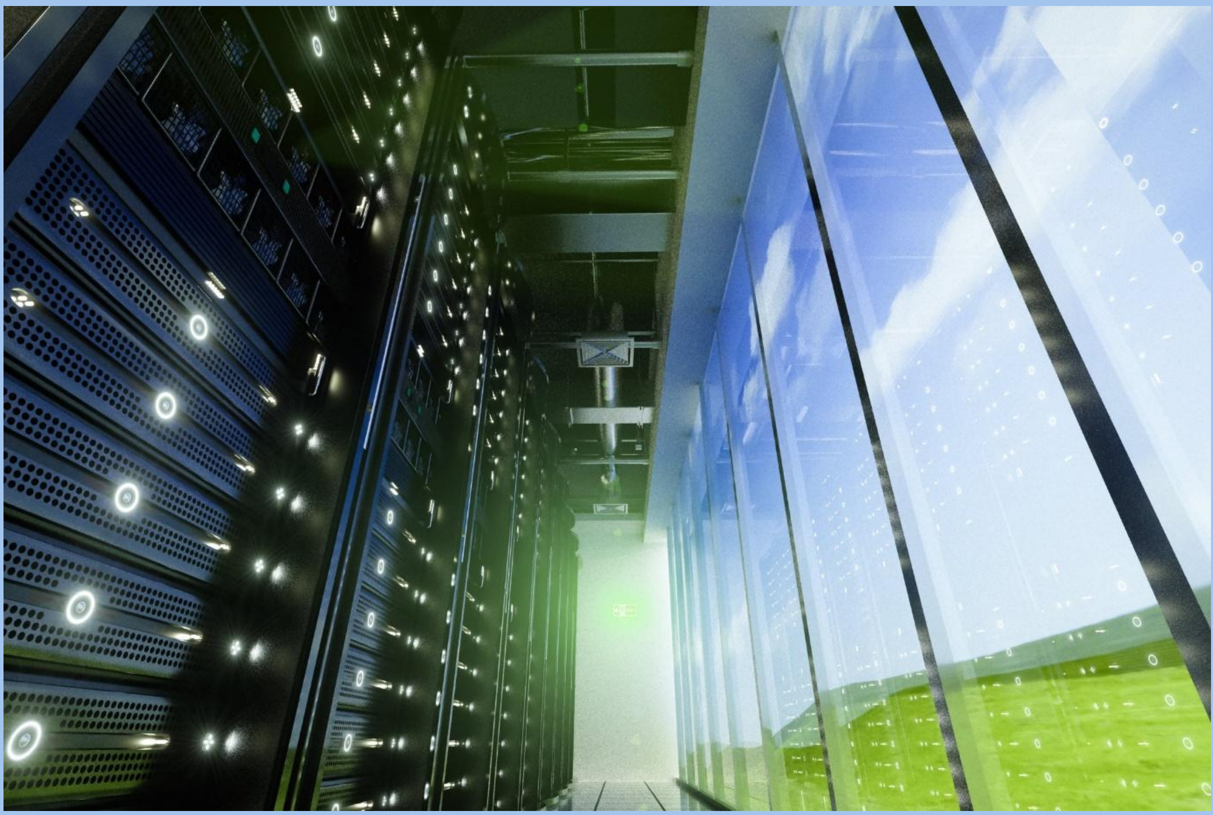

Balancing Data Centre Growth and Sustainability

Mapping the Future of Dutch Data Centres Integrating in the Energy Sector

Suzanne Meijer

June 2025

TU Delft Delft University of Technology

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by

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Cover picture (Hoptroff Smart Timing, n.d.)

TU Delft Delft University of Technology

Acknowledgement

Dear Reader,

The writing of this acknowledgement marks the final part of my master's degree in Complex Systems Engineering and Management. Over the past six months, I have enjoyed working on this research, in which I hope to give insights into the complex story in which data centres operate to contribute to a more sustainable energy sector. Initially unfamiliar with the data centre industry, I owe my understanding to the invaluable insights gained through interviews and events. Data centres, often debated yet largely unseen, inspired me to shed light on their technical possibilities and the challenges in achieving socially beneficial outcomes. Ultimately, I wanted to provide recommendations on how technical, institutional, and economic improvements can be realized.

To be able to do this, I would foremost like to thank my supervisors Aad Correljé and Ivo Bouwmans. My first supervisor Aad, was very flexible throughout the entire thesis with weekly update meetings and many inputs on the use of frameworks and structuring complexities. My second supervisor Ivo was very helpful with brainstorming sessions, together helping me to be able to come to this result. Additionally, I would like to thank all interview participants for freeing up their time, contributing to interesting conversations, showing insights into the data centre industry, and refer to next interviewees. Without their crucial input and being invited to different events, I would never have arrived at the complexity of this problem.

Finally, I would like to thank my fellow students, friends and family for their support and kindness throughout my entire study career. I have learned a lot at the TU Delft and look forward to continuing my path in working life.

It only remains for me to wish you, to enjoy the following pages, which I have carefully written to arrive at the recommendations. If you have any questions, please feel free to reach out to me.

Suzanne Meijer
Delft, June 2025

Executive Summary

This thesis explores the complex position of data centres within the Dutch energy system, driven by the increasing demand for digital services and energy, and the global race for AI dominance. In a world reliant on swiping, streaming, and scrolling, data centres are the unseen engines powering daily life. They operating 24/7 for services like video calls, online banking, and streaming. The Netherlands, as a major European data hub, faces the significant challenge of balancing the rapid growth of digital services and AI with critical concerns around energy consumption, sustainability, grid capacity, and local opposition. This central problem is formulated as, to what extent can the Netherlands continue to support the rapid growth of digital services and AI while ensuring that data centres evolve into sustainable, efficient, and socially accepted infrastructure? By doing explorative research, using a qualitative approach across three phases. The central research question is answered by five sub-questions:

What insights can support the development of policy instruments aimed at facilitating an acceptable role of data centres as intermediaries in the future Dutch energy system?

This research relies primarily on semi-structured interviews with various stakeholders and participation in events. The methodology includes the use of pattern modelling to structure the complexities, and the social acceptance frameworks from Wüstenhagen et al. (2007) and Ellis et al. (2023) to understand how social acceptance effects this.

Phase one, guided by the first two sub-questions, aimed to understand the current complex system and the role of social acceptance. The first sub-question focused on identifying the critical technical, institutional, and economic aspects influencing data centres in the Dutch energy system. This led to the development of the pattern model, firstly mapping technical aspects like grid congestion, data thermal solutions (heat reuse), energy flexibility, renewable energy use, and decentralisation. Secondly, institutional aspects like policy uncertainty, especially regarding the Collective Heat Act (WCW), visions from the national government, current regulations, and complexities introduced by Homeowners Associations (VvE's). Lastly, economic aspects like collaboration, land and resource availability, community acceptance, and business cases. Besides this, the model highlighted stakeholder interactions, including contextual and intern relationships grouped into six themes: heat recovery, public perception, contributing to grid stability, investment climate, decentral development, and efficiency.

The second sub-question delved into social acceptance for data centres, drawing comparisons from wind energy projects where academic literature is more available. Applying social acceptance frameworks, the research examined socio-political, community, and market acceptance, considering time, scale, and power dynamics. Findings indicated that public perception is often negative due to concerns over high energy consumption and past unfulfilled promises, leading to resistance, particularly locally. The research also outlined differing socially desirable future situations among stakeholders, revealing friction points regarding energy supply and heat demand.

Research **phase two** (sub-question three) explored potential future pathways. Two contrasting scenarios were presented. Pathway 1, characterized by limited integration due to persistent systemic barriers, and Pathway 4, representing a socially desirable future where data centres are integrated as active contributors to a sustainable and a resilient energy system. Pathway 4 envisions significant contributions, such as data centres acting as a major heat source, contributing to grid stability, and being supported by proactive, integrated government policies and improved public perception.

Based on this socially desirable future (Pathway 4), research **phase three** (sub-question four and five) identified seven potential roles data centres could play. From optimising energy efficiency, contributing to grid stability, supplying residual heat to heating networks, improving public perception, supporting decentralised data processing, advocating for integrated policymaking, to taking measurable steps towards sustainability. However, the realisation of these roles is hindered by obstacles. Which is why the last sub-question translates these obstacles into necessary policy incentives across the technical, institutional, and economic domains. These interventions aim to overcome barriers, enable the potential roles, and foster social acceptance. Proposed incentives include:

- Technical: Optimizing energy efficiency and heat temperature from data centres, creating conditions for grid stability contributions, and reducing reliance on foreign companies through decentralisation.
- Institutional: Promoting proactive government policies, including deciding about the WCW and creating a clear long-term vision, and improving collaboration among stakeholders.
- Economic: Providing financial incentives for energy flexibility and ensuring the business case and acceptance for heat networks.

The study ends with a recommendation for prioritizing the policy incentives. Which is based on immediate feasibility, urgency for energy transition, and the necessity of policy incentives. *Collaboration improvement* (institutional incentive) is seen as the most effective implementation before technical and economic incentives. Energy efficiency (technical incentive) follows, due to its technical feasibility, while other interconnected measures share a common priority level. These incentives collectively aim to drive system transformation. The last prioritization goes to decentral development. Even though, strategically important for geopolitical and data sovereignty reasons, it is deemed lower in urgency and requires long-term infrastructure changes.

Concluding, a significant strength of this research was the engagement with a wide range of stakeholders, which provided rich insights into the system's dynamics and challenges. The comparison with wind energy also offered valuable insights where data centre-specific literature was scarce. However, the research faced limitations, mostly due to time and resource constraints. This restricted the ability to investigate the practical implementation details of the identified policy incentives or validate findings with interview participants through follow-up discussions. The subjective nature of qualitative data, based on stakeholder perceptions, is inherent to the method, although efforts were made to capture a broad spectrum of views. The pattern model itself reflects the complexity as observed within the scope and data gathered at the time of the study.

Certain topics were excluded due to insufficient data from the interviews or time constraints, such as detailed interactions with horticulture, water usage, in-depth international comparisons, business-to-business heat applications, differences between computing vs storage applications, energy hubs, and detailed spatial planning impacts. While acknowledged as potentially relevant, these were outside the feasible scope given the resources. Some aspects, though mentioned only once or twice, were still included if deemed significant, acknowledging that the lack of widespread mention in the interviews might mean other important aspects were missed.

Finalizing, this study identified eight topics of policy incentives that could improve the integration of data centres into the Dutch energy system. While technically feasible, sustainable data centre solutions in the Netherlands face barriers such as the Collective Heat Act (WCW), underdeveloped heat networks, grid congestion, and limited financial incentives. Opportunities also lie in areas for further exploration, enhancing collaboration, enabling energy flexibility, expanding heat infrastructure, or ultimately develop small, decentralised data centres to enhance sustainability and reduce dependency. Together, these incentives can contribute to realising intermediary roles for data centres in a future-proof Dutch energy system.

Content

List of Abbreviations

Abbreviation	**Definition**
ACM	Authority for Consumers and Markets
AI	Artificial Intelligence
DC	Data Centre
DH	District Heating
DSO	Distribution System Operator
EML	Erkende Maatregelen Lijst (Recognized Measurements List)
ERE	Energy Reuse Effectiveness
EU	European Union
MLP	Multi-Level Perspective
NIMBY	Not-In-My-Backyard
PUE	Power Usage Effectiveness
RVO	Rijksdienst voor Ondernemend Nederland (Netherlands Enterprise Agency)
SMR	Small Modular Reactor
TSO	Transmission System Operator
VvE	Vereniging van Eigenaren (Association of Owners)
WCW	Wet Collective Warmte (Collective Heat Act)
WGIW	Wet Gemeentelijke Instrumenten Warmtetransitie (Act Municipal Instruments Heat transition)

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Chapter 1: Problem Definition

In a world where we swipe, stream, and scroll our way through daily life, data centres are the silent engines powering everything behind the scenes. Whether it's a video call, online banking, or a late-night Netflix, data centres are working 24/7 to keep our digital lives running smoothly. The growing hunger for digital service, and the global race to develop cutting-edge AI, data centres surge in energy demand that's pushing the limits of what our current infrastructure can handle. The Netherlands, often seen as a digital gateway to Europe, is both a frontrunner for success and a pioneer in infrastructural problems in this story. On one hand, the country's strong digital infrastructure and strategic location have transformed Amsterdam into a major European data hub. On the other, concerns about sustainability, electricity consumption, and local opposition are throwing serious challenges into the mix. This thesis dives into the heart of these challenges, stating with a problem definition.

This Chapter highlights the growing demand for digital services and the race for AI dominance. From there, it breaks down what data centres are, why they matter, and how they've evolved in the Netherlands. Leading to regulatory efforts to push the sector toward a higher energy efficiency. Together this provides a contextual understanding from where a literature review (section 1.2) will help to determine, the central research problem: *To what extent can the Netherlands continue to support the rapid growth of digital services and AI while ensuring that data centres evolve into sustainable, efficient, and socially accepted infrastructure?* This Chapter will end with a connection to the CoSEM master's program in section 1.3. Chapter 2 *Methodology* will address the research questions and structure.

1.1 Context

Growing use of digital services

Today's society gets increasingly dependent on digital service, with the importance of data centres in the Netherlands becoming crucial to increase prosperity. Data centres are not only essential for online services but also crucial for supporting critical sectors such as healthcare, law enforcement, government operations, and educational institutions (Jones, 2018). The exponential growth in digital activities, fuelled by the rapid adoption of AI and cloud services, underscores the increasing demand for data centres (Oxford Institute for energy studies, 2025).

According to BloombergNEF (2021), the Netherlands is about to experience a growth rate of data centres, projected between 5.1% and 7.5% annually until 2030. This growth is driven by the increasing digitalization across Europe. The Netherlands has emerged as a leading data hub in Europe, with almost 200 locations spanning a total area of 1.7 million square meters (Dutch Data Center Association, 2025). This growth is supported by robust internet infrastructure, including the AMS-IX in Amsterdam, one of the world's largest internet exchanges, known for its reliability and connectivity (Anp, 2024). The strategic location benefits from extensive telecom networks and proximity to transatlantic cables, further enhancing its appeal to data centre operators. Economically, the data centre sector contributes to 25 billion euros to the Dutch economy (Dutch Data Center Association, 2025). This contribution continues to expand as the demand increases for cloud computing, AI advancements, and digital infrastructure.

However, this growth presents challenges, particularly in terms of electricity consumption and infrastructure sustainability (McKinsey Quaterly, 2025). The growth of data centres, data traffic, and AI use contributes to the rising energy demand in the Netherlands in several ways. This is partly due to the high electricity consumption of data centres. Data centres use around 3% of all European energy, even with it being a relative energy efficient industry (Dutch data centre association, n.d.). Electricity consumption is only expected to grow in the coming years, this is mainly due to AI and cloud services, crypto mining and streaming (International Energy Agency, 2025; Kok et al., 2022).

Race for AI

Europe is a major player in the global digital landscape. The International Energy Community (IEA) researched the development of AI in Europe and came out with a report in April 2025. The IEA predicted that Europe will remain one of the largest regions for data demand in the coming years, alongside the United States and China, which have an even greater demand (International Energy Agency, 2025).

However, the race for AI leadership is seen as a strategically crucial, in which Europe has positioned itself on a third place after the US and China. Europe has a strong focus on ethics, sustainability and strategic autonomy. In April 2025, the European Commission launched the *AI Continent Action Plan* which highlights the importance of developing its own infrastructure, such as AI factories, to support large-scale AI models (Europese Commissie, 2025). This should make Europe less dependent on US and Chinese technologies, which is increasingly high on the agenda with current geopolitical tensions. For this reason, the EU plans within the European *AI Continent Action Plan* to invest 10 billion to increase sustainable AI developed (Europese Commissie, 2025). The idea is to have the data centre capacity tripled in the next five to seven years (Boone, 2025). This should not only boost innovation, but also ensure strategic independence in critical sectors such as healthcare and defence (Europese Commissie, 2025). In addition, by collecting high-quality data, Europe aims to create a single market for data that can scale up AI solutions. However, the Netherlands is already encountering a problem in doing so while developing a Dutch AI tool (GPT-NL). NRC investigated this, highlighting that the process of developing an ethical Dutch AI tool, lack data and money, which is making it very difficult to develop a tool with the same quality as the ones currently on the market from US and Chinese competitors (Bronzwaer, 2025). Despite various efforts, Europe lags behind in terms of global impact. A report by Stanford University points out that only three significant AI models come from Europe, compared to 40 from the US and 15 from China (Bakhtin et al., 2024). This highlights that Europe still needs to take steps to become a leader.

What is a data centre?

Without even noticing, almost everyone is using data centres every day. Data centres have emerged as a fundamental infrastructure to support a wide range of internet services (Huang et al., 2024; Edwards et al., 2024). On a day-to-day basis, people use their phones to watch content on social media, communicate in meetings via Microsoft Teams or use an app to do their banking administration. These are all commonly used activities that run on a data centre, besides these, also more advanced computational activities take place, like running AI servers for optimisation, mining bitcoin or advanced mathematical computations. Almost all industries rely on data centres nowadays, hospitals need to ensure their computers work, educational instances run processes, governments need to process administration, airports need them for flight safety and scheduling, and these are only a fraction of things that happen in a data centre. It's important to see that our modern day society cannot function without data centres, only most people see data centres as big ugly boxes that consume too much energy (De Avondshow met Arjen Lubach, VPRO, 2022).

According to the Dutch data centre association (n.d.) *A data centre is an industrial, highly secured building, built with a clear purpose: ensuring that computer servers with digital applications run uninterruptible, 365 days a year, 7 days a week, 24 hours a day*. Data centres are connected via fiberglass in the ground or transportational cables over sea. Within Figure 1.1 the existing data connected cables to the Netherlands can be seen (Sovacool et al., 2022). This is an overview, when zooming in, it can be seen that Amsterdam has a relatively dense cable connection compared to other European cities. This is prior to the fact that Amsterdam was early with the connection of telecom cables, already in 1845 (Telecom, 2024). These telecom cables provided a basis for the digital possibilities within the Netherlands, leading to a frontrunner role for Amsterdam at the beginning of the century. This pioneering role stopped when the municipality of Amsterdam decided to stop the increase of data centres within the region from 2023 (Wagemakers, 2023). Now, Amsterdam's reputation is of a city with high energy prices, low grid capacity, much resistance from the public and low capacity for new data centres[1]. Even with this decline in reputation, data centre operators continue to push the sector forward, highlighting the need for data centres and the potential for sustainable solutions[2].

