om samen verder te denken, ben je benieuwd naar de resultaten of heb je verdere vragen?
Scan voor contactgegevens:

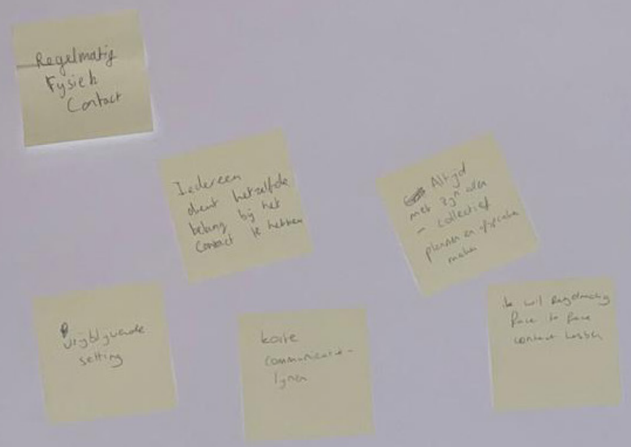

Zoek jezelf!
Welke rol heb jij binnen het ontstaan van e-hubs?
Klopt jouw omschrijving? Reageer met een post-it!
Asset leveranciers
Het leveren van assets, zoals batterijen, zonnepanelen, kleine windturbines, infrastructuur, meetapparatuur en hardware.
Bedrijven die activa leveren, zoals Kenter, Jouliz, Groendus.
Geld, betaald door de rol die de 'financier' hoed draagt.
Veroorzaakt geen direct relevante obstakels door vervangbaarheid van deze roldrager
Feedback, toevoegingen, ideeën, reacties
Consortium
Stimuleren van innovatie en samenwerking, verkrijgen en delen van kennis. Het bieden van een netwerk van experts, het bieden van begeleiding tijdens het ontstaansproces. Kan ook helpen met financiering en juridisch advies
Programma Verduurzaming Bedrijventerreinen (PVB), Topsector Energie, TKI Urban Energy, Landelijk Actieprogramma Netcongestie (LAN), Rijksdienst voor Ondernemend Nederland (RVO), maar deze rol kan ook worden ingevuld door stichtingen zoals Energy Scale-up, of kennisinstellingen zoals TNO
Publiek belang, gestimuleerd door de Nederlandse overheid / Ministerie van Economische Zaken en Klimaat (EZK).
Veroorzaakt geen direct relevante obstakels.
Feedback, toevoegingen, ideeën, reacties
Meetbedrijf
Kwantificeren, monitoren en analyseren van energieverbruiks- en productiegegevens, waarmee het ontwerpproces van e-hubs gerealiseerd kan worden. Niet elk bedrijf heeft een contract met een energiemeterbedrijf, maar de meeste grotere bedrijven wel.
Bedrijven zoals Jouliz, Groendus, Fudura
Geld betaald door bedrijven die een contract hebben met het meetbedrijf
Het veroorzaken van een lock-in als alle bedrijven in de hub een contract moeten hebben met het meetbedrijf om gegevens te verkrijgen.
Feedback, toevoegingen, ideeën, reacties
Beleidsmaker
Het beleid wijzigen om innovatie en samenwerking te stimuleren, wetten en regelgeving veranderen om innovatie en samenwerking mogelijk te maken. Staat voornamelijk financiering en juridische mogelijkheden toe.
Ministerie van Economische Zaken en Klimaat (EZK), Autoriteit Consument & Markt (ACM).
Publiek belang
Traag zijn in het veranderen van wet- en regelgeving en het creëren van financieringsmogelijkheden.
Feedback, toevoegingen, ideeën, reacties
Investeringsfonds
Geld verzamelen van meerdere investeerders om professioneel te beheren en te investeren in diverse assets en initiatieven. Risico's worden gemminimaliseerd, bijvoorbeeld door het ontwerpen van standaardcontracten voor samenwerkingen tussen bedrijven in de hub (niet tussen de bedrijven en de netbeheerder; dat is de verantwoordelijkheid van de netbeheerder)
Invest-NL
Monetaire opbrengsten genereren, risico's verkleinen
Niet genoeg vertrouwen hebben in de opkomende hub, investeert alleen wanneer er een geloofwaardige business case is.
Feedback, toevoegingen, ideeën, reacties
Bank
Investeren in projecten die een rendementspercentage opleveren, zoals batterijen die kunnen handelen op de energiemarkt
Elke bank, maar in de context van Nederlandse e-hubs zijn momenteel Rabobank en ABN Amro het meest prominent.
Monetaire opbrengsten genereren, risico's verkleinen.
Niet genoeg vertrouwen hebben in de opkomende hub, investeert alleen wanneer er een geloofwaardige business case is.
Feedback, toevoegingen, ideeën, reacties
Lijkt het je leuk om samen verder te denken, ben je benieuwd naar de resultaten of heb je verdere vragen?
Scan voor contactgegevens:

APPENDIX H COLLABORATIVE BRAINSTORM OUTCOMES

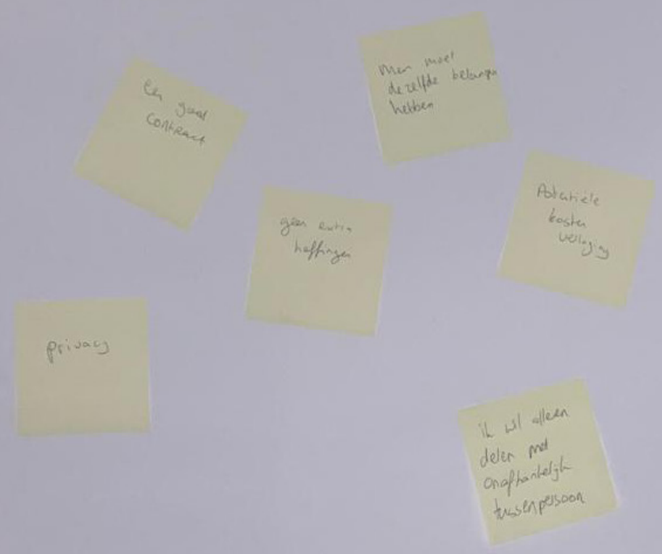




3. Hoe moet het contact met andere bedrijven eruit zien om goed samen te kunnen werken? (regelmaat? medium? locatie? onder welke omstandigheden? etc.)

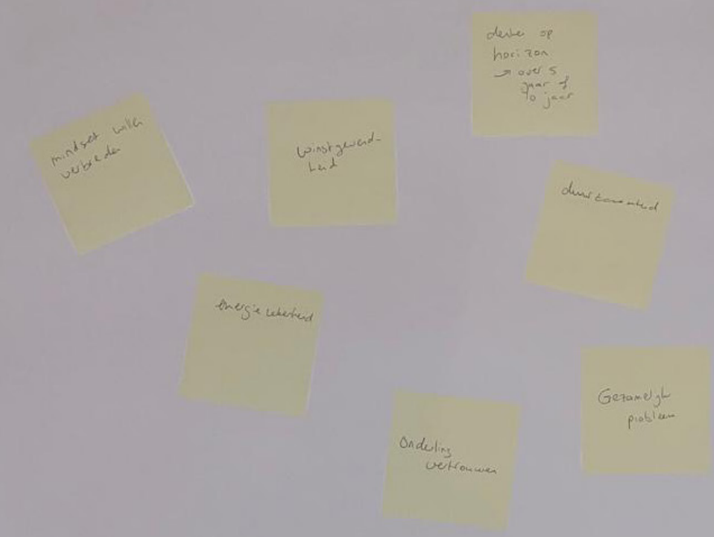


4. Wat zijn voor jou voorwaarden om met goed vertrouwen jouw energiedata te delen met potentiële partners?

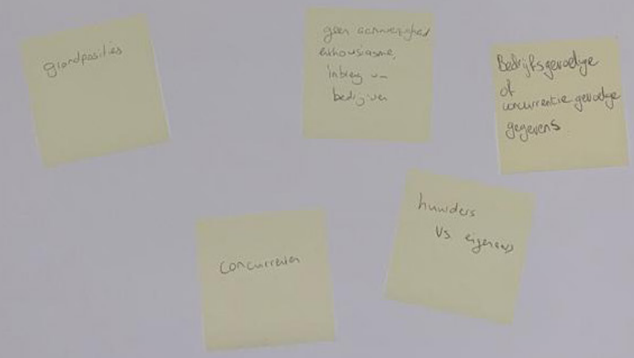


Lijkt het je leuk om samen verder te denken, ben je benieuwd naar de resultaten of heb je verdere vragen? **Scan voor contactgegevens:**