[1] Event Data cloud Energy & ESG

[2] Event Data cloud Energy & ESG

Figure 1.1 Overview of high speed digital cables connected to the Netherlands. Source: retracted from Telegeogragaphy (2025)

There are three main types of data centres, *Enterprise*, *Colocation* and *Hyperscale's*, of which an overview is given in Appendix A. The Netherlands has three hyperscale data centres, around 180 colocation data centres and many smaller enterprise data centres. These three types of data centres have different business models, however, some aspects are the same for all commercial data centres. For this thesis, it is important to know that all data centres require a high and reliable energy supply, and a 24/7 server availability. Meaning that data centres, commonly have a high energy consumption, and they need energy on a predictable constant basis.

Reporting duty data centres

To gain better insight into the energy consumption of data centres and to take the first steps toward implementing energy-saving measures, the Netherlands Enterprise Agency (RVO), together with the environmental services, is working on mapping and enforcing this. In 2023, the Recognized Measures List (EML) was introduced for this purpose. Data centres with an annual consumption between 5,000 MWh and 10,000 MWh are legally required to submit an energy consumption report every four years. Data centres consuming over 10,000 MWh are obliged to do research into energy-saving techniques that have a payback period of five years or less.

This is often perceived as a burden, as it requires a lot of time and paperwork. Vague guidelines contribute to a generally negative perception of the obligation[3]. For colocation data centres, this is particularly complicated since they have little visibility into what their clients are actually doing within the data centre. A colocation data centre is comparable to a hotel, where the owner is unaware of what goes on in each room, yet still being held accountable for a wrongful event. The general attitude of data centres toward investigating sustainable alternatives, is that these kinds of obligations, fall outside their *core business*. The same goes for energy-saving measures, if something is easy to implement, it will be done, but only if there is a clear financial benefit. That said, the EML list is never complete, and many data centres are not aware of simple energy-saving actions they could be taking[4].

In the interview with Omgevingsdienst Noordzeekanaalgebied (environmental service of the region of Amsterdam), Lambregts (2025)(Omgevingsdienst Noordzeekanaalgebied) *mentioned that Dutch data centers often claim to be very energy-efficient. However, this assertion is not further substantiated by the industry. The laws and regulations on the sustainability of energy use in companies that the environmental services oversees provide the industry the opportunity to substantiate this claim. She emphasized that data centres must first start with themselves by minimizing their own energy and water consumption before focusing on subsequent steps such as diverting waste heat for third parties.*

[3] Event Workshop EML

[4] Event Workshop EML

Efficiency Data centres

The reporting duty highlights a step that was taken in order to decrease the energy efficiency from data centres. To determine the efficiency of a data centre, the *Power Usage Effectiveness* (PUE) is a widely used measurement in the industry (Jones, 2018). This measurement determines the energy efficiency of an energy using entity, for which the calculation can be seen below. The lower the PUE, the better the energy efficiency of an energy consuming entity (Xue et al., 2023). The Netherlands strives to data centres with a PUE of 1.2, which are already quite efficient, conventional data centres typically have a PUE of 1.92 (Avgerinou et al., 2017; Jones, 2018). However, the Dutch average lies currently between the 1.2 and 1.4 (Rijksdienst voor ondernemend Nederland, 2025b).

$$PUE = \frac{Total\ Facility\ Power}{IT\ Equipment\ power}$$

*Equation by *Xue et al. (2023)*

$$PUE = \frac{IT\ Equipment\ Power + Cooling\ system\ Power + Supply\ and\ Distribution\ Power + Others\ Power}{IT\ Equipment\ Power}$$

*Equation by *Xue et al. (2023)*

There are different technological options investigated to decrease the PUE of a data centre. This entails increasing cooling efficiency, choosing the right locations, energy-efficient hardware or workload consolidation. The energy used by the cooling systems of data centres is one of the major points of energy consumption for data centres, and entails on average 38% of the total energy consumption (Xue et al., 2023; Zhou et al., 2018). Increasing the cooling efficiency can contribute to an overall increase in energy efficiency (ChannelConnect, 2025; Jones, 2018).

Once the data centre is in a colder climate, efficiency tends to be higher because there are more options available for free cooling (Jones, 2018). Free cooling can be used once the outside temperature is lower than the average data centre temperature, this can significantly improve data centre efficiency (Avgerinou et al., 2017).

Eco-modus of servers, is the standard modus at the moment of installation, which is different from high performance modus and requires less energy to be used[5]. Using this modus instead of the high performance modus is in Dutch practice one of the most common energy saving methods at the moment[6].

Last, Microsoft has experimented with AI cooling models changing workloads to avoid creating hot spots within data centres, and therefore they reduce the overall need for cooling and thus lowers the PUE of the data centre (Hota, 2024). This is a way of thermal time shifting, which is studied by Skach et al. (2017), they found that this technique can decrease the peak cooling load with 12%. Also Google has experimented with this, by implementing an AI-based cooling optimization system, Google achieved up to a 40% reduction in energy used for cooling at their data centres. AI with Artificial Neural Networks (ANNs) are most popular and able to predict thermal conditions, adjust fan speeds, and even modify chiller settings to maintain optimal energy use (Hota, 2024; Cai & Gou, 2024).

These alternatives, to create a lower PUE, can be helpful to create more sustainable data centre solutions within the Dutch energy system. However, this may not provide enough change, into a sustainable future. Therefore, the next section *Literature Review and Problem Statement* explores the status of alternatives beyond energy saving measurements.

1.2 Literature Review and Problem Statement

Since this topic is relatively new, there is limited academic literature available, the literature that is available was found via Google Scholar and through references from articles between January and February 2025. The selection criteria for this review were based on: year, mostly include recent studies between 2019 and 2024, and relevance, to provide valuable insights into different aspects of integrating data centres into energy systems. The goal of this analysis is to get valuable insights into potential knowledge caps providing challenges for the growing amount of data centres in the Netherlands. For this analysis, fifteen papers were analysed. This literature review

[5] Event Workshop EML

[6] Event Workshop EML

dives deeper into the technical possibilities of sustainable data centres development, economic feasibility and policy status, and lack of societal implementation. This section ends with the definition of the problem statement based on these findings.

Technical feasibility

From a technical standpoint, the notion that data centre sustainability is solely an engineering issue is outdated, several studies highlight higher efficiency, and the role for reusing generated heat. Terenuis et al. (2023) highlight that modern data centres are already highly efficient, necessitating a multidisciplinary approach to sustainability that integrates renewable energy systems and innovative technologies, such as reusing heat. Research by Yuan et al. (2023) and Pärssinen et al. (2019) demonstrates that data centre heat can be effectively reused through district heating (DH) systems, heat pumps, and thermal energy storage (TES) to mitigate supply-demand mismatches. Prioritization for heat utilization should focus first on proximate heating needs, followed by leveraging existing DH networks and enabling renewable power generation where heat pumps are employed (Davies et al., 2016). Heat pumps, as Ebrahimi et al. (2014) note, can significantly enhance the quality and usability of heat recovered from low-temperature sources like data centres. Wahlroos et al. (2018) observe that TES systems, can further improve seasonal flexibility by storing excess heat for later use. The integration of renewable energy systems into data centre operations has been explored with promising results by Sovalcool et al. (2022), while Han et al. (2023) propose clustering smaller data centres to optimize both data and heat capacity.

Another critical factor in the technical feasibility of data centres acting within the energy system is geographic location. For instance, Wahlroos et al. (2018) demonstrate that colder climates, such as those in Nordic countries, enhance the performance of data centre heat recovery systems. Li et al. (2021) addresses that the availability of existing district heating systems, as an aspect that can increase the potential integration of data centre heat into the energy system. Huang et al. (2019) and Kant (2009) argue for the difference in system efficiency between higher and lower populated aeras, in which the distance differs between the heat sources and the heat users, advising to take the density of the area into account when determining the technical and economic system efficiency potential.

Economic feasibility and policy status

The technical status of sustainable data centre solutions seems promising according to the so far analysed literature. There are also some studies explaining the economic feasibility and policy status of sustainable data centre energy systems. According to Yuan et al. (2023) there is a relatively short payback period for heat recovery projects, typically ranging from two to eight years. However, there are also high initial investment costs, unclear business models for data centre operators, and limited expertise in the energy sector from data centre owners that create significant barriers to implementation (Wahlroos et al., 2018). Addressing these challenges, Monsalves et al. (2023) conducted a case study in Denmark, concluding that transparent collaboration between stakeholders, alongside supportive policies, is critical to overcoming these obstacles.

Different case studies highlight success stories that can guide policy and economic strategies. For example, Terenuis et al. (2023) documented a project in Stockholm where data centre heat is successfully integrated into a district heating system, with heat reuse from a data centre being particularly effective for heating a swimming pool.

Last, the literature consistently points to the need for robust policies to support the integration of data centre projects into the energy system (Wahlroos et al., 2018; Huang et al., 2019; Monsalves et al., 2023). Huang et al. (2020) underscores the necessity of balancing economic and environmental performance when designing sustainable energy projects, suggesting that decision-makers must evaluate trade-offs to maximize both revenues and burdens among stakeholders. Besides this, Koronen et al. (2020) highlight financial incentives, including tax exemptions and electricity cost differences between countries, as crucial elements for promoting data centre sustainability. However, they also note the scarcity of comprehensive EU directives and policy instruments to address the specific challenges to data centre heat recovery.

Lack of societal implementation

The societal implementation of sustainable data centre solutions has been inadequately explored, particularly in the context of collaborative efforts among diverse stakeholders (Wahlroos et al., 2018). While successful examples exist in Nordic countries, similar applications have not been realized in the Netherlands, highlighting a geographical and contextual gap. This provides an opportunity for this research to define the role for data centres in a Dutch energy system as intermediaries, particularly their potential for demand flexibility and heat recovery which is challenged by cost, infrastructure development, stakeholder collaboration and clear policies (Monsalves et al., 2023; Gürsan et al., 2023).

The literature review shows promising opportunities from other countries for data centres to act within the energy sector. However, the context sketch shows a somewhat negative general perception, for ongoing projects that go beyond just optimizing internal energy use. Even though, the described developments and the growth in digital services and AI, could contribute to a shifting energy system in the Netherlands, one in which data centres could play a key role. Leading to the problem identified to be analysed within this thesis:

To what extent can the Netherlands continue to support the rapid growth of digital services and AI while ensuring that data centres evolve into sustainable, efficient, and socially accepted infrastructure?

1.3 Relevance with CoSEM

The connection between these challenges and the *Complex System Engineering and Management* (CoSEM) master's program lies in addressing the interaction between technological systems and societal structures. This research integrates systems thinking by creating an overview of the complex situation, stakeholder analysis, finalizing pathways and creating policy recommendations which might address bottlenecks in scaling the amount of data centre's in the Netherlands. By understanding the complexities, that contribute to data centres acting in the energy system, this study aims to provide Dutch policymakers with actionable recommendations. This aligns with the CoSEM material of managing technical systems while addressing the technical, institutional, economic dynamics even as the stakeholder interactions between them. With a clear overview of the current situation and policy recommendations, this study contributes to the sustainability of the built environment and supports the Netherlands' transition to a climate-neutral energy system.

Chapter 2: Methodology

This Chapter outlines the methodology and research questions that guide this research. It details the research design and the specific sub-questions. Furthermore, this Chapter explains the use of interviews as a key qualitative research method for gathering insights from various stakeholders involved. This Chapter ends with the theoretical basis explaining the use of pattern modelling, the influence of transaction costs economics, social acceptance, and the scenario study applied in this thesis. Together, this provides the basis for understanding how this thesis aims to explore and answer the central research question regarding the development of policy instruments for an acceptable role of data centres in the future Dutch energy system.

2.1 Research Design

This thesis explores the complexities, examining the rise of data centres, their impact in the Dutch energy system, and efforts to make the sector more energy-efficient and sustainable. Such as shown in Chapter 1 *Problem Definition*. This problem will be addressed using a qualitative research method, primarily relying on semi-structured interviews and events with various stakeholders. This approach is chosen to capture a diverse range of viewpoints and perceptions regarding the role of data centres in the Dutch energy system and the potential policy instruments that could facilitate their integration. The central research question for this thesis is as follows:

What insights can support the development of policy instruments aimed at facilitating an acceptable role of data centres as intermediaries in the future Dutch energy system?

To answer this research question, this thesis is divided into three phases and five sub-questions, which helped to give guidance through this thesis. The first Chapter already provided a clear problem definition, which included a basic understanding of what a data centre is and in which context this research is done. This methodology section shows how the rest of research is done and provide a basic understanding of the frameworks that has been used. After which, phase one will start.

Phase one is about the ***current situation,*** to get a better understanding of the current technical, institutional and economic aspects in the system data centres are operating in as well as the stakeholder interactions. This leads to the first sub-question:

SQ1*: Which aspects within the Technical, Institutional and Economic domains are critical for understanding the role of data centres interacting in the Dutch energy system?*

To be able to answer this sub-question, pattern modelling is used, this method can contribute in finding links between technical, institutional and economic aspects as well as the stakeholder interactions between them. Section 2.3 *Pattern modelling,* will dive deeper into the understanding of this technique. To be able to find those patterns, interviews were conducted, which is elaborated on in section 2.2 *Interviews.* The results from answering the first sub-question lead to an understanding of how the current situation regarding data centres acting within the energy sector looks like. However, not only static technical, institutional and economic aspects affect the development of sustainable data centres solutions. There are interactions between stakeholders which determine the dynamic relationship between the different aspects. These will be addressed within seven different themes, all covering parts of the complex system.

Different studies over time have shown that giving attention to the issues of social acceptance can increase the change for successful development of technology (Wüstenhagen et al., 2007; Heiskanen et al., 2008; Enevoldsen & Sovacool, 2016; Segreto et al., 2020). This is the reason that phase one is extended with a second sub-question that dives into the social acceptance of data centres. Leading to sub-question 2:

SQ2*: To what extent can the concept of Social Acceptance be used to analyse the impact of social acceptance for data centres in the Dutch energy system and the formulation of socially accepted futures?*

To answer this sub-questions, the frameworks from Wüstenhagen et al. (2007) and the extension on this framework from Ellis et al. (2023) are used. Section 2.5 *Social Acceptance of Renewable Energy* will elaborate on the working of these frameworks. While doing the literature review, it was found that there is not much literature available to define the social acceptance of data centres. However, other renewable energy sources were widely discussed in academia. This leads to the decision to first review the social acceptance of wind energy projects. These results will be compared with the data centres acting in the energy sector, which will be described in Chapter 4 *Social Acceptance*. A literature review of sixteen studies was done to obtain the most important lessons for social acceptance of wind energy projects, which can be read in section 2.5 *Social Acceptance of Renewable Energy.* These lessons are used to compare the situation for data centres. A socially acceptable future, can be different for different stakeholders, therefore, this Chapter will also give attention to the different social acceptable futures per stakeholder group.

With the complex pattern model and the social desired futures found in phase one, **phase two** starts in Chapter 5 *Potential Pathways*. The goal of phase two is to ***define potential pathways***. To show stakeholders what ideal future pathways look like, needed to answering the third sub-question:

***SQ3**: How can insights into the complex system contribute to the formulation of future pathways to obtain a sustainable energy system?*

Chapter 5, answers this sub-question, determining four extreme pathways by designing qualitative scenarios. How these pathways will be developed is discussed in section 2.6 *Scenario Study.* These pathways are developed from a stakeholder perspective, using the interview data as a basis for the desired situations. For each pathway, a distinction will be made for how different stakeholders will value this future path. This will provide insight into where stakeholder agree and where they are opposed.

Phase two has contributed to the outline of potential future pathways for which advice will be given for the future Dutch energy system in the last research phase, **phase three.** In which first, will be explored what **role data centres** can play in the most socially-accepted future path, which lead to answering sub-question 4:

***SQ4**: Which possible intermediary roles can be foreseen for Dutch data centres to contribute in the future Dutch energy system?*

Chapter 6 *Role of Data Centres and Policy Incentives,* dives into the seven different roles data centres can play within the desirable future pathway. Even though these roles are technically feasible, there are some obstacles which hinder the realisation of these roles and the final realisation of this future pathway. These obstacles highlight the need to overcome them. Therefore, the last sub-question toughest upon the **policy incentives** that need to create movement within the technical, institutional and economic domains to overcome the obstacles. Which leads to the last sub-question of this research:

***SQ5**: What policy instruments can be useful to create an acceptable Data Centre role within the Dutch energy system?*

Therefore, Chapter 6, will end with a recommendation of different technical, institutional and economic aspects that need to change before stakeholders will move into the direction of the desired future pathway. Last, it reflects on the impact from these roles on the social acceptance for data centres. Together, these three research phases and five sub-questions will contribute to answering the central research question:

What insights can support the development of policy instruments aimed at facilitating an acceptable role of data centres as intermediaries in the future Dutch energy system?

This research question will be answered within Chapter 7 *Towards an Acceptable Role for Data Centres: Synthesis and Recommendations.* This Chapter will prioritize the incentives, synthesise the research, and tough upon the impact on the broader Dutch energy transition realizing an acceptable role for data centres as intermediaries within the future Dutch energy system.

2.2 Interviews

Research interviews are part of a qualitative research method in which the viewpoint of different involved stakeholders can be taken into account (Hannabuss, 1996). A sufficient interview provides data to help answer the research question (De la Croix et al., 2018; Remenyi, 2011). Interviews are about understanding perceptions for which it is important to create structure within the interview. De la Croiz et al. (2018) describes some types of interviews and highlights the fact that interviews can create new information and perspectives which cannot be obtained via other sources.

Some limitations of interviews as tool to do qualitative research, are pointed out by Hannabuss (1996), stating that it is time-consuming, and interview participants might give socially desirable. For example, if a participant is very enthusiastic about a particular subject but is unaware of external obstacles. So a business owner could be more optimistic about certain situations occurring than a controlling body or policymaker. Therefore, it is important to take different perspective into account as well as different interview settings. To be able to capture these different views, not only one-to-one interviews were taken but also group interviews, and external events were attendant. Appendix B provides an overview of the 24 interviews that were done and the four events that were attendant between February and May 2025.

Most of the interviews were done online via Microsoft Teams, an online interview was conducted as follows. First preparing the interview, in which back-ground knowledge was collected about the interview participant to create a set of questions and a guideline through the interview. The set of questions, a short explanation of the interview set-up and a consent form, which can be seen in Appendix C and D respectively, were emailed to the participants a couple of days before the interview took place. Hannabuss (1996) highlighted the fact that participants need to warm up, this warm-up can be achieved by giving the participants time to think about their answers already beforehand. All online interviews were recorded, transcribed and summarised to gather the data and to be able to use the data within the thesis. The participants were notified about this and were able to go off-record if they wanted. The interview summaries were emailed back to the participants and there was asked for feedback on it, after which the summaries could be used within the thesis, for specific quotations, this consent is verified by the interview participant. Within the interview itself, there is an attempt to keep the discussion going by listening to the participant, trying to ask clarifying questions, and by avoiding yes/no questions or judgemental reactions as advised by Abell & Myers (2008). Besides the one-on-one interviews, there were two group interview, which was more challenging to conduct. This type of interview is also interesting, because the researcher can see the dynamic between the different participants and can obtain information about participants talking to each other. The preparation of this type of interview was the same as for the one-on-one interviews, also a summary was created which was sent back to the participants for feedback.

Interview participants were collected via a number of sources. First, the network from Aad Correljé was used to get interviews with the first participants. The next line of participants were collected via interviewees, creating a snowballing effect. Besides this method, connections were made at the different events that were attendant. After a while, interview participants started to refer to participants that were already interviewed and some attendees were met at different events, seeing this as a natural point where enough interviews were done to get the variety of insights.

Besides the interviews, four events were attended, of which can overview can be seen in Appendix B *Interview Participants and Attended Events.* These events also contributed to a greater understanding of the complex situation data centres are operating in. During these various events, an interaction between different stakeholders could be observed. In addition, informal contact during these events, can be very valuable for explorative research. During these moments, thoughts and perceptions are shared that are sometimes difficult to get on record in interviews. This valuable information is therefore also included in the research.

Throughout this rapport, I shall refer to the interviews in two different ways. First, some nuances were said during the interviews or observed during events. In this case, a footnote is added to the sentence with a reference to the specific interview or event where this information was observed. Appendix B, table B1, list which interviews are done, some names are left out due to privacy concerns. In other cases, there is a specific person who shared his or her vision, in these cases, the person is quoted which can be directly seen in the text. With ‘surname (2025) (expertise) *citation’,* of which an overview can be seen in Appendix B, table B2. These citations are verified with the interview participants.

2.3 Pattern Modelling

Data centres act within a complex system, meaning different technological, institutional and economic aspects influence the development of sustainable data centre solutions. One way to bring more structure into the analysis is to use the concept of pattern modelling described by Wilber & Harrison (1978). This concept comes from the institutional economic theory. However, traditionally, there is spoken of the neoclassical economic movement. Which assumes rational thinking people, a market of perfect information, and individuals maximising their social well-being and making trade-offs to create the most efficient or '*pareto-optimal'* solutions (Goodland & Ledec, 1987). An alternative movement to this, is the new institutional economics, which highlights patterns and human behaviour created by institutions who set the rules of the game influencing economic welfare or prices (Hodgson, 1998). Wilber & Harrison (1978) used this movement to get attention for pattern modelling. This entails identifying patterns that influence economic and social behaviour by habits, norms, rules and market structures. Also, Ramstad (1986) uses this method, to show that it allows more structure into complex interactions between individuals or parties. Resulting in a system which can be better understood, an example structure from Ramstad (1986) can be seen in Figure 2.1. In this example, the different areas A, B and C stand for the different social aspects within a system, like technical, institutional or economic aspects. The figure shows that the technical aspects in area A are connected to institutional aspects in area B and the economic aspects in area C, which can all change over time. Such a figure will be created within this thesis. Applying an iterative process, every bit of information, interview and event will add new aspects leading to the final complex pattern model at the end of Chapter 3 *Defining the Pattern Model.*

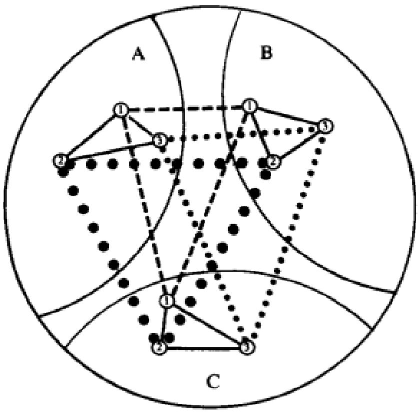

Figure 2.1 Example system of pattern modelling by Ramstad (1986)

There are four steps to apply pattern modelling described by Wilber & Harrison (1986) and Ramstad (1986). Both studies highlight that these analyses can be best obtained by using different kinds of research strategies. This thesis investigated patterns by doing desk research, literature reviews, investigating case studies, semi-structured interviews, and attending data centres related events. The first step in pattern modelling is, the identification of patterns, this can be done by giving an overview of the technical possibilities for sustainable data centre solutions, which will be done in section 3.1 *Technical Aspects*. Not only a technical overview is important, in identifying patterns, it is also crucial to prioritize which aspects are more relevant than others. Within this thesis, this is done by adding technical aspects as nodes, which are spoken of within several interviews. After the identification of technical aspects, the causes need to be analysed, causes can be obtained via institutional rules and regulations which are active or lack existing within the system. This is done by adding institutional aspects, discussed within the interviews, as nodes in section 3.2 *Institutional Aspects*. Step three, is the understanding of the consequences of these technical and institutional patterns and causes. These consequences need to be analysed within a broad holistic social context, they create (sub-)optimal economic situations, these in interviews discussed economics aspects are added as last nodes in section 3.3 *Economic Apspects*. The last step in pattern modelling is a dynamic analysis of changing patterns over time and the influence of stakeholder interactions upon this, both Wilber & Harrison (1986) and Ramstad (1986) mention that human behaviour is not rational which can lead to unexpected dynamic changes. Therefore, interconnections between the technical, institutional and economic aspects (nodes) are connected via stakeholder interactions. Because the stakeholders interactions are also complex relationships on itself, they will be divided into different themes. These themes will each describe a part of the complex relationships between the stakeholders. The implementation of the themes within the pattern model will show the relationship between the different nodes and how they contribute to the complexity of the energy system in which data centres operate in the Netherlands.

After the problem definition in Chapter one, an empty pattern model can be created, including the contextual factors as external nodes, this model can be seen in Figure 2.2. The first research question will dive into the findings of the technical, institutional and economic aspects, adding them as nodes within the empty pattern model. However, as can be seen, the first technical node, *Energy Efficiency (EE),* is already added, as this has been highlighted within Chapter 1 *Problem Definition.* After the identification of all nodes, they can be connected to each other via stakeholder interactions, described in section 3.4 *Stakeholder Interactions.* These interactions define the last step of pattern modelling, including seven different themes which will discuss the complexities in more detail. Leading to the final complex pattern model. This model can be used to identify future pathways and roles for data centres within research phase two. Appendix F provides an overview of the abbreviations used within the pattern model figures.

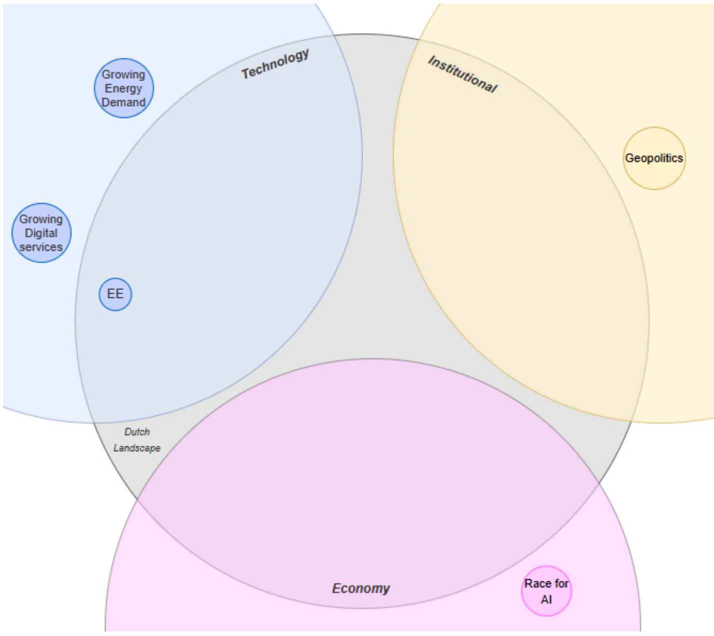

Figure 2.2 Empty pattern model with contextual factors and Energy Efficiency (EE)

2.4 Transaction Costs Economics

Before the economic aspects can be obtained within the pattern model, there is one crucial economic theory which needs to be understood. This is about *Transaction Cost Economics* (TCE), which is a crucial framework for understanding how organizations structure their economic activities to minimize costs associated with transactions. Williamson (1989) discusses the TEC in which he examines how governance structures emerge to minimize costs associated with economic transactions such as planning, negotiation, and enforcement. Transaction costs include expenses related to gathering information, negotiating contracts, and enforcing agreements. Williamson argues that these costs can lead to inefficiencies, such as opportunistic behaviour and the risk of contractual failure, which in turn influence whether transactions occur within firms or in the open market.

To be able to explain the working of TCE, Williamson (1998) starts with the four layer of institutions overview, which can be seen in Figure 2.3. With this figure, Williamson explains that transactions occur, within the third layer of institutions. The first layer is about norms and values within a society, these change very slow. The second layer is about organising economic activity, this layer is also called "*the rules of the game*", here it is determined how political set-up is organised and what is against the law. The third layer, where transactions occur, is about institutions and governance. Within this level, "*the game is played*", where markets are created, or firm structures take place. The last level, is the neoclassical economic and agency level. This entails, among others, responding to market changes in terms of price and supply and demand. Having a basic knowledge of each level and where certain processes occur gives more insight into the changing dynamics of these processes and how certain processes might be influenced.

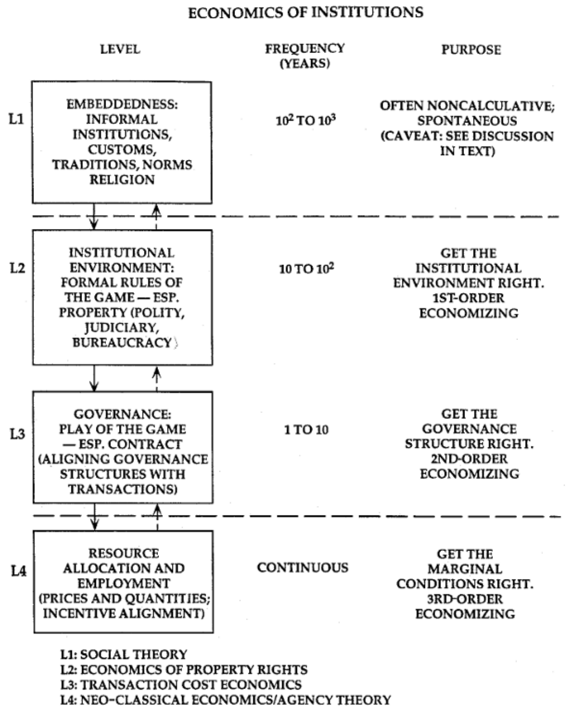

Figure 2.3 Describing four layers of economic institutions by Williamson (1998)

Besides the four layers of economic institutions, Williamson's framework emphasizes bounded rationality, asset specificity, and opportunism as key determinants of whether firms internalize activities or rely on markets. Bounded rationality refers to the limited cognitive capabilities of decision-makers. It recognizes that people have constraints on their ability to process information and make fully rational decisions (Williamson, 1998). Bounded rationality makes it impossible to write complete contracts that account for all external factors to be influenced by. This increases the costs of negotiating, monitoring, and enforcing agreements, and therefore the transaction costs. Also, asset specificity is important here, which describes investments that are specialized to a particular transaction or relationship and have limited value outside that context. Suck costs play a role in assent specifically, because they tend to be high for these types of investments. This can create the potential for hold-up problems, where one party may try to renegotiate terms after relationship-specific investments are made. This increases the costs of safeguarding investments and adapting to changes. Last, Williamson discusses *opportunism*, this entails deliberately putting your own interest above that from someone else, often through deception or withholding information. Opportunism combined with asset specificity and bounded rationality creates the need for governance structures to mitigate potential exploitation. This increases the costs of establishing control mechanisms and resolving disputes.

These factors make transactions more complex and costly to manage, leading to higher transaction costs. High costs, driven by uncertainties, specialized investments, or frequent negotiations, often lead organizations to adopt in-house operations rather than market-based solutions. Within the Dutch data centre industry, TCE principles influence sustainable development strategies. For instance, investments in energy-efficient designs, renewable energy integration, or applying data thermal solutions require asset-specific infrastructure, which increases transaction costs if outsourced. Getting insights into the factors that play a role in the TCE of Dutch data centres gives a better overview of why certain choices occur.

This theory will be taken into account while addressing economic aspects within the pattern model. TC (Transaction Costs) will be the first node added in the economic domain of the pattern model. This will influence all other economic aspects within the model, because adding nodes, adds complexity to the pattern model. The higher the systems' complexity, normally, the higher the transaction costs, because more collaboration is needed to overcome planning, negotiation, and enforcement costs. This can lead into more challenges realising projects, the complex system relations described within this thesis will highlight this. Adding the TC node to the model can be seen in the updated version of the pattern model in Figure 2.4.

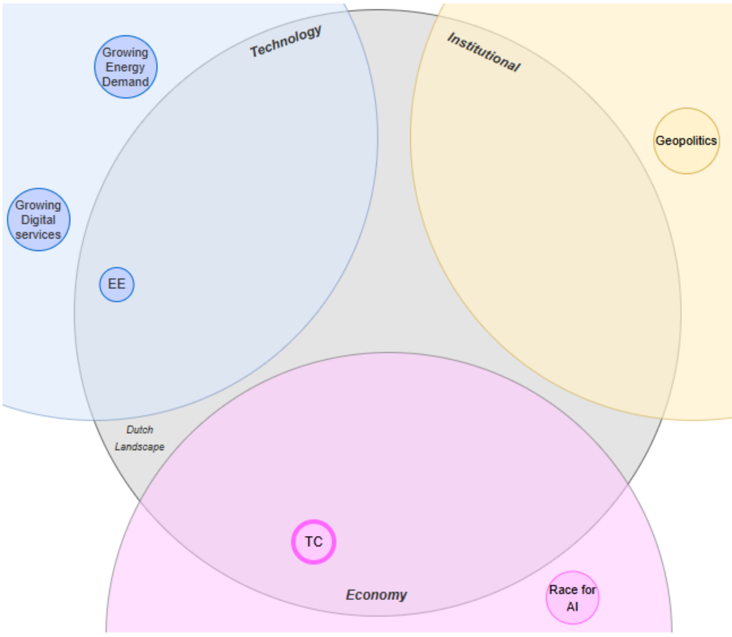

Figure 2.4 Adding Transaction Costs (TC) to the pattern model

2.5 Social Acceptance of Renewable Energy

The Social Acceptance of renewable energy innovation concept was developed by Wüstenhagen et al. (2007). This concept was originally developed to shed light on social acceptance for new renewable energy concepts like wind energy. The goal of this concept is to provide policymakers with a clearer definition of social acceptance. This clear definition is created by the deviation of social acceptance into three pillars: *Social political acceptance, Community acceptance* and *Market acceptance,* which can be seen in Figure 2.5.

Social political acceptance, the most general level, is the social acceptance by the public, key stakeholders and policymakers. Second, **community acceptance**, is the local level of social acceptance by local stakeholders like residents and local governments. Last, **market acceptance**, refers to the level in which market participants adopt an innovation. A renewable energy technology is accepted by the market once an innovation creates new market potential. Market potential in the broader sense, consisting of consumers wanting a certain product and investors, investing in certain types of products.

Extension of the concepts by Ellis et al. (2023)

The concept of social acceptance by Wüstenhagen et al. (2007) is widely used to analyse wind energy projects. For example, Segreto et al. (2020) did a literature review on twenty-five studies that have applied this concept across different European countries. Even though, many researchers use this framework, the concept stays general (Gaerde & Rowlands, 2018; Ellis et al., 2023). This is a reason that different researchers like, Ellis et al. (2023), Hübner er al. (2023), Sovacool & Ratan (2012), Devine-Wright (2005), Devine-wright et al. (2017), and Fournis & Fortin (2017) have developed additional aspects to the concept, to create more robust and in depth frameworks. The extension from Ellis et al. (2023) is most relevant for this research. They argue that social acceptance is not static but evolves over time. Adding this time dimension creates opportunity within the analysis to look back at how the transition has developed in the past.

Ellis et al. (2023) divided social acceptance not only in a time component but adds two other components as well, which can be seen in Figure 2.5. First, **time dynamics**, refers to the fact that social acceptance can change over time. Positive or negative consequences of renewable energy projects can influence the amount of social acceptance within all described levels from Wüstenhagen et al. (2007). Second, **scale dynamics**, changes when the size of certain renewable energy projects changes. Third, **power dynamics**, which highlights the fact that a power imbalance can impact decision-making. Local communities might feel excluded from decisions which can cause a lower social acceptance (Borch et al., 2020).

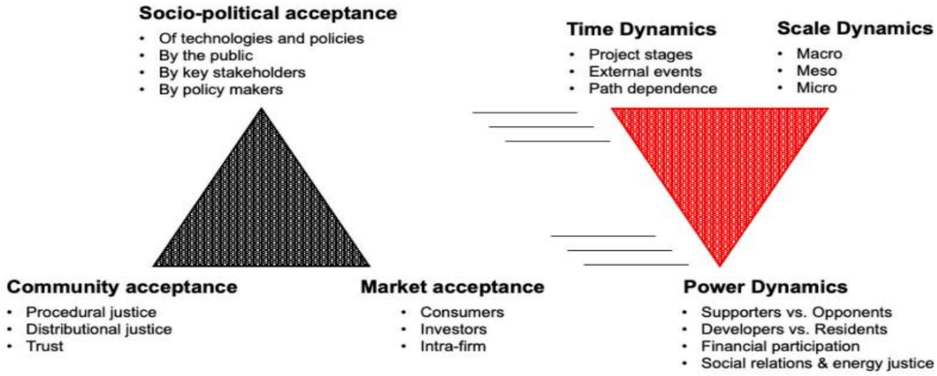

Figure 2.5 The social acceptance of renewable energy concept by Wüstenhagen et al.(2007) (left) and the dynamic perspectives of social acceptance by Ellis et al. (2023) (right).