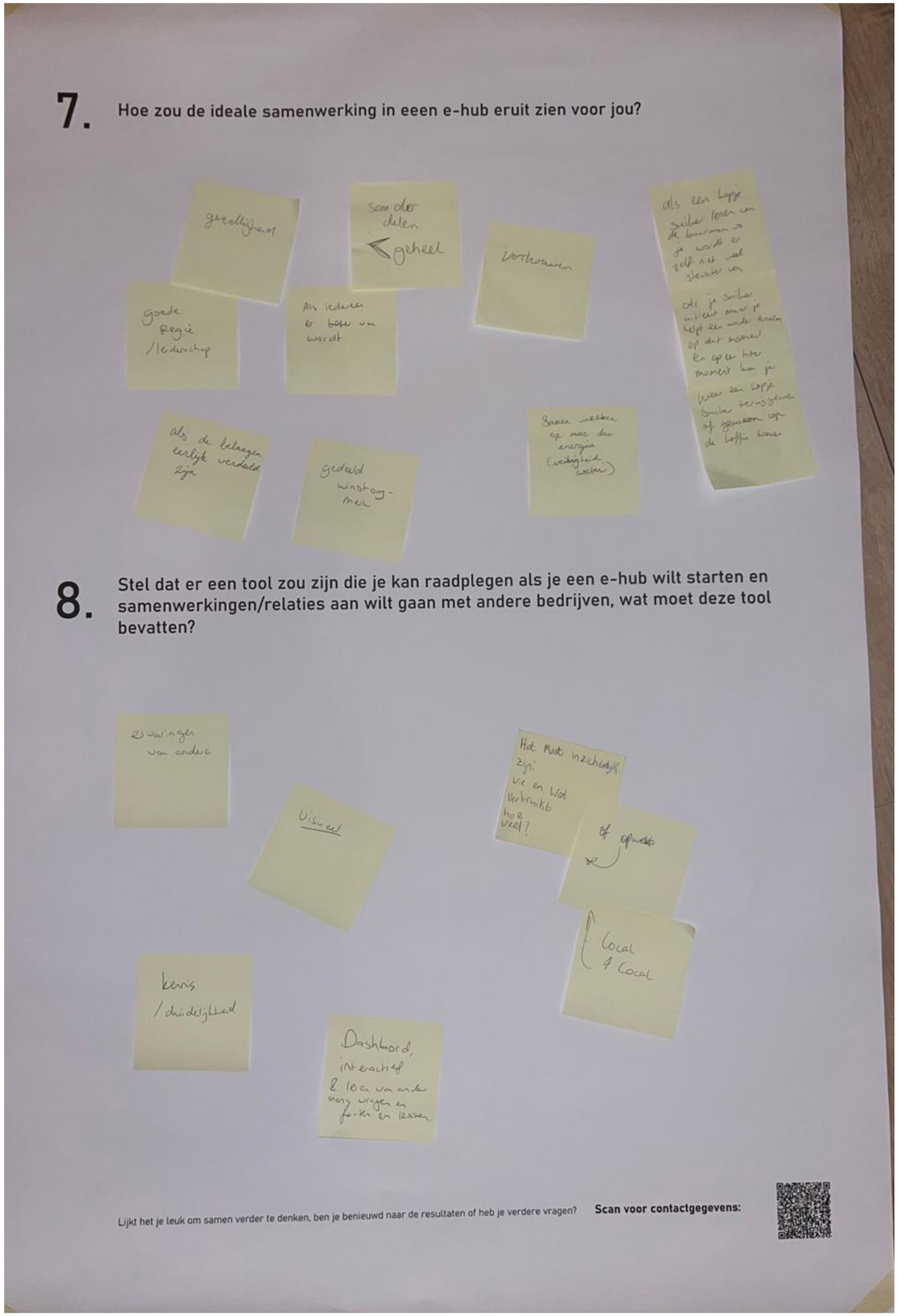
5. Welke gezamelijke doelen en waarden zijn belangrijk om goed samen te kunnen werken met een ander bedrijf?



6. Wat zijn praktische zaken en/of conflicterende belangen waarorm een samenwerking spaak zou kunnen lopen?



Lijkt het je leuk om samen verder te denken, ben je benieuwd naar de resultaten of heb je verdere vragen? **Scan voor contactgegevens:**



APPENDIX I MINUTES OF VALIDATION SESSION WITH FRONT-RUNNERS GROUP E-HUBS

When: 30 april 2024

Where: Utrecht

Who: front-runners of e-hubs. Around 25 attendees. Most attendees have a facilitating role, 8 attendees have a good image of the participants.

Take-aways for improvement of the proposition:

- Participants have little time. Attending a workshop will be a barrier for them. There could be a step in between: requesting a quick scan. This can provide a broad indication of whether a collective is feasible at all. Two projects are already underway with attendees from the session to design these quick scans. These could be added to intervention 1: the information page for participants.
- Many entrepreneurs are not yet aware that they will also face these problems within a year. Therefore, it is already very relevant for them to participate in the orientation phase, but they do not know that yet. You could reach them by designing a flyer about future challenges. An attendee did this at a business park, and suddenly people were much more cooperative.
- It is not yet clear whether an e-hub is desirable from the perspective of the energy network on one cable or per substation. You should take this into account in intervention 2: the invitation for the workshop series.
- In the calculation tool in session 3 of the workshop, consideration should be given to which data will be used. Historical data quickly becomes outdated, as businesses expand and transition to sustainability rapidly. Ideally, real-time simulation is preferred. Further research into this is needed.
- For facilitators, a physical meeting place on a regular basis is most desirable, such as this monthly flagship group meeting. New facilitators register with the EnergyScale-Up Foundation, which organizes these gatherings.
- It should be avoided that a lock-in occurs among the early participants. Further research needs to be conducted on how to achieve the ambassador effect effectively; how does the group remain open and flexible?

Validation of the research and proposition:

- A first and very interesting research incorporating the social view of participants. Normally research to e-hubs focuses on policy-advise or technical possibilities.
- The first time that a workshop is proposed – all earlier propositions focus on digitalisation and data flows. This is important for the change-management that is needed for e-hubs.
- Interesting and complete view of the viewpoint of the participants. This can be used by facilitators who are not in direct contact with participants, such as policymakers or decision-makers in provinces, municipalities, DSOs, etc.

APPENDIX J INFORMATION THAT SHOULD BE PROVIDED IN INTERVENTIONS 1 AND 3 OF THE PROPOSITION

1. Crash course on energy and the problems
    1. The grid and its problems
    2. Why can't problems be solved?
    3. What does this mean for Dutch companies?
2. Possible solutions
    1. Individually
    2. With the grid operator
    3. As a group (the e-hub)
3. E-hubs
    1. What are e-hubs?
        1. How do e-hubs work (legally, technically, organizationally)?
        2. Advantages of e-hubs
        3. Examples of e-hubs
    2. Who can form an e-hub?
    3. How does an e-hub come into existence?
4. What does this mean for my company?

1. Crash course energy

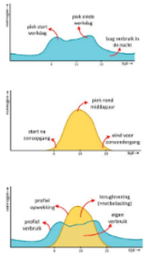


Figure J.1 (Stedin, 2024)

1. The grid and its problems
    1. https://www.youtube.com/watch?v=Zc2BZTlHNN4
    2. Different layers - high voltage, medium voltage, low voltage
    3. Due to more sustainable generation and consumption: grid congestion
    4. How big is this problem - show congestion map
2. Problems cannot (quickly) be solved by just upgrading the grids
    1. Not enough materials
    2. Not enough workforce
    3. Not enough time to meet the growing demand
    4. So: the grid operator cannot solve the problem alone
3. What does this mean for Dutch companies?
    1. Contracted capacity: you cannot exceed this, peaks must remain within this capacity.
    2. Waiting for connections
    3. Unable to grow Unable to become more sustainable
    4. Searching for solutions together"

1. Individual solutions
    1. Peak Shaving: reduce your peaks in generation and/or usage. Set devices correctly, match your own demand with your own supply, match your own supply with your own demand
    2. Load Shifting: smartly distribute usage and generation throughout the day, for example with dynamic load balancing and smart charging
2. Solutions with the grid operator

Figure J.2 (Stedin, 2024)

3. Solutions for groups: the e-hub

3. E-hubs

1. What is an e-hub?
    1. An energy hub (e-hub) is a group of customers who coordinate demand and supply among themselves, jointly buy or sell energy, and sometimes even exchange energy.
        1. Legally: The grid operator facilitates this through a group contract. The group capacity agreement provides customers with a collective grid boundary that replaces individual contracted capacities.
        2. Technically: Participants can adjust their peaks with each other, balance each other's peaks, and collectively shape the contracted capacity. This can be done through a closed distribution system (CDS) or a virtual grid.
        3. Organizational: Hub participants must collaborate to create capacity, make agreements among themselves, and adhere to the agreements made.
2. Advantages of e-hubs: ability to expand and sustain in congestion areas, joint procurement of energy and assets (heat networks, batteries, etc.), joint energy management and knowledge acquisition, savings on the energy bill through joint procurement and smart management.
3. Disadvantages of e-hubs: due to different profiles, different sizes of connections, and different wishes of participants, an e-hub is not always possible or the desired option. Also, in an e-hub, you depend on the other participants; you have to collaborate and trust each other.
4. Examples of e-hubs: REC Tholen"

3.1.1: Legal example

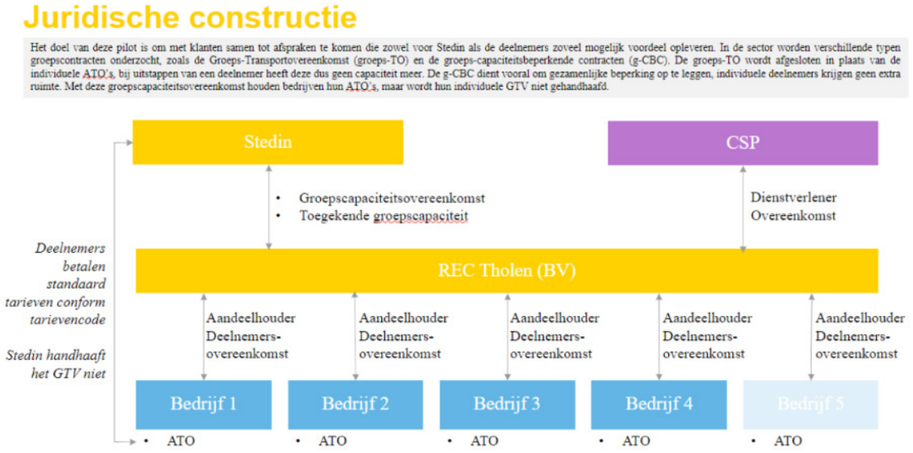


Figure J.3 (Stedin, 2024)

3.1.2: Technical example

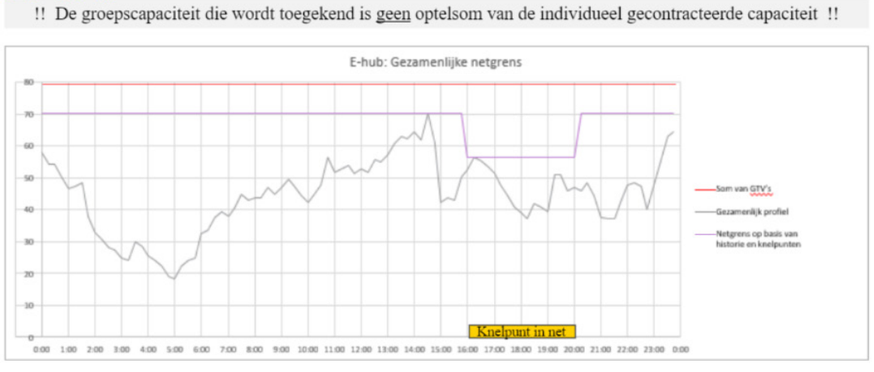


Figure J.4 (Stedin, 2024)