Combining the Wüstenhagen et al. (2007) concept and the extension from Ellis et al. (2023)

Both the Wüstenhagen et al. (2007) concept and the extension from Ellis et al. (2023) rely on a broader former framework, the multi-level perspective (MLP) framework from Geels (2002). He stated that analysing system dynamics over time is important in the society we live in, in which we face structural environmental problems (Geels et al., 2006). Geels (2002) has created the MLP framework in 2002, which is still broadly used within academic literature. The MLP framework explains systems innovation with respect to transitions in sociotechnical systems in a dynamic changing environment. Even though the wide application of the framework, the framework can lack some goal orientated purpose and might lose some complexity compared to the real situation (Geels, 2019; Smith et al., 2010).

Therefore, the analysis of social acceptance of data centres in the Netherlands, will be based on a combination of the Wüstenhagen et al. (2007) concepts and the extension from Ellis et al. (2023). Within literature, both frameworks are commonly applied on analysing the social acceptance of wind energy (Fournis & Fortin, 2017). There is no research yet found on the analysis with these concepts of the social acceptance of data centres. To be able to provide such an analysis, this research will first elaborate on literature findings about wind energy. The wind energy analysis can provide an example and comparison for the analysis of social acceptance from data centres.

Social acceptance of wind energy

A literature review is done to explore the social acceptance of wind energy, focusing on the Netherlands while drawing comparisons with Germany, Denmark, and Sweden. Sixteen scientific sources using frameworks like Wüstenhagen et al. (2007) and insights from Ellis et al. (2023) emphasizes three dimensions of acceptance: social-political, community, and market acceptance, and explores how time, scale, and power dynamics influence perceptions and adoption of wind energy projects. A visual representation of the outcomes can be seen in Figure 2.6.

First, **social-political acceptance** of wind energy in the Netherlands and neighbouring countries is influenced by various factors. Key among these are financial support systems, planning policies, collaborative decision-making processes, and adherence to social norms. For instance, Wolsink (2012) identifies the Dutch "Acceptatie en Participatie Wind op Land" (Acceptance and Participation Wind on Land) code, which ensures equal distribution of financial benefits from wind energy projects and involves communities in decision-making through participation plans. Similarly, Scherhaufer et al. (2017) emphasize the role of social norms in shaping institutional acceptance and community attitudes towards wind energy.

Second, **community acceptance** is often challenged by the "*Not-In-My-Backyard*" (NIMBY) phenomenon, where local support for wind energy depends on minimal environmental disruption and transparent communication about project benefits. Studies by Fournis & Fortin (2017) and Enevoldsen & Sovacool (2016) underscore the importance of trust in local leaders and developers. Effective communication strategies, highlighted by the study from Karakislak & Schneider (2023) in Sweden, demonstrate how structured engagement events can mitigate opposition and build community support. Conversely, miscommunication, (social) media or perceived lack of transparency can fuel resistance, as noted in studies by Lundheim et al. (2022) and Borch et al. (2020).

Third**, market acceptance** of wind energy depends on policy incentives, consumer willingness to pay, and economic viability. Policies like feed-in tariffs and tax credits play a crucial role in attracting investment, as highlighted by Wolsink (2012) and Lindvall (2023). However, Lindvall (2023) also discusses how uneven distribution of economic benefits and perceptions of unfair compensation schemes can lead to local opposition, despite overall policy support. The economic advantages of wind energy, such as its low marginal costs once operational, are outlined by Solomon & Loveless (2025), but effective policy frameworks are necessary to ensure these benefits are realized and distributed equaly.

Over **time**, acceptance of wind energy projects follows a U-curve pattern, where initial support gives way to concerns during development phases, before potentially increasing again post-implementation. Studies by Enevoldsen & Sovacool (2016) and Hübner et al. (2023) highlight how successful projects can create positive feedback loops, enhancing local acceptance. Conversely, negative perceptions and conflicts can persist if initial opposition is intense and unresolved, as observed in studies by Karakislak & Schneider (2023).

Scale dynamics take place at three different levels, local, meso-political and macroeconomic. Local governments often mediate between national policies and community concerns, influencing project outcomes (Fournis & Fortin, 2017). For example, the "Lokaal Eigendom" (local ownership) program in the Municipality of Rotterdam, demonstrates how municipalities empower local communities to participate in energy projects (Gemeente Rotterdam, n.d.). Some of these local initiatives could be realized because of proactive governmental support (Macquart et al., 2023). Scale dynamics also influence public perception; large-scale projects may face greater opposition due to visual and environmental impacts, while small-scale community projects can enhance local sustainability and acceptance (Wolsink, 2012).

Last, **power dynamics,** wind energy projects are shaped by financial procurement systems, investment patterns, and community engagement practices. Developers and investors keep significant influence over project outcomes, often prioritizing financial returns over community interests (Wolsink, 2012; Lindvall, 2023). The role of policy in redistributing power and addressing community concerns is critical, as discussed in studies by Ellis & Farro (2016) and Boyle & Galvin (2024). Effective engagement and transparent decision-making are essential to mitigate power imbalances and foster sustainable wind energy projects.

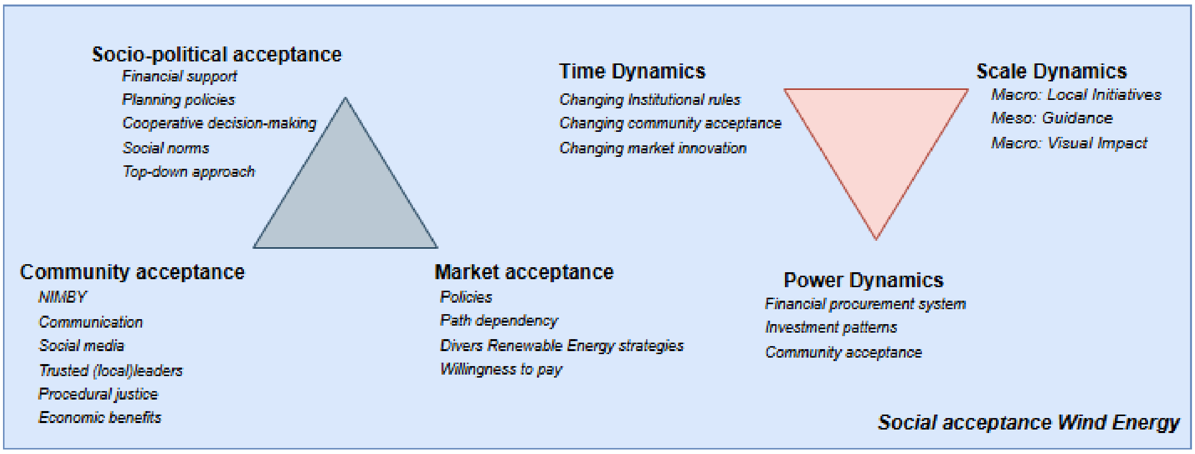

Figure 2.6 Overview social acceptance of wind energy projects according to literature findings

Achieving a widespread acceptance of wind energy requires navigating a complex landscape of policy frameworks, community engagement strategies, and economic incentives. By addressing concerns related to environmental impact, economic fairness, and effective communication, stakeholders can enhance the prospects for sustainable and socially accepted wind energy initiatives. Chapter 4 *Social Acceptance,* will dive deeper into the application of this framework on Dutch data centres. However, before this can be done, an overview of the current Dutch data centres situation needs to be given. Therefore, the next Chapter will first sketch de current situation by *Defining the Pattern Model.*

2.6 Scenario Study

Lindgren & Branhold (2003) argue that scenario study is essential in fast-moving and complex business environments. They highlight that traditional forecasts are often inadequate for anticipating on large or unexpected changes, therefore, scenario studies can help to shed light on possible futures. To determine the pathways in Chapter 5 *Potential Pathways,* several methods are available. Creating scenario's or pathways differs fundamentally from forecasting, Scenario's and pathways accept uncertainty, tries to understand it and makes it part of it (Cornelius et al., 2005). Cornelius et al. (2005) describes that pathways are designed to help companies and governments challenge their assumptions, develop strategies and test plans. They deliberately confront decision-makers with environmental uncertainties by presenting fundamentally different futures. In particular, focusing on extreme differences can expose where the obstacles are located.

Lindgren & Brandhold (2003) developed future paths using the TAIDA (Tracking, Analysing, Imaging, Deciding, Acting) framework. In which scenarios are developed, on the basis of tracked changes observed from a general picture. This fits well with the exploratory research done in this study. However, a shortcoming of this form of pathway development may be that the perspective and motivations of the various stakeholders are not sufficiently taken into account. This means that theoretically sufficient future pathways can be outlined, only that in practice stakeholders do not behave like this because they represent different interests. Therefore, this study uses the stakeholder's perspective as a basis to formulate future paths.

The interviews and participated events contribute to the data for the development of these future paths. Therefore, section 4.2 *Social Acceptable Future Situations,* provides different socially accepted futures per stakeholder group. Based on these desirable situations, the future paths will be determined in Chapter 5*,* which will be used for further analysis.

Chapter 3: Defining the Pattern Model

To describe the complex social-technical system of the Dutch environment in which data centres operate, pattern modelling plays a crucial role in addressing the first sub-question. This sub-question aims to explore the different aspects within the technical, institutional, and economic domains that influence the role of data centres in the Dutch energy system and connect these aspects via stakeholder interactions.

To what extent can the concept of Social Acceptance be used to analyse the impact of social acceptance for data centres in the Dutch energy system and the formulation of socially accepted futures?

The goal is to gain a comprehensive understanding of the different factors within data centre operating in the Dutch energy sector. This analysis draws upon a variety of sources including scientific papers, policy reports, industry insights, conferences, webinars, workshops and the interviews as described in section 2.2 *Interviews.*

This Chapter will be guided by pattern modelling, using the different data sources to get insight into the patterns. It is an iterative process which started with a basic understanding of the situation sketched within Chapter 1 *Problem Definition*. Each interview added new information, leading to the patterns described in the end. To be able to sketch a global overview of the situation, there is tried to do interviews with the different stakeholders involved. Appendix B shows an overview of all interviews that were conducted and events that were attended between February and May 2025. Detailed insights into the pattern modelling approach can be found in section 2.3 *Pattern Modelling*. Subsequent sections 3.1, 3.2, and 3.3 delve into the specific technical, institutional, and economic aspects respectively. Within these sections, the nodes for the pattern will be discussed. These nodes will be connected in the last section of this Chapter, 3.4 *Stakeholder Interactions.* Here*,* the crucial interlinks across the domains, highlight the relationships between the stakeholders within seven complex themes. These insights provide a basis for the rest of this research, indicating the current situation and potential points of changing roles for Dutch data centres.

3.1 Technical Aspects

This section deals with the technical aspects in which data centres can figure in the Dutch energy system. The following components are discussed: grid congestion, data thermal solutions, energy flexibility, renewable energy use, and decentralization. While conducting the interviews and attending the events, these were the main technical components discussed. Therefore, these technical components are used as the technical nodes within the final pattern model.

3.1.1 Grid Congestion

Nowadays, companies cannot easily get a new connection to the grid, due to grid congestion, what this technically entails is elaborated on in Appendix E.1. The reason that the grid is much congested within the Netherlands is among others, the growing use of renewable energy sources like wind and solar, growing use of electricity devices like electrical cars and heat pumps, the growing economy, and the need for decarbonization, which all contribute to more electricity use and therefore more difficulties in getting a grid connection (Zhang & Zavala, 2022; Netbeheer Nederland, n.d.). On a longer run, this will affect sustainability initiatives or preventing new companies from establishing themselves within congested areas[7].

Technical solutions for grid congestion

Because grid congestion is such a big problem at the moment in the Netherlands, many studies have been done on ways to mitigate or prevent grid congestion. The best way is to expand the electricity grid. This is a huge task for the Dutch TSO (TenneT) and all DSO's, which will take time. There are some short term solutions in the meantime, grid congestion platform GOPACS or Cable Pooling, which are explained in Appendix E.1. Individual solutions could be, a direct line with the TSO, small scale flexible options or off the grid energy generation.

[7] Interview consultant2

Individually, industries can have a direct energy line to bypass congested grid areas. For example, in Alkmaar, where a business park connects directly to local energy-producing facilities (Budding et al., 2024). Similarly, EdgeConneX operates with a direct connection between its Amsterdam data centres and a high-voltage substation from TenneT, bypassing the medium-and-low voltage sub-stations.

Smaller-scale strategies can also contribute. These include optimizing consumption through energy-saving measures and adjusting demand to match grid availability. While not suitable for all sectors, this can reduce peak loads (Budding et al., 2024). Electricity storage using batteries or generators providing backup during shortages. Excess electricity can also be converted into hydrogen or heat, supporting grid stability[8]. Capacity-limiting contracts offer financial incentives for users to reduce demand during peak times, a strategy now promoted by TenneT for industrial and data centre users (Koster, 2025; TenneT, n.d.). However, data centres require constant power, making such contracts less suitable for them[9].

Lastly, on-site energy generation is gaining interest. At the data could Energy & ESG event attended for this research, speakers discussed using natural gas and Small Modular Reactors (SMRs) for local power, particularly for data centres[10]. In the U.S., firms like Amazon and Google are investing in SMR technology for future deployment (Jennifer, 2024). ExxonMobil, for instance, plans to build a 1.5 GW natural gas plant for data centres (Skidmore, 2024). While these technologies are not yet operational in Europe, Dutch companies like Equinix are monitoring them closely as potential long-term solutions, especially since solar and wind remain less reliable due to fluctuations[11].

3.1.2 Data Thermal Solutions

One potential development to create more sustainable data centre applications is reusing heat that is generated in the data centre, industry also refers to this as data thermal solutions[12]. A data centre produces a big amount of heat created by (1) server racks, where the computational load takes place. (2) Network equipment, where data transmission takes place, (3) storage units, where data is stored, and (4) cooling, needed to cool the systems but which also produces vast amounts of heat (Oró et al., 2015; Hota, 2024). Using the heat from data centres can increase the total energy efficiency of data centres, of which more technical details can be found in Appendix E.1.

Different case studies and experiments have shown that reusing heat from data centres can provide effective solutions in, for example, district heating networks. A case study from Terenius et al. (2022) in Sweden suggests that reusing data centre heat for a district heating system is feasible. They also state that it's practicality depends on various factors, including the temperature of the heat, the availability of alternative heat sources, and the specific needs of the surrounding community or industry. Also, Microsoft has created an efficient reuse project in cooperation with Fortum in Espoo, Finland (Fortum, 2022). Because of an outstanding district heating network in Finland, they were able to create a connection between the data centre heat and the residence living in Espoo[13]. Additionally, a successful Dutch example, from the Van Nelle fabric in Rotterdam. Here, a data centre and consumers are located on the same premise. The Ven Nelle fabric is Enesco's world heritage, which made it hard to do isolation, leading to high gas bills. Now using the heat from the near located data centre significantly reduced this, leading to a higher system efficiency[14].

These projects highlight the importance of location. However, It is critical to understand that the best locations to recycle heat are influenced by different aspects. The local possibilities will affect the potential for reusing heat (Coa et al., 2022). Because data centres provide a low temperature heat, not all buildings and industries are suitable for connection due to heat losses.

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[8] Interview Liander1

[9] Interview Switch Datacenters 1

[10] Event Data Could energy & ESG

[11] Interview Equinix

[12] Event Data Could energy & ESG

[13] Event Data Could energy & ESG

[14] Interview Province Noord-Holland

A new technical development which can increase the heat from data centres is Artificial Intelligence (AI). Data centres, which process AI, generate significantly more heat than traditional non-AI data centres (Deshev, 2024; Gandhi & Subraminiam, 2024). This increased heat generation is primarily due to the following factors. Firstly, power-hungry hardware, AI workloads require specialized hardware like GPUs, TPUs, and ASICs, which consume more power and generate more heat than traditional CPUs (Gandhi & Subraminiam, 2024). Secondly, a higher power density, modern AI chips, have an increased power density, which leads to hotter chips and more heat (Deane, 2024). Thirdly, an increased rack density, the average rack density in data centres is expected to jump, largely driven by AI workloads, which will result in higher data centre temperatures (Gandhi & Subraminiam, 2024). Lastly, concentrated heat generation, AI hardware tends to create localized hotspots, making it more challenging to maintain and cool (Deshev, 2024). However, more research needs to be done to determine if this is actually the case in practice[15].

District heating system

A district heating network is according to Hoogervorst (2017) *a pipeline network that connects heat sources with a heating demand from consumers, when sustainable heat sources or waste heat is used, this can contribute to an environmentally friendly heating solution for the future.* Hoogervorst (2017) did a study to showcase the potential for heat networks in the Netherlands, he highlighted a technical feasibility of providing heat to Dutch residents connected to a heat network. On the other hand, he also highlights several bottlenecks which can lower the feasibility. These bottlenecks can for example be high consumer prices, an unclear revenue model for producers, risks of heat security, low heat returns, lack of trust between collaboration stakeholder, bad services from commercial companies and strong incentives from industry partners to collaborate.

Data centres can integrate into existing 4th generation District Heating (4GDH) systems, which currently distribute heat from centralized sources to end users at temperatures ranging from 30 to 65 degrees Celsius (Guo et al., 2024). However, this system faces challenges like limited connectivity between different demand requirements, restricted network expansion due to energy concentration, and the need for heat pumps to raise temperatures (Terenius et al., 2022; Coa et al., 2022). These limitations have led to the development of 5th Generation District Heating and Cooling (5GDHC), enabling ultra-low temperatures (35–45 degrees Celsius), better temperature control with heat pumps, and enhanced flexibility with Thermal Energy Storage (TES). These advancements facilitate integrating data centres into district heating networks for sustainable thermal solutions, of which Huang et al. (2020) developed an overview, which can be seen in Figure 3.1.