3.1.3: Organisational example

Figure J.5 (Stedin, 2024)

2. Who can form an e-hub?
   2. Connections must be on the same ring (network topology map)
   3. Profiles must be able to complement each other
   4. Profiles with the possibility of flexibility (shifting demand)
3. How does an e-hub come into existence?
   2. Involved roles (demonstrate on next slide)
   3. Customer Journey (demonstrate on next slide)
   4. MOOI EIGEN tool

APPENDIX K TOOLS AND METHODS OF INDUSTRIAL SYMBIOSIS

Tools and methods can be structured into three main dimensions: an environmental/technical dimension, an economic dimension and a social dimension (Ji et al., 2020; Neves et al., 2019; Sonel, Gür & Eren, 2021; Taddeo et al., 2017; van den Bergh & Janssen, 2004). Existing tools and methods either fall into one of these dimensions, or cover multiple. These three dimensions are supported by two essential aspects that should be accounted for in the design process of ISN: technological aspects and organisational aspects (Jacobsen and Anderberg, 2004; Taddeo et al., 2017). More background on different tools and methods that are commonly used in IS design will be explained in this section.

Although a vast amount of research has been conducted on methods and tools focussing on different dimensions and aspects of the design of ISN, little studies focus on multidisciplinary and integrated methodologies (Nunez and Perez-Castillo, 2023). Two main frameworks can be identified with holistic characteristics, the 'IS creation process framework' by Yeo et al. (2019), where clear creation steps and examples of activities are drafted, and the 'Industrial Symbiosis Design Process' framework by Baldassarre et al. (2019).

Baldassarre et al. describe a new view on the design process of IS, and combine the traditional IE perspective on IS (which describes IS as 'a socio-technical process unfolding through a set of events from starting conditions towards outcomes, with a strong focus on environmental impact assessment') with a Circular Economy (CE) perspective on IS (which describes IS as "a sustainable business model in which several stakeholders collaborate on a technical innovation, with a strong focus on business viability') (Baldassarre et al., 2019).

Design methods and tools for the creation of IS have been increasingly researched over the last three decades (Neves et al., 2019). Different studies entail different aspects of and angles on the emergence or design of IS networks (ISN). In existing literature, a practicality - comprehensiveness paradox can be identified. The more focus is put on a single case, the more practicality is offered, including clear methods and tools, however missing applicability for different cases. The more focus is put on general design guidelines for IS, the more comprehensiveness is offered, however practicality in terms of clear methods and tools are often lacking. In solving the case for net-congestion for Stedin both angles are needed, practicality in order to allow for quick and smooth implementation and comprehensiveness in order to allow for accessibility and flexibility of the hubs, as well as multifunctional usage for the design of other hubs. Therefore, this literature research will first focus on practical tools, then on more comprehensive integrated methods, followed by methods and tools that are not IS-specific, but do give more insight into the design of ecosystems in general.

Design tools for IS

Different aspects include technological aspects, organisational aspects, economic aspects, environmental aspects and social aspects (including cultural, institutional and legal) aspects (Jacobsen and Anderberg, 2004; Ji et al., 2020; Neves et al., 2019; Sonal, Gür and Eren, 2022; Taddeo et al., 2017). In order to allow for a holistic framework that focuses on the diverse set of variables needed for the transition of a socio-technical system, these different factors are explored, and specific tools and methods are extracted. Although a vast amount of research has been conducted on methods and tools focussing on different aspects of the emergence or design of ISN, no study includes a summary of tools and methods used to implement industrial symbiosis (Nunez and Perez-Castillo, 2023). In this chapter, tools generally used for the different dimensions and aspects of IS are explained.

Environmental dimension

In existing literature on methodologies and tools for IS, the environmental dimension was of all aspects the most quantified (Neves et al., 2020n). The most used method for the environmental dimension in existing literature is Life Cycle Assessment (LCA), which allows the quantification of potential environmental impacts throughout the life cycle (Neves et al, 2019). Another frequently used method is Material Flow Analysis (MFA), which allows the analysis of flows and stocks of materials, by-products, wastes and resources, mapping out possible leverage points for the emergence of IS. Another frequently used method is the emergy method, which allows taking into account the contribution of the natural ecosystem to the development of synergies (Neves et al., 2020). Tools that focus on the environmental dimension of IS show possible leverage points for the emergence of ISN, however they pay little attention to financial feasibility or social challenges.