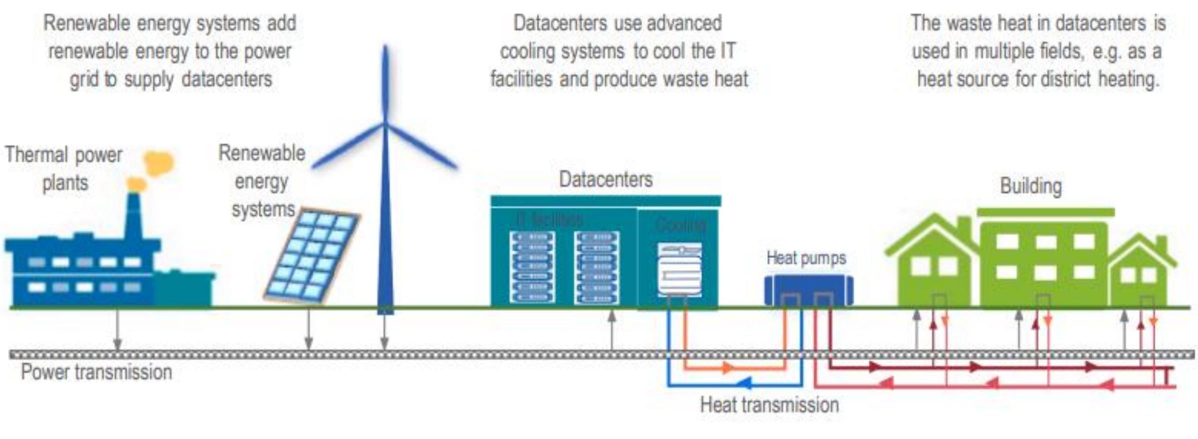

Figure 3.1 Overview of data centres providing heat in district heating networks made by Huang et al. (2020).

To be able to harvest heat from data centres, there needs to be a coupling between the data centre heating system and the district heating network. There are no standards yet for creating this uncoupling of data centre heat (Franchimon et al., 2024). Besides this, Huang et al. (2020) has explained that a heat pump is needed to increase the temperature within a district heating network. Because, the low temperature heat provided by data centres is not enough to heat most residential buildings in the Netherlands. To heat the older residential

[15] Interview Equinix

buildings, a higher temperature of around 70 degrees is needed, therefore a heat pump could be used to increase the temperature. On the other hand, new better isolated buildings, also need lower temperatures for their heating demand, in these situations the low temperatures from data centres might be enough to provide heating.

Besides using data centre heat in district heating system, there are also other applications, reusing the heat. Ebrahimi et al. (2014) had studied the technical and economic potential of nine different technologies, they provide the district heating system as a potential solution but also highlight other high potential solutions. These solutions are elaborated on in Appendix E.1, however, they were not yet discussed within the interviews which leave them for further investigation.

Availability of data thermal solutions

To connect heat from data centres to a heat network, there must be some guarantee that the heat source can provide heat for a longer period of time[16]. This reduces the risks when investing in a heat network and heat connection. This was discussed in serval interviews: Van Essen (2025) (Switch Datacenters), *said in this regard that they can say with certainty that they can decouple residual heat from around 30 degrees for at least 10 years. Besides this, because data centres are always on, heat production is also 100% guaranteed. He said that after that, technological developments might make it possible to disconnect even higher levels of heat.* Grove (2025) (Data centre branch) *indicates that Dutch data centres want to contribute to more sustainable initiatives and that in doing so, the decoupling of residual heat over a longer period could be a possible way to do so.*

3.1.3 Energy Flexibility

Data centres are increasingly recognized for their potential in providing energy flexibility, due to their large energy loads, rapid industry growth, and flexible backup systems (Wierman et al., 2014). Energy flexibility involves modifying the production or consumption of distributed energy, categorized into power and thermal flexibility (Guo et al., 2024; Skach et al., 2017).

Data centres have several technical opportunities for enhancing power flexibility within the grid. Firstly, through IT equipment, hyperscale data centres can employ load shifting strategies. Data centres manage diverse workloads across their servers throughout the day, allowing for time and location shifting of processes to optimize energy demand (Wierman et al., 2014). Time shifting involves running workloads during off-peak hours, while location shifting redistributes workloads to regions with lower energy costs (Driesse et al., 2024). Load shifting not only optimizes energy costs but also plays a crucial role in grid stability during peak periods of congestion (Zhang & Zavala, 2022). Companies like Google and Microsoft already utilize these techniques to mitigate energy expenses and reduce CO_2 emissions (Riepin et al., 2025).

Secondly, data centres can contribute to energy flexibility through backup systems and batteries. These systems, involve disconnecting from the main power grid during emergencies and relying on backup generators, UPS systems, and batteries (Al Kez et al., 2020). UPS systems, essential for uninterrupted data centre operations, are also leveraged for grid balancing and frequency regulation services due to their efficiency and reliability (BloombergNEF, 2021; Peng et al., 2022). For longer outages, backup generators powered by fossil fuels like diesel or natural gas provide essential backup, although their environmental foodprint presents challenges for grid integration[17]. Future alternatives such as lithium-ion batteries or hydrogen show promise in reducing emissions associated with backup operations (BloombergNEF, 2021).

Lastly, cooling systems in data centres, crucial for maintaining operational temperatures, can also contribute to energy flexibility. Techniques like preventative cooling involve pre-cooling data centres during periods of low energy supply, allowing temperatures to rise slightly during peak demand periods (Al Kez et al., 2020; Cai & Gou, 2024). Operating within a flexible temperature range further enhances the potential of cooling systems to support grid stability (Driesse et al., 2024).

[16]Event Data Could energy & ESG

[17]Interview Omgevingsdienst Noordzeekanaalgebied

3.1.4 Decentralization

Technically, it is an easy option for any company to manage and control its own data. Companies used to arrange their own data storage in house[18]. However, currently the amount of data is much more centralised, this is mainly because the amount of data has increased enormously (McKinsey Quaterly, 2025). Companies do not want to get into the data storage business. Therefore, they use '*data* centres', where the storage, power and security is taken care of[19]. This leaves companies with more space to carry out their daily tasks. Because of these centralised data management, the overall data storage efficiency has increased over the past years[20].

Local data management and decentralized AI-training

Even though more data management is centralised nowadays, there are also ideas of movements from people that will remove themselves from big data centres and focus on smaller scale onside options (ChannelConnect, 2025). Which would mean that bigger companies could be likely to store their data inhouse again. Dintzner (2025) (Data steward, TPM, TU Delft) *told during the interview that this would occur significant costs, for instance: local servers, competent staff, or egress costs from cloud providers, that even large institution would struggle to cover, making it an unlikely large-scale solution at the moment.*

Besides this, data centres can store more efficiently than companies on their own, so this might create a societal less attractive outcome. On the other hand, Boonstra (2025) (Research ICT Expert, TU Delft) *touches within the interview upon the fact of digital sovereignty. He explained that since 2024, more and more institutions are reconsidering the decision to move to the cloud. He highlighted that the Dutch government already has been knocked back in this regard, and is still storing its data 'on premise'.* Partly due to the geopolitical relations at the moment, there is slowly some movement towards parties storing their data more decentral again[21]. It could be that due to geopolitical situations more bigger instances like governments will bring their data back home, but it will not be likely that smaller companies are going to do that as well[22], also Bloomberg (2025) highlighted this within their study. They address that companies are likely to move data closer to their clients.

Besides this, there are also developments for decentral AI training. Modern training models like large language models (LLM) are used more frequently and therefore more data centre space is needed. The first market reaction to this, was building more and bigger, hyperscale data centres[23]. However, due to technical limitations from bigger data centres: the grid is not able to connect such high energy demands. There needs to be looking at solutions, one of these could be the perspective from Hussein et al. (2025). They show recent publications from Douillard et al. (2024) and Jaghouar et al. (2024) highlighting the possibility of running AI servers at colocation data centres because of technical developments which makes it easier to run AI processes decentral. Up till now, training LLM models was only possible in bigger hyperscale data centres. However, with this new technology, it becomes possible for distributed AI-training. This can open the opportunity to spread workloads over different data centres[24].

In contradiction to what most industry data centres say, bigger data centres might not always be better[25]. An advantage of bigger hyperscale data centres (+5,000 servers) is that more data can be processed, AI can be trained, and a higher efficiency can be obtained[26]. However, Wahab et al. (2024) did a study on the decentralization of federated learning (FL) AI-based models. Training these AI-models mostly happens in centralised data centres at the moment, but they highlight a 10-12% improvement in performance with a decentralized model in which the AI is trained at different data centres. This can be of potential when developing

[18] Interview Province Noord-Holland

[19] Interview Data steward TU Delft2

[20] Interview Province Noord-Holland

[21] Interview Consultant1

[22] Interview Data steward TU Delft1

[23] Event Data Could energy & ESG

[24] Interview Consultant1

[25] Event Data Could energy & ESG

[26] Interview Province Noord-Holland

several smaller scale data centres instead of bigger hyperscale data centres[27]. Besides this, Fridgen et al. (2017) has found that geographically distributed data centres can provide the opportunity of migrating load between physical locations, contributing to a more stable grid.

3.1.5 Renewable Energy Use

99% of all Dutch data centres use 100% green power (Vermeulen, 2024). Technically, this is not possible because electricity is a homogeneous product, so where it is generated cannot be decided by a user. However, data centres and especially their users would like to be CO_2 neutral and want to have a low as possible carbon footprint[28]. This is why data centres buy green certificates. With this purchase, data centres can show that they buy green power and claim to be operating with 100% sustainable electricity besides using Diesel back-up generators (Vermeulen, 2024).

Using renewable energy like wind and solar

To provide renewable energy to Dutch data centres, commonly wind and solar energy are being used. Using wind and solar energy, commonly results in lower power costs and creates a better reputation (BloombergNEF, 2021). However, using renewable energy sources, a higher demand for energy flexibility rises as renewable energy options like wind and solar are not available at all times (Agarwal et al., 2021).

To address the intermittency of renewable energy in data centres, Agarwal et al. (2021) propose the *virtual battery* concept, shifting from traditional back-ups to aligning workloads with renewable availability. Instead of relying on conventional power plants, workloads are increased during sunny periods with available solar energy and reduced at night. This is especially viable when renewables are co-located with data centres. Issues like grid congestion and space constraints limit the feasibility in the Netherlands. Alternatively, Li et al. (2017) suggest combining *energy storage devices* with opportunistic scheduling to store surplus renewable energy and shift intensive processes to periods of high availability, ideal for small to medium-sized data centres. Yet, most solutions rely heavily on grid cooperation. To overcome grid limitations, Gnibga et al. (2024) propose an autonomous data centre using co-located renewables and hydrogen storage. Although technically feasible, this approach incurs significantly higher costs than traditional grid electricity.

Using Nuclear energy

Data centres run 24/7 to process their data, which means that they have a well estimated and constant base load of energy they need[29]. Renewable energy contributes to the need for back-up power. Hjelmeland et al. (2025) has investigated this and found that nuclear power has potential in reducing the need for transmission, energy storage, renewable energy use and land use, when used by data centres.

Even though there is technical potential for nuclear energy use in combination with data centres, there are not many practical examples showing these outcomes[30]. European governments are hesitant to invest in such projects, which leads to a lack of deployment (Hjelmeland et al., 2025). Böse et al. (2024) has also investigated the potential for nuclear energy and highlight that policymakers should be careful implementing policy about nuclear options. With their literature research, they show that there are many different parameters and assumptions taken into account while developing feasibility models. This can result in less usable data for clear and safe policy recommendations for nuclear power. Even though, US companies are already seriously investigating these options[31].

Hydrogen

Hydrogen is a sustainable option that is now being further explored in the data centre sector. A few projects have been realised in the process. Barentsen (2025)(Province of Noord-Holland) *explained that data centres now use*

[27] Interview Consultant1

[28] Interview Switch Datacenters1

[29] Interview Switch Datacenters1

[30] Event Data Could energy & ESG

[31] Event Data Could energy & ESG

diesel generators as back-ups because this is; a robust technology, efficient in terms of distribution and is relatively cheap. In his view, deployment of hydrogen has a longer-term opportunity in this industry, and the first experiments look promising. However, there are currently two challenges in deploying hydrogen generators by data centres. First, hydrogen is currently still far too expensive compared to diesel. Green hydrogen is even more complex and expensive to produce. In addition, the planned hydrogen back-bone is projected to connect the largest gas consuming industries, which makes distribution of hydrogen to data centres a challenge and increases the already significant costs. However, data centres could start experimenting deploying modern natural gas generators as primary or back-up power sources, which can be modified for the use of hydrogen in the future.

One example of a data centre that is experimenting with hydrogen is NorthC, they installed fuel cells with green hydrogen instead of Diesel generators as emergency power supply, in doing so, they are the first company realising this in Europe (Derksen, 2022). The hydrogen fuel cells have a capacity of 500kW and an expected lifespan of 20+ years, NorthC (n.d.) also highlights that the hydrogen cells are more expensive than traditionally used Diesel generators. However, they see high prices coming for fossil fuels, in which they expect that this investment will pay back.

This looks promising but, during different events, it was mainly stressed that an intermediate step has to be taken first[32]. Data centres are first moving to gas-powered backup turbines, which could possibly be converted to use hydrogen in the future[33].

These discussed technical aspects add five nodes to the pattern model, which can be been in Figure 3.2. This figure shows that there are five relations already between these technical aspects. Firstly, highlighting the relation between renewable energy use (RE), which mostly increase electrification which increases the load on the grid (GC). Secondly, increasing Energy Efficiency (EE), Data centre Energy Flexibility (DEF), Data Thermal Solutions (DTS) and Decentralization (D), which technically can help to balance the grid (GC). Appendix F provides an overview of all the abbreviations used within the figures 3.2 till 3.19.

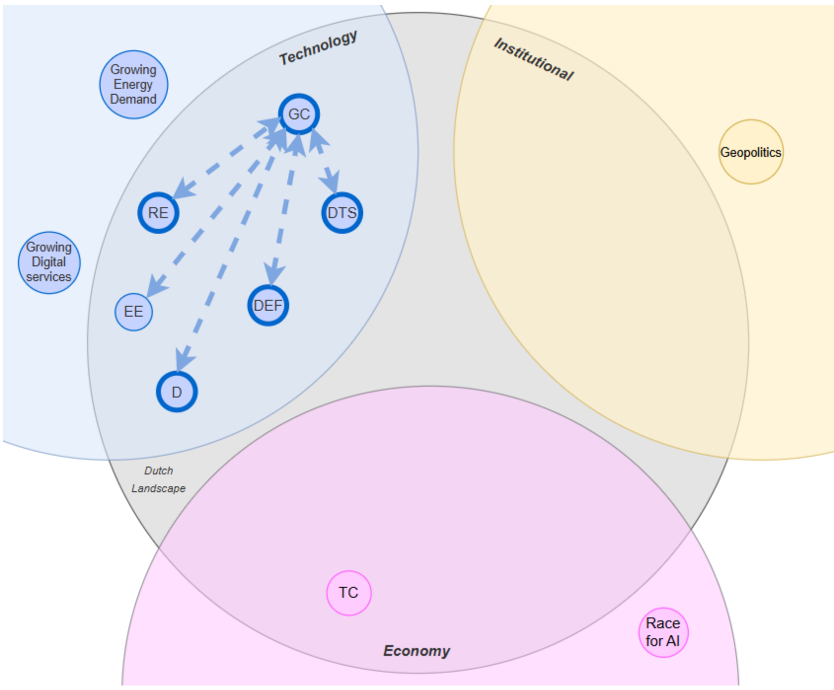

Figure 3.2 Nodes and links after describing technical aspects

3.2 Institutional Aspects

This section deals with the institutional aspects in a situation in which data centres can figure in the Dutch energy system. The following components are discussed: policy uncertainty about the Collective Heat Act (WCW), views

[32] Event Data Could energy & ESG; Event Workshop EML

[33] Interview Data centre branch

from the national government, grid prioritization, and current policy. While conducting the interviews, these were the main institutional components discussed. Therefore, these components have been chosen to shed more light on.

3.2.1 Policy Uncertainty about The Collective Heat Act

Franchimon et al. (2024) has done research within the Amsterdam south-east region to determine uncertainties in creating data thermal solutions. They did a qualitative study to investigate why data thermal solutions didn't get realised within this region. They have highlighted among others, three main political uncertainties. First, the Collective Heat Act (WCW), many interview attendees highlighted the importance of this not yet realised law as well. Second, the lack of instruments from policy to give guidance into the heat transition. Last, the uncertain responsibilities of certain stakeholders within the project region. Because almost all interview participants, highlighted the WCW, this will be discussed in more detail.

The Collective Heat Act (Wet Collective Warmte (WCW))

The Collective Heat Act (WCW), is a Dutch law under consideration, for many years which will influence the possibilities to use heat from industries like data centres. The upcoming law aims to facilitate the development of new heat regulations. NPLW (n.d.) (Nationaal Programma Lokale Warmtetransitrie) created an overview of the latest version, including the following. The law has been finalized and is almost ready for implementation after approval by the Dutch first and second chambers. Stakeholders hope that it comes into effect on January 1st, 2026[34]. This legislation will impact the potential reuse of heat from data centres. With the current developments, several key aspects will be crucial for data thermal solutions. Firstly, the municipal leadership role, allowing municipalities to determine the routes of heat networks, who can offer heat, and who will construct these networks. The goal is to develop small-scale collective heating systems. Residents will still have the choice to use this network or not, but this decision must be collective[35]. Additionally, a heat company will manage the disconnection of heat from the data centre to the connection with households. This company will be obligated to recover and deliver heat, and at least 51% of the company must be publicly owned[36]. The law also includes tariff regulation, transitioning towards a more cost-based rate per heat parcel. The law aims for sustainability by creating a minimum pathway for greenhouse gas emissions and giving industry the right to donate and collect heat. To make these heat networks beneficial for households, supply security and consumer protection are integral parts of the legislation. Lastly, a seven-year transition period will allow for temporary deviations from the law, after which such deviations will no longer be permissible (NPLW, n.d.).

The discussion about the WCW came up in almost all interviews. Many stakeholders experience uncertainty due to the precise implementation of the law[37]. There is already a draft, of which the participants in the interviews mainly believe that the law will look broadly similar in its final form. However, it still needs to pass through the Dutch first and second chamber. As it stands now, this is expected to happen this autumn. There are still details that could change, for example, within the interview with MeerEnergie was mentioned that there is still an article in the law that could be very unfavourable for a Neighbourhood Cooperatives wishing to install a heat network[38]. There are lobbies for changes to the specific details. However, partly due some potential changes, stakeholders are now waiting for more clarity until the law is officially passed[39].

3.3.2 National Government and Grid Prioritization

Different political parties have different views on the Dutch data centre infrastructure creating a fragmentation, for example. GroenLinks-PvdA and NSC (Nieuw Sociaal Contract) advocate to be less dependent on US data

[34] Interview MeerEnergie; Interview AMS institute; Interview Municipality Diemen3; Event EnergyLab Zuid-Oost

[35] Event EnergyLab Zuid-Oost

[36] Interview Firan

[37] Interview MeerEnergie; Interview Data centre branch; Interview AMS institute; Interview Switch datacenters1,; Interview Switch Datacenters2; Interview Firan; Interview Liander1; Interview Liander2

[38] Interview MeerEnergie

[39] Interview Switch datacenters1; Interview Municipality Diemen1; Interview Municipality Diemen2

providers like Microsoft, promoting a more diversified and secure digital infrastructure for the country (Loohuis, 2024). However, PVV advocates for municipalities to take a leading role in determining data centre policy, they argue that this is not a role for the national government (Hartholt, 2024). Last, Partij voor de Dieren, PvdA, D66 en VVD, do want a national sustainability vision for Dutch data centres (Hartholt, 2024). This fragmented government issue, in combination with the pressure from other decisions which needs to be made within the government, leads to the fact that there is not a universal national policy[40]. Even the minister of Economic affairs is not willing to take a directing role within the transition of sustainable data centre solutions[41].

Prioritisation grid congestion

Due to the major problem of grid congestion in the Netherlands, the ACM (Authority for Consumers and Markets), has set up a prioritisation framework. This states which industries are given priority when obtaining a new connection. For example, hospitals and industries in the critical sector have priority over industries considered less important by the ACM. If an industry is low on the prioritisation list, its chances of getting a new grid connection are low. Data centres are not prioritized within this list, leading the industry to go to court[42]. Following this, the judge declared the priorities list from the ACM invalid, which means that a new list will have to be drawn up by the ACM. Whether data centres will then be on it, is not yet known. In the meantime, the old list will be valid till the first of January 2026 (College van Beroep voor het bedrijfsleven, 2025). The consequence of this prioritisation is that new data centres currently receive almost no new connections, which is why many data centres relocating elsewhere in Europe, for example in the Nordics or Ireland[43].

3.3.3 Current Policy

There are three main levels of policy regulations, EU-level, national level and local level, which influence the current possibilities, for further development.

EU-level policy and regulations

Different international EU-level legislation affect Dutch data centres. The most important once are explained in more detail in Appendix E.2. These regulation affect Dutch data centres via directives which are incorporated in the Dutch legislation. What is interesting about all these European legislation is that, for the European Union, its main purpose is to gain insight into the development of energy efficiency in the sector (Rijksdienst voor Ondernemend Nederland, 2025b). However, from the sector itself, parties experience it as a burden. Regulations that mainly creates more paperwork and not more actions to look for sustainable alternatives[44].

National-level policy and regulations for data centres

Dutch regulations have contributed to the fact that the growing amount of data centres in the Netherlands is slowing down (BloombergNEF, 2021). Regulations that have contributed to this are, the regulation from the first of January 2024: *hyperscale data centra* this regulation implies that there are not more hyperscale data centre allowed in the Netherlands, except for two locations located in the municipalities of Hogeland and Hollands Kroon (de Jonge, 2023). Besides this reduction in hyperscale data centres, the *Environmental Act* (Omgevingswet), entails various environmental aspects, such as noise control, air quality, and spatial planning. Data centres need to comply with these (Royal HaskoningDHV, n.d.). The recognised Measures List (EML), is a regulation, active from June 8th, 2023. Requires data centres to comply with a list of energy saving measures as discussed within Chapter 1 *Problem Definition* (Royal HaskoningDHV, n.d.).

Local-level policy and regulations

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[40] Interview Data centre branch; Interview AMS institute

[41] Event Webinear data centers in the MRA

[42] (Interview Data centre branch)

[43] (Interview Data centre branch)

[44] (Event Data Could energy & ESG; Event Workshop EML)

Local-level regulations are mostly common in the municipality of Amsterdam, because they are the biggest data centre hub in the Netherlands and proactive with legislation. The municipality of Amsterdam has some restrictions as of December 2023, new data centres may only be built in specific business parks in the areas of Amsterdam and Haarlemmermeer. The expansion of existing data centres is limited, and new data centres are only allowed if they benefit Amsterdam and do not cause additional grid congestion (Judge, 2024; datacenters.com, 2024; Soares et al., 2024). Besides this they have a power management rule, the municipality has introduced regulations on power management in data centres. Fines can be imposed on data centres that fail to implement power saving measures from the EML (datacenters.com, 2024). Last, they have sustainability requirements, the municipality emphasizes the importance of use of residual heat, water savings and the integration of data centres into the landscape (Judge, 2024).

Juridical boundaries in changing VvE's

The Association of Owners (VvE), is a key legal structure influencing the local level policy in the Netherlands. This significantly affects the feasibility of implementing sustainable heat networks in living complexes[45]. Therefore, it affects the business case of developing heat networks with heat from data centres and other industries. This is an example of institutional obstacle, contributing to the realisation of sustainable data centre solutions.

Every apartment owner automatically becomes a member of a VvE, which is responsible for maintaining shared areas such as hallways, lifts, and roofs. There are approximately 1.4 million homes in the Netherlands under a VvE structure (Steenkamp, 2024). While the organizational setup of VvEs appears manageable, with regular meetings and small involvement, there are deeper legal, and financial challenges that complicate sustainable development. Leading to obstacles in realising heat networks within VvE buildings.

Legally, VvEs face significant decision-making constraints. For major changes such as the installation of new heating systems, small VvEs (fewer than 20 members) require unanimous consent, while larger ones typically need 80 to 85% agreement[46]. These thresholds are established in the splitsingsakte (deed of division), a foundational legal document that outlines the scope of permissible decisions. Amending the splitsingsakte is a long and expensive process, as it requires approval from all owners, the municipality, leasehold owners, and mortgage lenders. Most existing splitsingsaktes do not permit the installation of sustainable heating technologies like heat pumps or district heating[47].

Financial and social dynamics further complicate the issue[48]. VvEs operate with limited financial means, relying primarily on modest monthly contributions from residents. Additionally, apartment complexes are home to people with diverse financial situations and priorities. Since the average resident stays in one place for about ten years (Noorslag, 2024), many are either unable or unwilling to invest in long-term, high-cost sustainability measures. These legal, technical, and financial barriers collectively result in few sustainable initiatives being successfully implemented within existing housing complexes. Even routine maintenance can become a challenge.

When successful projects do occur, they are usually driven by a particularly active and committed resident within the *VvE. As potential solutions,* Van der Woude (2025)(President of a Dutch VvE Association) *suggests rethinking legislation to ease sustainability transitions, professionalizing VvE management through mandatory (and certified) professional administrators, improving financing and subsidy structures, and analyzing the splitsingsakte of individual buildings in advance to assess feasible sustainability measures.*

This example highlights juridical complexity which can hinder the realisation of effective heating solutions in which data centres could contribute to a more sustainable build environment. Within section 3.4 *Stakeholder Interactions,* will be highlighted how this complexity will affect other aspects as well.

These discussed institutional aspects add six additional nodes to the pattern model, which can be been in Figure 3.3. This figure shows that there are three relations already between these institutional aspects. Firstly,

[45] Interview VvE

[46] Interview VvE

[47] Interview VvE

[48] Interview VvE

highlighting the reactions between local and national governments (NG, LG), which interact with each other to determine rules and regulations and to exploit them. Secondly, the European Union (EU) and the national government (NG), these institutions also interact with each other to determine rules and regulations. Lastly, the national government (NG) is connected to the Collective Heat Act (WCW) because they decided over the precise outcome of this Act.

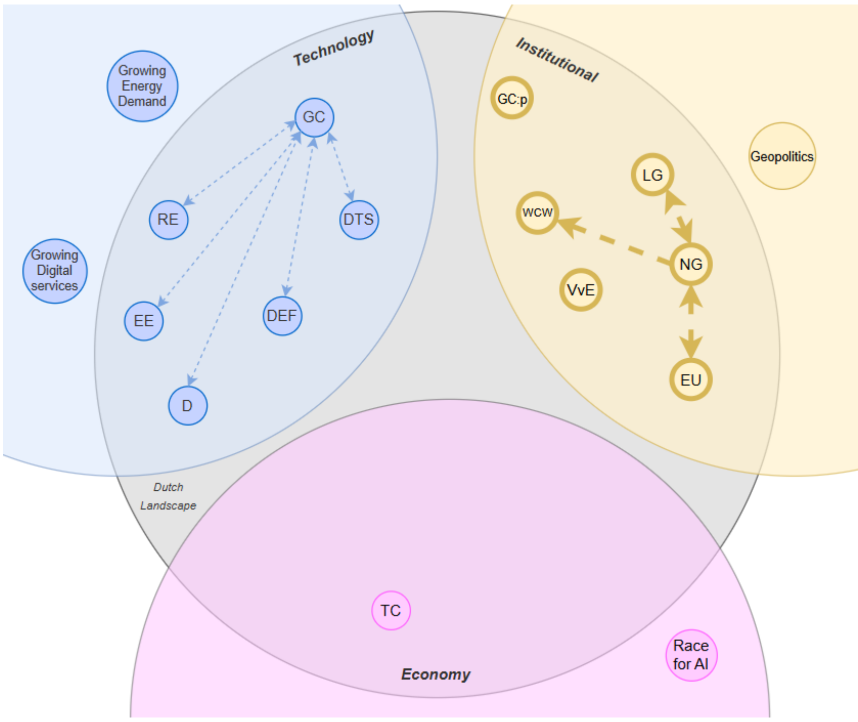

Figure 3.3 Pattern model after identification of technical and institutional aspects

3.3 Economic Aspects

This section deals with the economic aspects in which data centres can figure in the Dutch energy system. The first important economic aspect, Transaction Costs Economics (TCE), is already discussed within Chapter 2.4 *Transaction Costs Economics.* The other economic aspects, influencing the TCE highlighted within the interviews are the importance of collaboration, land and resource availability, social acceptance from the community and the impact on the business case. While conducting interviews and attending different events, these were the main economic components discussed. Therefore, these components have been chosen to shed more light on.

3.3.1 Collaboration

Taking the example from the study in Amsterdam Zuid-Oost by Franchimon et al. (2024) about the realisation of a data thermal project. They investigated why the project was ultimately not realised. The white paper written in the process gives good insight of obstacles in this area. They point to different uncertainties within the projects which makes parties wait-and-see, which prevents projects from being realised. The main advice of Frachimon et al. (2024) is that a strong collective approach will be needed to actually realise data thermal projects.

Williamson (1998) describes collaboration as an initially direct and short-term process. However, if the magnitude of projects becomes more complex, these collaborations require long-term promises, increasing the transaction costs (Williamson, 1998). The transaction costs will increase due to more coordination which will be needed to get parties on the same page. When it comes to longer term, the additional costs for this can be substantial. Schelvis (2025)(Equinix) *also emphasized that Equinix as data centre operator is very willing to collaborate on projects to realise data thermal solutions, but that they must weigh the effort they put in investigating, against the likelihood of a project actually being realised.*

Several interview participants talked about the importance and need of collaboration between involved parties[49]. The group interview with Switch Datacenters and the municipality of Diemen showed that both parties would like to work together to realise a data thermal project[50]. However, the parties do not yet have a concrete picture of how this collective approach should look like. The interview with neighbourhood initiative MeerEnergie also highlighted that collaboration is important, this is an initiative to create a community owned heating network within the aera of Middenmeer near Amsterdam. MeerEnergie is trying to build a heat network together with Firan, a company providing heat networks. They depend on available heat from the Equinix data centre located at the Amsterdam Science Park, the municipality for financial resources and the government making a concrete plan for the Collective Heat Act (WCW). Currently, the project is entering a critical phase as several pieces need to fall into place for the project to finally materialise[51].

What these projects have in common is that they involve many stakeholders who, due to risks and a lack of longer-term plans, have limited self-commitment to the project[52]. This is because the costs involved are large and companies are reluctant to incur sunk costs. As a result, many parties signing a '*Letter of Intent*' and wanting to participate in sustainability projects. However, whether these stakeholders will also stay with the project when costs get really high remains to be seen in practice. In the project of Franchimon et al. (2024), parties themselves stepped out of the project as realisation got closer.

3.3.2 Land and Resource Availability

Land and resource availability is about the components needed to stimulate certain development and innovation. In this case, it concerns the availability of scarce resources such as (cheap) energy and locations, which data centres and other industries in the Netherlands are currently struggling with.

Power need

Power availability is a major constraint for data centre development[53]. Some projects are being delayed due to power limitations[54]. Therefore, data centres explore alternative solutions like on-slide power generation, including microgrids or temporary power solutions while waiting for infrastructure upgrades or increase their interest in natural gas as a short-term solution in the US (Soben part of Accenture, 2025). In many interviews was the problem of power availability mentioned, showing that this is one of the biggest issues at the moment[55]. Because companies cannot obtain new or heavier grid connections, several projects are being delayed. A direct consequence of the lack of power availability is that data centres who want to increase their heat temperature with a heat pump to be able to utilise in a district heating network. Also, cannot obtain a grid connection for the heat pump[56].

Data centre location

Locations are important for the profitability and realisation of data centres, as well as the possibility to apply data thermal solutions. Companies carefully determine which locations are most suitable and require different strategies[57]. Edwards et al. (2024) has investigated this and found that there are globally three important components which influence the location of a data centre: Politics and price, climate, and infrastructure. Firstly, political stability includes favourable taxes and legislation, and low power prices increase the likelihood of data centres to establish in certain areas. Secondly, climate influences location, colder climates are preferred to lower the cooling costs. Lastly, infrastructure is important, data centres need a connection to the energy grid for

[49] Interview AMS institute; Interview MeerEnergie; Interview Switch Datacenters1

[50] Interview Switch Datacenters1; Interview Switch Datacenters2; Interview Municipality Diemen1; Interview Municipality Diemen2

[51] Interview MeerEnergie

[52] Interview AMS institute

[53] Event Data Could energy & ESG

[54] Interview Data centre branch

[55] Interview MeerEnergie; Interview AMS institute; Interview Data centre branch; Event Data Could energy & ESG

[56] Interview Liander1; Interview Liander2

[57] Event Data Could energy & ESG

development. Preferably, a data centre is located near a district heating network, so heat can be reused[58]. Van Essen (2025) (Switch Datacenters) *points out a problem here, he says that they would like to partner with the district heating operator to build data centres on sites where the heat network is being built, however, the speed of development differs such that this collaboration is difficult to get off the ground.*

Besides this, Soben part of Accenture (2025) has done research on new locations where data centre hotspots occur. They highlight that new data centre hotspots are emerging, driven by power availability and renewable energy sources. In Europe, Nordic countries attracting massive investments due to the profitable colder climates and Ireland due to the favourable tax system. The Netherlands used to be a well seeded location because of good connectivity, however, a lack of available power and locations leads to less attractiveness at the moment[59].

The data centre capacity in the Netherlands is almost reached, which means that to be able to generate more data, new data centres need to arise within locations that might be available already for other purposes (van Veen, 2024). This is one of the reasons, that Switch Datacenters decided to create a data centre in an old distribution location[60]. Also, Equinix has experienced with the retrofit of locations into data centres. Velkova (2023) has done a study in which a data centre was created in an old bunker in Helsinki, Finland, providing a hopeful example.

3.3.3 Social Acceptance: Community

Social acceptance for data centres is highly important to be able to realise projects, Chapter 4 *Social Acceptance,* will dive deeper into social acceptance of data centres from all aspects. However, this subsection will though upon social acceptance perspectives obtained within the interviews. Highlighting the needed growth for data centres according to different stakeholders and the formulation of public opinion.

Data centre use and growth

Many people work in a digital environment supported by a data centre, according to the DDA, there are about 2.1 million people relying on a data centre for at least 50% of their working day (Dutch Data Center Association, 2025). Comparing this to everyone that is using digital services, this amount is even higher. This size shows the need for the Netherlands to invest in data centres. However, several interviewees highlighted different perspectives on the growth of the number of data centres in the Netherlands[61].

First, Nicolaï (2025)(Neighbourhood cooperative) *emphasizes that data centres are not only a "nice" source of heat, but certainly also an environmental burden on society due to their enormous electricity consumption. She sees the reuse of heat from data centres as helping to solve an existing problem.* Brandligt (2025)(consultant) *is also more conservative when it comes to the number of data centres in the Netherlands. He sees the Netherlands struggling with severe grid congestion, which makes expansion of data centres difficult. Brandligt therefore thinks that new data centres are unlikely to be built, in large amounts, in the Netherlands any time soon due to power shortages*.

On the other hand, some interviewees were more open to solutions to integrate data centres. Schaart (2025)(Firan) *acknowledged the importance of Data centres in the Netherlands and stressed that the Dutch government need to deal with a way to integrate them more sustainably in society. For example, by using their residual heat in heat networks. Before that can be realised, she sees that the market is still in a transition phase where a critical mass needs to be reached before greater acceptance occurs. The so-called 'fear of the unknown' plays a role. Besides this, she sees that the social network is an important factor in influencing choices made by residence. Successful example projects are needed to show the benefits of heat networks and might cause a change.* Newton (2025)(Data TU Delft) *argues that the Netherlands should be in more control or could demand more. Acutely, saying 'no' to more data centres is probably difficult and undesirable. However, it probably could be better investigated how data centres can be used optimally. He points to the lack of policy on the purpose of such a data centre. For example, if Microsoft wants to build a new data centre, is there a check on what the*

[58] Interview AMS institute; Interview Switch Datacenters1

[59] Event Data Could energy & ESG

[60] Interview Switch datacenters1

[61] Interview MeerEnergie; Interview consultant2

purpose of data will be stored there and whether it is really needed for the Netherlands or that it aligns with our values? One counterargument is that such a check could halt innovation. Perhaps an easier condition could be that a data centre should each year reduce their energy and water usage (or become more self-sufficient) by half, in similar spirit to the EU Eco design directives for other products such as TVs or vacuums. Perhaps in the future, a distinction could be made as to which data centres we do and do not want in the Netherlands.

There are also data centres and a branch association that look very positively at the number of data centres in the Netherlands. Grove (2025)(Data centre branch) *stresses that Data Centres are crucial for the digital infrastructure in the Netherlands, as they facilitate the IT equipment of companies and governments. They run entirely on green power through certificates and contracts. The Netherlands currently has a strategic position as a data centre hub because of its digital infrastructure and geographical location and to stay there, however, it will be a continued investment.*

Public opinion and Image Data Centres

Public opinion is made up from different perspectives. Much of it is created by the influence of (social) media that can paint a certain exaggerated positive or negative picture[62]. For example, an episode from *De Avondshow met Arjan Lubach*, a Dutch television program that playfully highlights news items. Within the episode, *Datacentrum in Zeewolde,* where the negative aspects of a data centre overly highlighted. This episode appeared on TV and was also viewed more than 300,000 times on YouTube (De Avondshow met Arjen Lubach, VPRO, 2022). Different interviewees highlighted the fact that this kind of news items can really damage the image of the data centre industry via public perception influencing politics[63].