Economic dimension

Economical aspects play a crucial role for ISN to attain financial feasibility. Yazan et al. (2020) conclude: "an IS relationship between two companies can only be established successfully if both parties gain economic benefits from the collaboration". Financial feasibility of ISN starts with the investments needed to create the network and a calculation of its payback time. For energy-specific ISN, this includes a calculation of exergy saved, and thus anergy prevented (Hin and Zmeureanu, 2014, Nevez et al., 2020). In the case of Dutch energy-hubs, this includes the amount of curtailment prevented, meaning a more effective usage of all generated, what leads to more revenue (or less potential revenue being lost). Methods and tools used for this dimension include Life Cycle Cost Analysis (LCCA) (Durairaj et al., 2002; Nevez et al., 2020), and mathematical optimizations that determine the ideal network in order to minimise the total cost and maximise possible revenue (Lawal et al., 2021, Nevez et al., 2020). These mathematical optimization tools include several input-output matching tools as the Facility Synerg Tool (FaST), the Designing Industrial Ecosystems Tool (DIET), and the Regulatory, Economic, and Logistics Tool (REaLiTy) (Chertow, 2000; Lawal, 2021).

Social dimension

Mortenssen & Kornov (2019) define the emergence of IS as a dynamic social process. IS activities are shaped by the context in which they occur, described in terms of cognitive structural, cultural, political, spatial and temporal embeddedness (Boons and Baas, 2006), and are based on socio-relational aspects (Taddeo et al., 2017). Mortenssen and Kornov (2019) created a methodology for the emergence of ISN based on three phases: 1) the awareness and interest in industrial symbiosis, 2) reaching out and exploration of connections, 3) organising. These phases come with five groups of critical factors for the emergence of IS: contextual conditions, actors, actor's roles, actor's characteristics and actor's activities. Network analysis can form a tool that is useful to support this methodology as it studies the relationships between entities in a network, focussing on connections between entities as well as the characteristics of the entities themselves (Vahidzadeh et al., 2021; Yu et al., 2013). More insight into behaviours of stakeholders and the behavioural characteristics of ISN can be gained through Agent Based Modelling (ABM) (Bichraoui et al., 2013; Yazan and Fraccascia, 2019; Lange et al., 2021). Real world experimentation is often impracticable for exploring many parameters and actor behaviours, making ABM an essential tool to gain insight into these complex relationships in order to allow for successful ISN design (Lange et al., 2021). A correct exploration and execution of the social dimension of ISN creation creates a 'space of cooperation', which forms the basis of each ISN (Yazan and Fraccascia, 2019). An evaluative tool for measuring the social effects of a life cycle is Social Life Cycle Assessment (S-LCA), used to evaluate the potential positive or negative effects of a product in its whole life cycle in social aspects. This includes the process of raw material mining, production, distribution, application, reuse, maintenance, recycling and finally disposal (Yang et al., 2020)

Technological aspects

Technological aspects are allowing factors for the implementation of IS. They include tools for information sharing and communication between actors within the ISN (Grant et al., 2010; Kosmol, 2019; Maqbool et al, 2019), as well as tools to model the potential or simulate the results of IS (Cecelja et al., 2015; Demartini et al., 2021). With the trend of growing amount of digitised knowledge, coupled with machine learning algorithms, collective intelligence can be aggregated for the optimization of ISN design (Yeo et al, 2019).

Organisational aspects

Organisational aspects form the basis for the implementation of the environmental, economic and social dimensions, and thus are essential for the viability of the ISN. Organisational aspects translate into business models, which make the three dimensions actionable in creating and capturing value, and to serve as templates to implement strategies that companies can adopt to create IS (Nunez and PerezCastillo, 2023). This aspect is crucial to clarify how and why firms applying IS can gain competitive advantage (Fracciscia et al., 2019). A study by Fraccascia et al., (2019) identifies four extreme business models based on two governance features (1) need for coordination and (2) centralisation of control. The creation of IS-specific synergetic business models has not been extensively researched yet.

Integrated methodologies

Research into integrated methodologies for IS instead of individual tools is quite new but emerging (Lawal et al., 2021). It brings together the different dimensions and aspects of separate tools, and combines viewpoints on the design of IS. Process Integration (PI) is an integrated method explained by Lawal et al. (2021), focussing on a holistic view from the standpoint of supply, demand and end of-pipe approach. It aims at improving material and energy efficiency, as well as environmental and economic sustainability of networks (Branca et al., 2021). Van Fan et al. (2021) explain Pinch Analysis (PA) as an extension of PI, namely a sequential/targeting method to facilitate the planning and system design. PA is a mathematical tool for network integration, improving the integration of processes and often developing simpler, more elegant networks (Kemp, 2007). PI and PA are integrated methods, however are still mostly focussing on the Industrial Ecology (IE) perspective of Industrial Symbiosis. Baldassarre et al. (2019) describe this IE perspective as 'A socio-technical process unfolding through a set of events from starting conditions towards outcomes, with a strong focus on environmental impact assessment.' Next to the IE perspective a Circular Economy perspective on IS can be recognized, framing IS as 'a sustainable business model in which several stakeholders collaborate on a technical innovation, with a strong focus on business viability' (Baldassarre et al., 2019). Combining CE and IE views is essential to obtain a holistic framework that includes all dimensions and aspects described before, for a smooth 24 and successful design and implementation of ISN. The framework proposed by Baldassarre et al., (2019) includes creating a collaborative strategic vision and business design as well as impact assessment, therefore makes the design and implementation of ISN actionable. Yeo et al. (2019) make the design of ISN even more actionable, and describe an 'IS creation process framework' with clear creation steps, examples of activities and the corresponding IS driving mechanism (selfdriven, top-down or intermediary).