Several interviews toughed upon the image of data centres, which is not so positive at the moment[64]. Currently, there is a widespread perception that data centres are black, big and ugly boxes that consume too much subsidized sustainable energy (De Avondshow with Arjen Lubach, VPRO, 2022). As a result, their image is not very favourable. The industry is working hard to restore this image, for example, by using green certificates and thus ensuring 100% sustainable electricity[65]. However, from an investor's perspective, there was mentioned that there is still room for improvement[66]. Within the interviews it was mentioned that the industry can demonstrate how they contribute to green initiatives, this could persuade investors, as "*green*" is increasingly becoming a requirement[67]. The negative perception of data centres as heavy energy consumers might be encountered with facts when attempting to change[68].

3.3.4 Business Case

This section will explain the business case of data centres. As discussed in Chapter 1 *Problem Definition*, all data centres, whether Enterprise, Colocation or Hyperscale, has a core business to process data. An Enterprise data centre is often not directly for economic purposes, but to support a business with another main purpose. For example, hospitals, educational institutions or governments. On the other hand, colocation data centres are there precisely for an economic purpose. A colocation data centres can be seen as a kind of Hotel, where the customer can rent a room in the data centre to store or process their data[69]. The main purpose for the colocation data centre is to be able to store and process as much reliable and secure data as possible. Hyperscale data centres usually belong to a large company, offering an online service such as Microsoft, Google and Amazon. These mainly benefit from a lot of storage space and large facilities with big power connections.

Switch Datacenters and Equinix, are among others, both open to sustainable alternatives and therefore cooperate with municipalities, heat companies, neighbourhood cooperatives, DSOs , TSO and others to realise

[62](Interview Data centre branch)

[63](Interview Data centre branch; Interview Consultant1)

[64](Interview Data centre branch; Interview Consultant1; Interview AMS institute; Event Data Could energy & ESG)

[65](Interview Data centre branch)

[66] (Interview Investment company; Interview Consultant1)

[67] (Interview Investment company)

[68] (Interview Investment company)

[69] (Interview Switch dataceners1)

sustainable projects like residual heat[70]. However, there is a limit to where they can and want to contribute. They want to offer their heat for free because it is a residual product. However, when the initiative does not fit within the purpose of the data centre, they cannot take additional steps. Van Essen (2025) (Switch Datacenters) *also notes that currently the heat grid is analysing a go/no go business case based on outdated sources map. CE Delft is developing this and does not include heat from data centres as an available source. As a result, structurally wrong business cases are built and go/no-go decisions are made where heat networks can or cannot be built. Also, according to Van Essen, the price to consumers is completely miscalculated, without including free 30 degrees heat from data centres but assuming much more expensive other techniques. He stresses that this could be one of the reasons why heat networks are not getting off the ground when they could be economical if data thermal solutions are included.*

Other mentioned business cases are, flexible energy supply, building heat pumps, higher residual heat temperatures, or the development of decentralised cloud[71]. First, flexible energy supply, with could be useful to mitigate grid congestion, helping grid operators. Oost(2025)(Liander) *mentioned that the latest calculations indicate approximately 195 billion euros are needed to future-proof the grid in the Netherlands, as the total estimated costs of grid expansions for DSO's and TSO. This translates to over 10,000 euros per person. This involves a huge amount of money, so alternatives must also be considered to save costs and time. They also pointed out that data centres can primarily contribute to these issues in two ways. Firstly, by utilizing their heat through the establishment of heat networks, and secondly, by providing energy flexibility. This refers to the energy data centres can generate using their backup generators to help balance the grid. For both solutions, there needs to be social acceptance of data centres in order to contribute.* Additionally, Oost (2025) (Liander), *mentioned that when data centres would offer their backup capacity for compensation on the energy grid, almost all local grid congestion (on medium voltage level) will be levelled out. This would mean that the DSO would have more time to build up the grid capacity while keep more companies connected to the grid.* However, Van Essen (2025)(Switch Datacenters) *mentioned that it would be a too big risk for them to provide flexibility to the grid. Besides this, data centres have mostly diesel backup generators, which means that they have a higher environmental impact. Due to this, the data centre owner has, on average, only a permit to use the back-up only for back-up and testing with a maximum of 400 hours per year*.

Second, building heat pumps, data centre heat comes out of a data centre with an average temperature of 30 degrees, which is low compared to the heat needed in a district heating network. This means that the heat temperature needs to be increased from around 30 to around 70 degrees. To be able to that, an electric heat pump is needed, which needs to be connected to the energy grid. Goede (2025)(Municipality Diemen) *told that it will be most effective to build those heat pumps close near a data centre, maybe even on the same premise, so the heat pump can be connected to the heavy energy grid connection of the data centre.* However, data centre owners don't want to build a heat pump themselves, because it is not their core business[72]. Besides, due to security concerns, they also don't like to have someone else build this for them on their premise[73].

Also, higher residual heat temperatures due to AI, as discussed before, can increase the temperature of the data centra heat. However, getting a higher server temperature can lead to the fact that servers got a shorter life, meaning that they need to be maintained or changes sooner, which is economically less attractive[74]. Which is one of the reasons why data centre owners are hesitated with increasing their inhouse temperature to produce a higher heat temperature[75].

Last, within some interviews the development of decentralised cloud infrastructures with smaller facilities, less than 1 MW per site, as an interesting potential new market, was highlighted[76]. This segment is strategically important for Europe to spread data centre capacity more widely. The companies in this decentralised cloud are currently traditional telecoms players, and there is a need for more integrated solutions

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[70] (Interview Switch datacenters1; Interview Equinix)

[71] Interview Liander1; Interview Liander2; Interview Province Noord-Holland; Interview Municipality Diemen3

[72] Event Workshop EML; Interview Switch Datacenters1

[73] Event Workshop EML; Event Data Could energy & ESG

[74] Event Workshop EML

[75] Event Workshop EML

[76] Interview Consultant1; Interview Asperitas

for network, computing power and data storage[77]. There is a major European investment programme called '*Europe's Next Generation Cloud Infrastructure and Services 8ra'* to help drive this development.

These discussed economic aspects add five additional nodes to the pattern model which can be been in Figure 3.4. This figure shows that there are six two-sided relations already between these economic aspects. Firstly, highlighting the five relations between Transaction Costs (TC) and all other economic nodes. The reasons for this is that all nodes add higher complexity to the system and thus higher transaction costs to the collaborative efforts needed to realise projects, as being discussed in Chapter 2.4 *Transaction Costs Economics.* Important to notice is that these are two-sided relationships, meaning that one aspect can both influence the transaction costs as being influenced by the transaction costs. Higher or lower transaction costs can also create positive or negative feedback-loops regarding the aspect. For example, higher transaction costs can lead to a lower business case, which can consequently lead to even more transaction costs. Besides this, also the business case (BC) is two-sided connected to land and resources availability (L&R) because of the interconnectedness of these two aspects as discussed above.

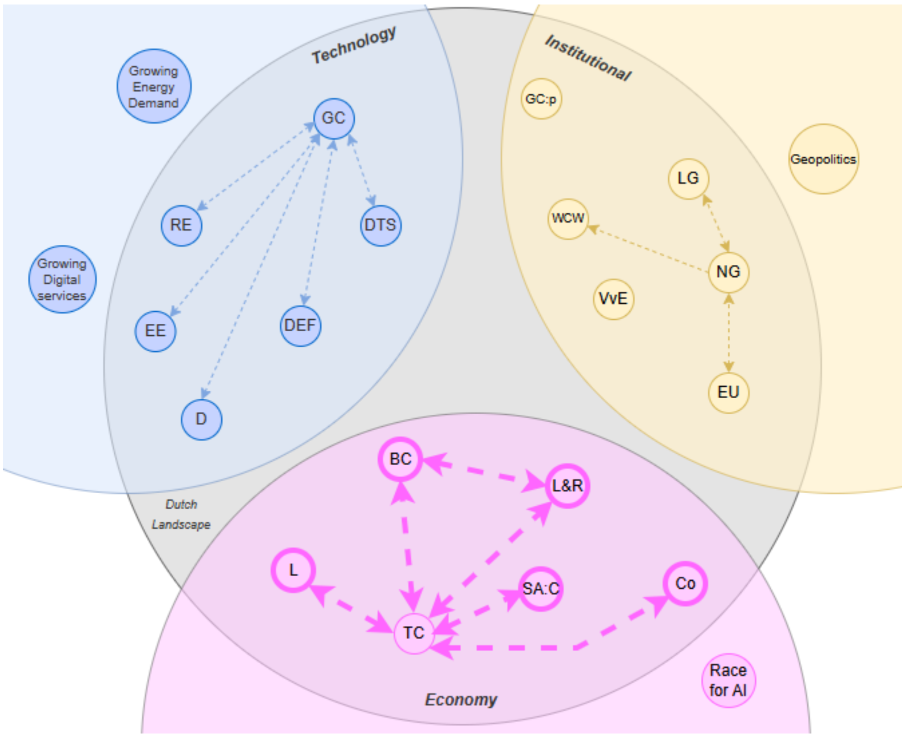

Figure 3.4 Pattern model after identification technical, institutional and economic aspects

The pattern model shown in Figure 3.4 is already starting to look complex, however, it is not done yet. It now, provides a basis of technical, institutional and economic aspects as discussed within this Chapter. The last section of this Chapter will delve deeper into the stakeholder relationships between these aspects, showing connections between the different domains.

3.4 Stakeholder Interactions

Within the complex network in which data centres operate, several stakeholders are involved. From the interviews with many of these stakeholders, it was possible to identify how they depend on each other and the relationships between them. The relationships between the stakeholders will connect the nodes described in the last three sections. Before this can be done, a first distinction was made between *contextual relationships* and *internal relationships*. The contextual relationships, discussed in subsection 3.4.1 *Contextual Relations Between Stakeholders*, assume relationships that will be affected by the context. These are laws, regulations, economic transitions and technical challenges which are mostly determined by eternal factors. For the scope of this study,

[77] Interview Asperitas

it is considered that these relationships provide a basis. In subsection 3.4.2 *Internal Relations Between Stakeholders*, the internal relationships are discussed. This deals with technical, institutional and economic system aspects where stakeholders, in the Dutch landscape, need each other and can influence each other. Within this thesis, the "*Dutch Landscape*" is the environment in which data centres operate with in the Dutch energy sector, as explained in the sections above. To give guidance within this complexity, these relationships are divided into six themes, each theme covers a part of the total complexity. The different themes are connected to each other, creating the connection between the nodes described in the former sections 3.1, 3.2 and 3.3. Connecting the nodes with the relationship themes will give an overview of the total complex situation, the final pattern model, data centres are operating in.

3.4.1 Contextual Relations Between Stakeholders

Before diving deeper into the certain relationships between stakeholders, the crucial stakeholders will be discussed. These different stakeholders play an important role in the realisation of data centres to function within the Dutch energy system. Based on the interviews, the following stakeholders can be determined as crucial stakeholders: data centre operators, municipalities, grid operators, the Amsterdam data hub, national government and regulatory authorities, residents and owner associations (VvEs), financial institutions and investors, and research institutions, knowledge partners and functional partners.

First, ***Data Centre Operators***, they are at the core of projects in this study, data centres are a potential source of heat and flexibility in energy consumption. All interviewed data centre operators, Switch Datacenters, Equinix and EdgeConneX, are actively exploring sustainable development projects[78]. Van Essen (2025) (Switch Datacenters) *sees a role for data centres to 'give something back to society' by supplying heat.* Schelvis (2025) (Equinix) *emphasizes the cooperation with governments and district heating grid operators. According to him, the willingness to invest in sustainable solutions within these organizations is essential.*

Second, ***Municipalities***, they play a directing role in the energy transition and are a direct partner for data centres when it comes to developing heat solution. A progressive municipality with regard to residual heat, is the municipality of Diemen, they are actively involved in investigating the possibilities and support among residents[79]. However, not all municipalities are so forward-thinking[80]. Municipalities are responsible for outsourcing the connection to heat networks and arranging acceptance with residents[81]. In addition, municipal in spatial planning and permitting can be a crucial factor. Municipalities can also use the Wet Gemeentelijke Instrumneten Warmtetransitie (WGIW) (Act Municipal Instruments Heat Transition) to support residents.

Third, ***Grid Operators*** (electricity and heat), the TSO (TenneT) and various DSOs such as Liander, Stedin and Enexis are essential for the infrastructure of both electricity and heat grids. They need to address the grid congestion issues that hinder, among others, the growth of data centres and the electrification of heat pumps[82]. Cooperation between grid operators and data centres is crucial for efficient utilisation of the grid and enabling energy flexibility[83]. Besides, parties such as Firan (part of Alliander) and Eteck are needed for the construction, operation and distribution of heat networks. Different interviews highlighted the complexity of developing heat networks and the need for cooperation with various stakeholders[84]. The Collective Heat Act (WCW) is an important factor determining the role and structure of heat companies. Financial feasibility and security of off-take are crucial aspects for realising heat network business cases.

Next, the ***Amsterdam Data Hub****,* this is not an ordinary stakeholder but a collection of data centres within the Amsterdam region. The attractive location of transatlantic cables, stable government and environmental factors make this an attractive place for data centres to locate till 2019 (Derksen, 2021). This has

[78] Interview Switch Datacenters1, Interview Equinix; Interview EdgeConneX

[79] Interview Municipality Diemen1; Interview Municipality Diemen2; Interview Municipality Diemen3

[80] Event EnergyLab Zuid-Oost

[81] Interview Municipality Diemen1

[82] Interview Liander1

[83] Interview Data centre branch

[84] Interview MeerEnergie, Interview Firan, Event EML workshop

led to Amsterdam becoming a well-known data hub in Europe[85]. However, due to limiting the number of new data centres, this attraction has decreased. Which changed the digital position of the Netherlands within Europe and the world (Derksen, 2021).

The ***National Government*** *and* ***Regulatory Authorities***. The government drafts the laws and regulations (frameworks) that affect the energy transition and the role of data centres, such as the Collective Heat Act (WCW) and regulations around energy efficiency. Bodies such as the RVO and the Environmental Agency's (Omgevingsdiensten) are responsible for enforcing energy saving obligations. The ACM (Authority Consumer & Market) partly determines tariffs for heat and price models for electricity. A clear and stable policy environment is essential to encourage investment in sustainable projects.

Residents and Owner Associations (***VvEs***) are also crucial for gaining support (social acceptance) and for the realisation of heat networks. Social acceptance and participation of residents is crucial and could be challenging to get on board[86]. Also, the legal and financial complexity of sustainability within VvEs, can be a major barrier to connecting heat networks among a large proportion of Dutch households[87]. Schaart (2025) (Firan) *highlighted that enthusing residents of the benefits of heat networks and removing 'fear of the unknown' is essential to get heat network projects off the ground.*

Financial Institutions and Investors also matter to get projects financed. The social contribution of certain projects and companies and reducing investment risks are important factors for investors to get into sustainable data centre projects[88].

Last, ***Research Institutions***, ***Knowledge Partners*** and ***Functional Partners*** are a driving force in innovation and more efficient techniques. The research and development of sustainable technologies for data centres, such as more efficient cooling and heat utilisation, is important in this regard[89]. For example, technology suppliers developing innovative cooling techniques such as immersion cooling, such techniques can be more robust for future AI developments that can handle higher temperature heat and improve energy efficiency[90]. Also, the European Union is supporting development in digital infrastructure and services by bringing together 12 EU member states and over 120 industry and research partners to do projects together (8ra Cloud Edge Continuum, n.d.)[91].

Theme 0: Context

Between these stakeholders, there are some contextual relationships, mostly concerting the contextual factors highlighted in Chapter 1 *Problem Definition*. Figure 3.5 shows the relationships between the stakeholders involved. The *growing digital services* lead to more data centres being needed and more acceptance within the European Union and other European countries, also the *Geopolitical situation* contributes to this development. European countries want to process more data themselves and thus contribute to the increasing extent of data centres. This increase has two certain consequences, first, more data centres is likely to increase local opposition coming from the NIMBYism, just as seen with wind energy (Kontogianni et al., 2014). On the other hand, more data centres contributes to a greater energy demand (McKinsey Quaterly, 2025). Not only, data centres demand more electricity, but also other industries and households. As a result, grid congestion is a major problem. The Dutch TSO and DSOs will have to deal with this by reinforcing the grid, but these costs are high and this will take time. These relationships are secure, meaning they are unlikely to change in the short term.