APPENDIX L TOOLS AND METHODS OF SYSTEMIC DESIGN

Heritage of systemic Design

Systemic design for sustainability finds its origins in Design for sustainable development. Design for sustainable development originated in the 1960s (Baldassarre et al., 2019). Originally, incorporating sustainability into design practices mainly focussed on the physical nature of sustainability challenges and focus on technological improvements, on material and product levels (da Costa Junior, 2020). In recent years, designers noticed bigger structures for sustainable development and have broadened their scope by adding economic, social and environmental perspectives. Focus has shifted from product level sustainable design innovation towards product service systems, where products can be shared and do not have to be owned to improve people's wellbeing. In more recent years design practices continued to broaden their scope, moving onto sustainable business models and later sustainable ecosystems, where multiple businesses cooperate towards increased sustainability. The scope of design for sustainability has shifted from technology or product-centred approaches towards socio-technical systems design (da Costa Junior, 2020). This broadened scope includes complex systems of stakeholders, business models, products and technologies. Da Costa Junior et al. (2019) conclude: "In order to address sustainability challenges, an integrated set of design for sustainability approaches are required, and solutions to those challenges need to cover a broad span of innovation levels."

Systemic Design Tools

Design researchers have made efforts to create various frameworks and methodologies to structurize design approaches in the broad scope of systemic design. A few of these methodologies will be highlighted in this research proposal. Circular Ecosystem Innovation (CEI) (Konietzko et al., 2020) focuses on designing ecosystems that consist of multiple locally, regionally or globally distributed entities that do not belong to a single organisation and involve dynamic, collaborative and competitive relationships. They often involve complementary products, services and capabilities, and evolve as actors constantly redefining their capabilities and relations to others. These are all characteristics of energy hubs, therefore this method is relevant for the design of energy hubs. CEI aims at changing how actors relate to each other and how they interact to achieve a desired outcome (Konietzko et al., 2020). This method fills the gap left by Industrial Symbiosis tools, where residential, commercial and agricultural hubs were not accounted for. Industrial Symbiosis is part of CEI, however CEI focusses on a broader scope as well (fig. L.1)

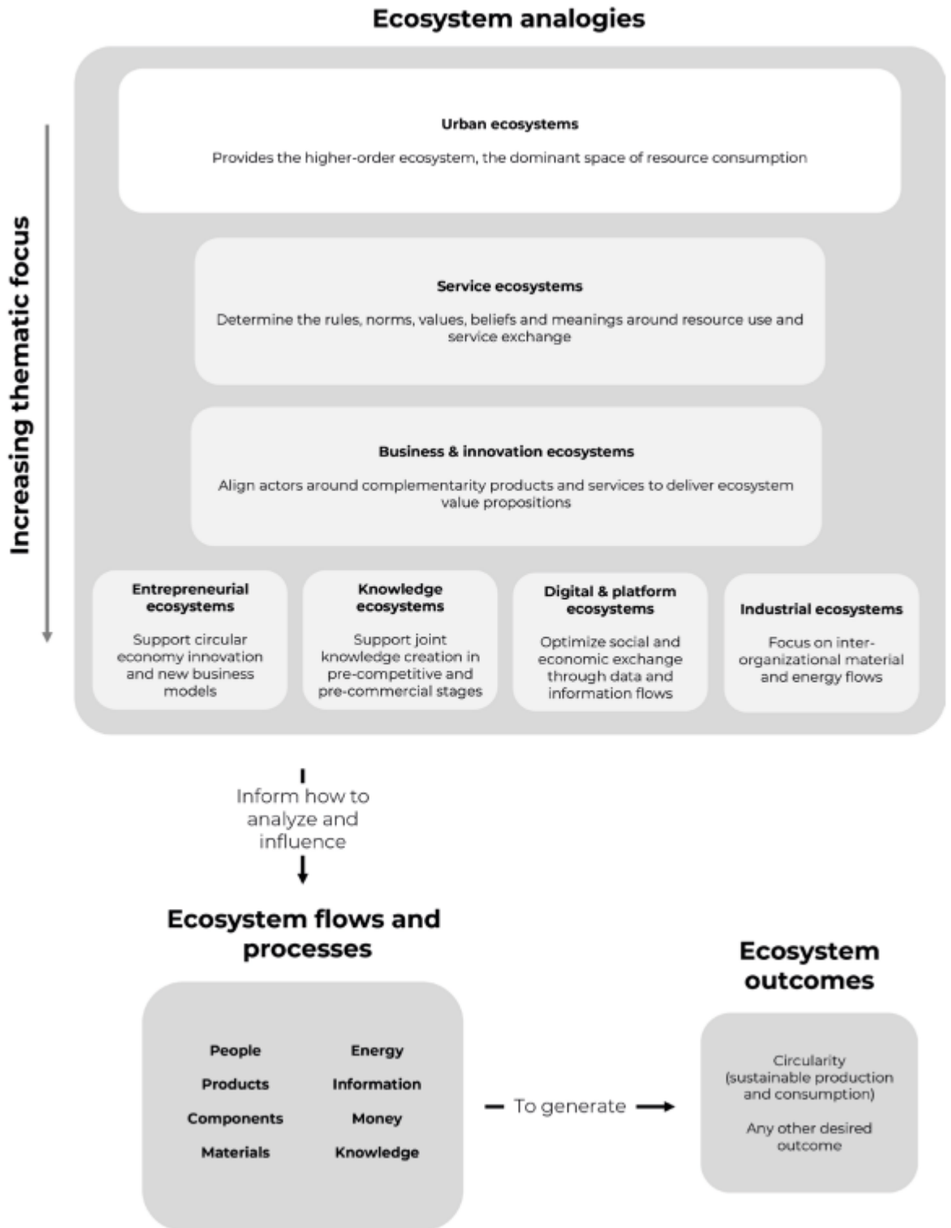


Figure L.1: An integrative framework for innovation in circular economy ecosystems (image source: Konietzko et al., 2020

A philosophy and a variety of methods increasing the applicability and success of energy hubs is user-centred design. This is a broad term to describe design processes in which end-users influence how a design takes shape. Needs and interests of actors are recognized and the usability of the design is pursued (Abras et al., 2004). A useful methodology, that again consists of a variety of methods, is co creation, in which input from users play a central role throughout the entire design process (Redlich et al., 2019). Co-creation leads the way in the transition from top down producer-centric economic notions towards bottom-up economics (figure L.2).

Lastly, systemic design tools include tools for creating shared visions amongst stakeholders and creating viable business models (Baldassarre et al., 2019). Designing business models within networks is explored by means of analysing dependencies on other businesses/ stakeholders (Bocken et al., 2019), by experimentation on systems level (Konietzko et al., 2018), by addressing the design-implementation gap by prototyping (Baldassarre et al., 2020) and by experimenting with circular business models (Konietzko et al., 2020b).

Other systemic design studies in current academic literature include System Oriented Design (Sevaldson, 2013), Holistic Sustainability Design (Reubens, 2016), Whole-Systems Design (Blizzard & Klotz, 2012), Multilevel Design Model (Joore & Brezet, 2015), Systems Design for Complex Societal Problems (Da Costa Junior, 2019). These researches help gain insight into analysing complex systems and consequently designing them, accommodating sustainable development, and will be further researched during the thesis process.

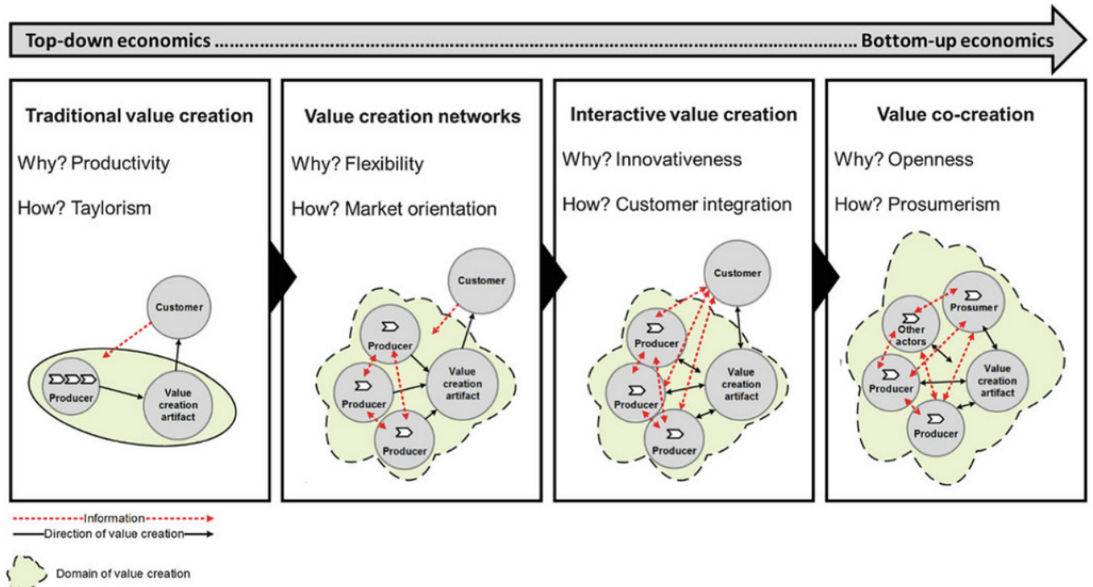


Figure L.2: The development from top-down value creation towards value co-creation in bottom-up economies (image source: Redlich et al., 2019)

Hi!

You are currently holding my master thesis report. In this report, I research the development of energy hubs on business parks in the Netherlands, 2024. I focus on identifying a key role that has the most power and involvement into this development, as well as the drivers and barriers experienced by this role. Consequently, I designed a new proposition consisting of four interventions in current practices. This proposition aims to stimulate the key role and thereby stimulate the development of energy hubs. Are you interested in my research and the designed interventions? Please open this report and read more!

Odile Niers