[85] Event Data Could energy & ESG

[86] Interview MeerEnergie

[87] Interview VvE

[88] Interview Investment company

[89] Interview Asperitas

[90] Interview Asperitas

[91] Interview Asperitas

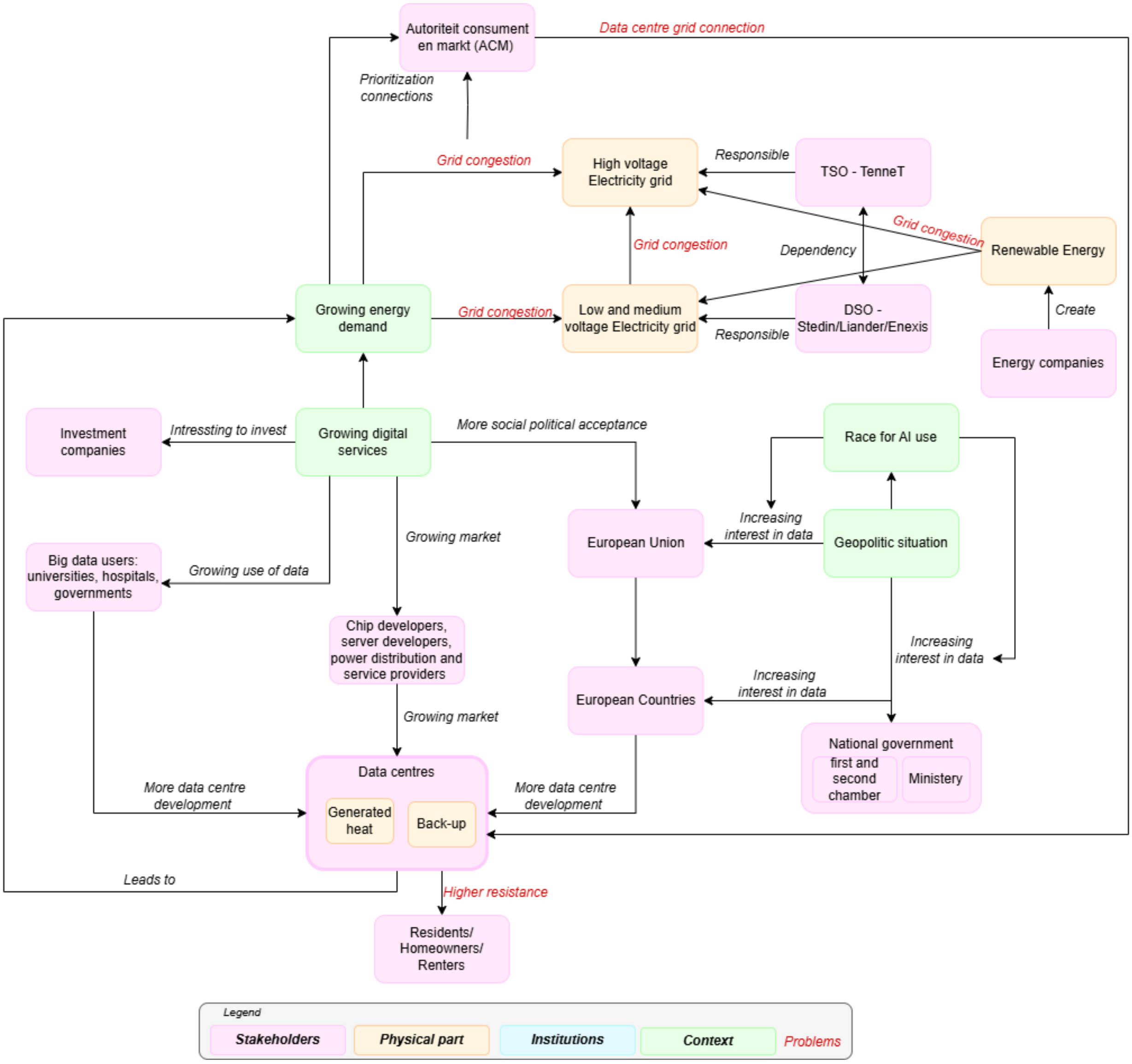

Figure 3.5 Visual representation of the contextual relations between stakeholders

Using the orange arrows, these relationships are firstly added to the pattern model figure, as shown in Figure 3.6. These lines provide the first layer of complexity in which data centres operate in the Dutch energy system. Adding relations between Growing Digital services, Growing Energy Demand, Grid Congestion (GC), Location (L), Geopolitics, National Government (NG), European Union (EU) and the Race for AI.

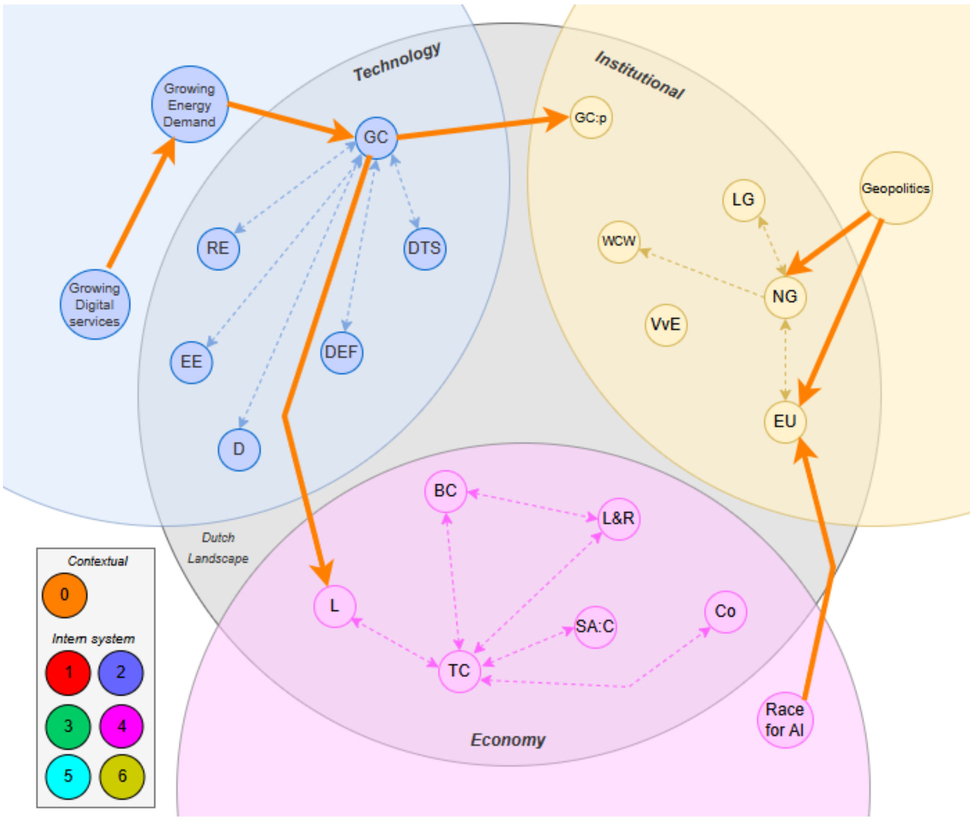

Figure 3.6 Build-up 1: Adding the contextual relationships between stakeholders to the pattern model (orange)

3.4.2 Internal Relations Between Stakeholders

The internal system relationships between stakeholders can be covered in six different themes: *(1) Heat Recovery, (2) Public Perception, (3) Contributing to the Grid, (4) Investment Climate, (5) Decentral Development, and (6) Energy Efficiency.* This subsection will describe the different themes and show how they are addto the pattern model.

Theme 1: Heat Recovery

The key relationships within the **Heat Recovery** theme can be seen in Figure 3.7 highlighting the relationships between data centres and municipalities, heat and electricity network operators, government and end users. Data centres are potential sources of significant amounts of heat that municipalities are exploring for district heating. Municipalities also play a directing role in the local energy transition and are responsible for the infrastructure connecting the heat source to residents and businesses. An example can be seen in the municipality of Diemen, Switch Datacenters, located in Diemen, is already nearly ready to provide heat for free to the municipality of Diemen for the next 10 years[92]. Equinix is also collaborating with the municipality of Diemen to investigate heat delivery for different areas[93]. However, the actualization of these projects requires the municipality to handle the connection to the heat network and engagement with residents to ensure sufficient public support[94]. Municipalities also conduct feasibility studies to assess the technical and financial viability of these projects[95]. They are waiting for the Collective heat act (WCW) before they want to organize a meeting with all stakeholders to determine the next steps. They didn't even start about residence for the local community, which can be hard to get onboard[96]. This is demonstrated with the project from the neighbourhood cooperative MeerEnergie, they are already working for ten years to create a local heat network near

[92] Interview Switch Datacenters1

[93] Interview Municipality Diemen1

[94] Interview Municipality Diemen3

[95] Interview Municipality Diemen1

[96] Interview Switch Datacenters1; Interview Municipality Diemen1; Interview Municipality Diemen2; Event EnergyLab

Middenmeer, in which they experience that local support is one of the obstacles to get the project of the ground[97].

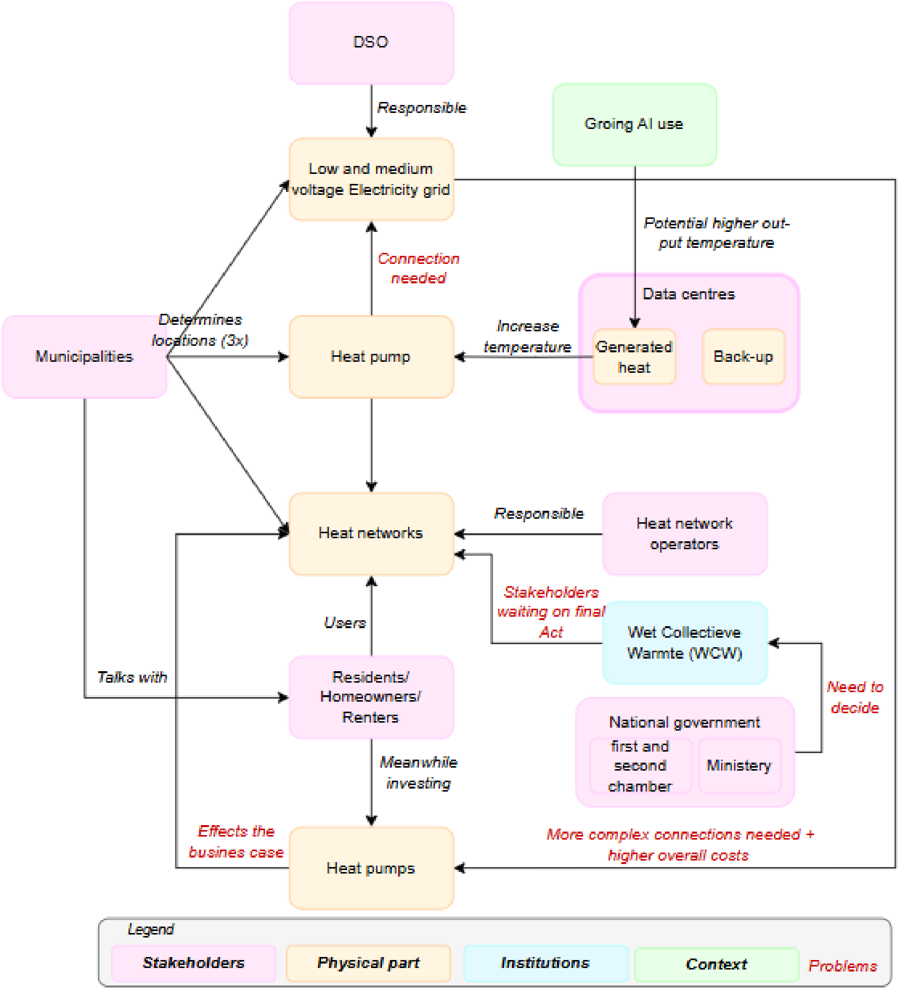

Figure 3.7 Visual representation of first theme: Heat Recovery

These relationships contribute to the build-up of the pattern model, adding the red lines within the figure, which can be seen in Figure 3.8. The *Heat Recovery* theme adds relations between Data Thermal Solutions (DTS), the Collective Heat Act (WCW), Local and National government (LG, NG), Location (L), the Community Acceptance (SA:C), and the Business case (BC).

[97] Interview Firan; Interview MeerEnergie

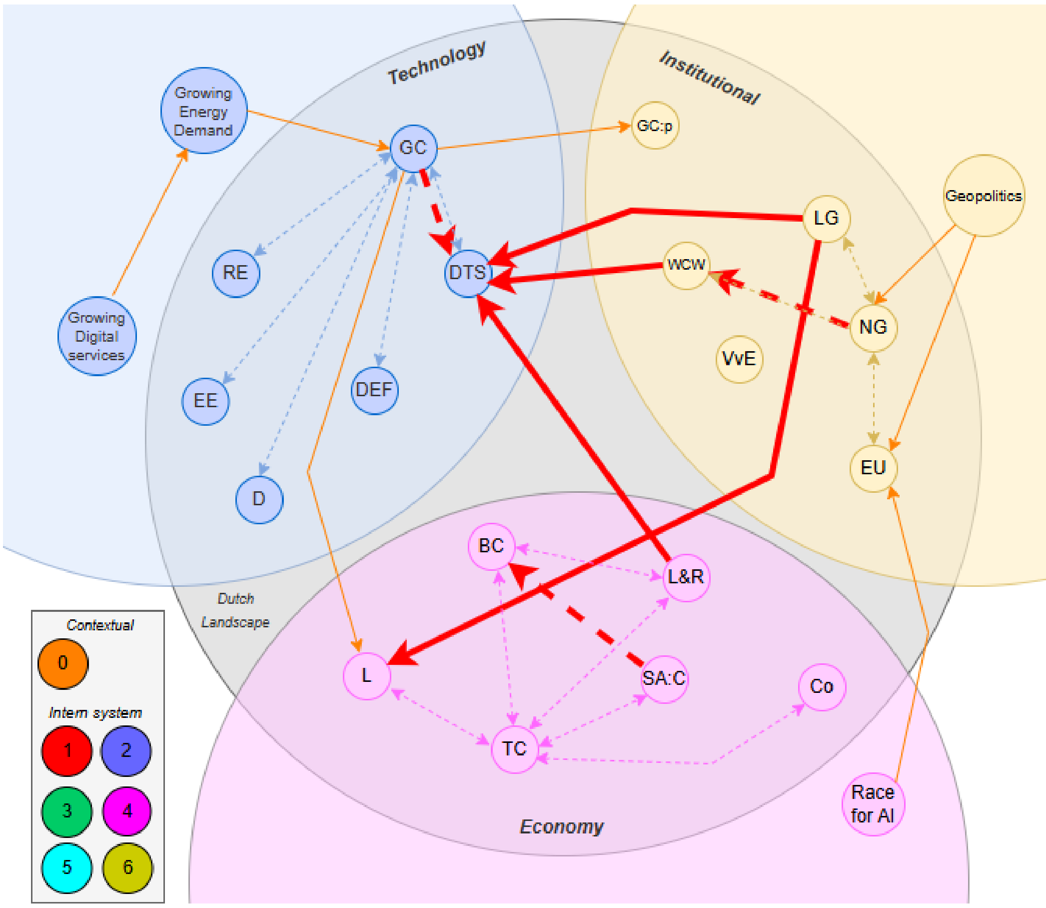

Figure 3.8 Build-up 2: adding theme 1 relations to the pattern model (red)

Theme 2: Public Perception

The success of heat network projects heavily depends on **Public Perception,** partly shown by the relationship between municipalities and residents, often organized within neighbourhood cooperatives or homeowners associations (VvEs). These relationships can be seen in Figure 3.9. Municipalities need to secure community acceptance for the transition to heat networks[98]. For VvEs, the transition can be complex due to legal limitations, requiring high levels of agreement for significant changes, and financial challenges related to the costs of new installations on top of existing mortgages[99]. Interview participants highlighted the challenges of convincing individual homeowners and the voting complexities within VvEs[100]. Municipalities can utilize the Act Municipal Instruments Heat Transition (WGIW) to support residents, but it is not yet discovered if this is going to be enough[101]. Besides this, currently more and more homeowners are buying their own heat pump to prevent gas use, which will decrease the business case for a heat network[102]. Local neighbourhood initiatives like MeerEnergie in Middenmeer, are trying to get a local heat network off the ground, however, they see that it is difficult to get the community on board to switch to a heat grid[103]. This has to do with uncertainty about future heat sources and costs. Last, the Collective Heat Act (WCW) still provides uncertainties and aspects which will hinder the final realisation of the project[104].

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[98] Interview Municipality Diemen1

[99] Interview VvE

[100] Interview VvE; Interview Firan; Event EnergyLab Zuid-Oost

[101] Interview Firan

[102] Interview Liander1; Interview Liander2

[103] Interview Firan; Interview MeerEnergie

[104] Interview Firan; Interview MeerEnergie; Interview Municipality Diemen3; Interview Equinix

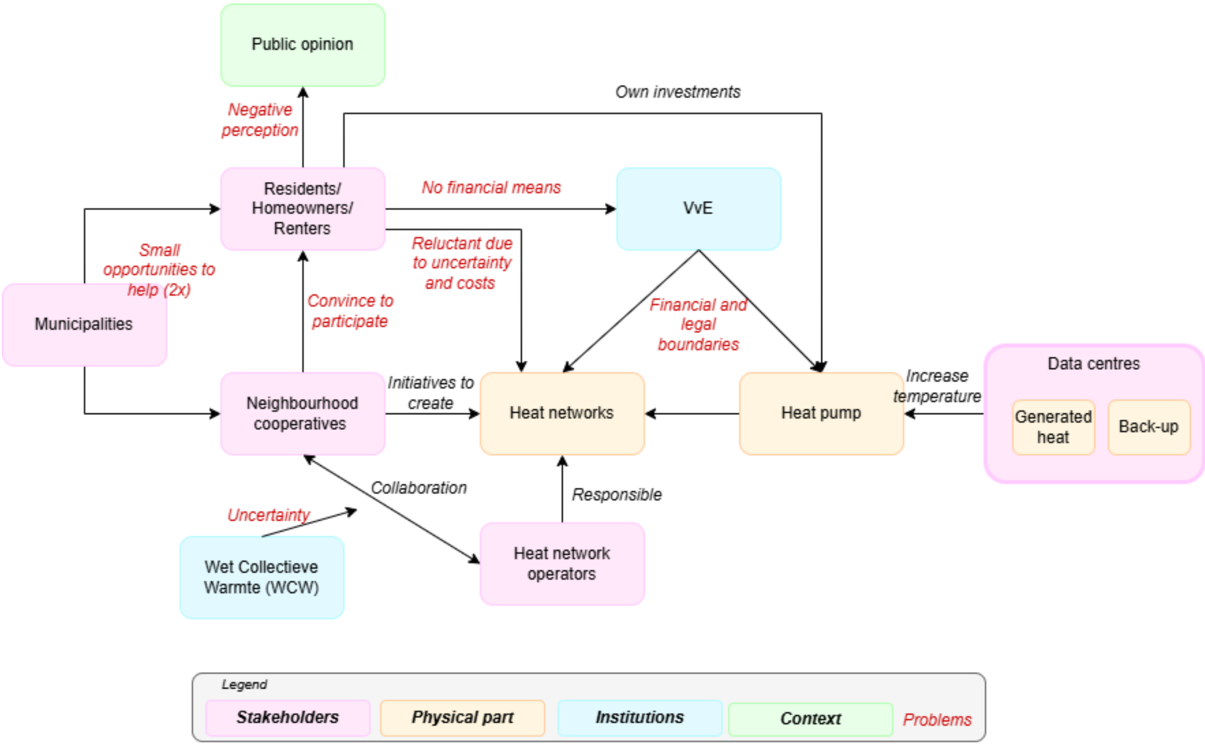

Figure 3.9 Visual representation of second theme: Public Perception

These relationships contribute to the build-up of the pattern model, adding the purple lines within the figure, which can be seen in Figure 3.10. The *Public Perception* theme adds relations between Data Thermal Solutions (DTS), Homeowners associations (VvE's) and the Business case (BC), The Collective heat act (WCW) and Collaboration (Co), Community Acceptance (SA:C) and Transaction Costs (TC).

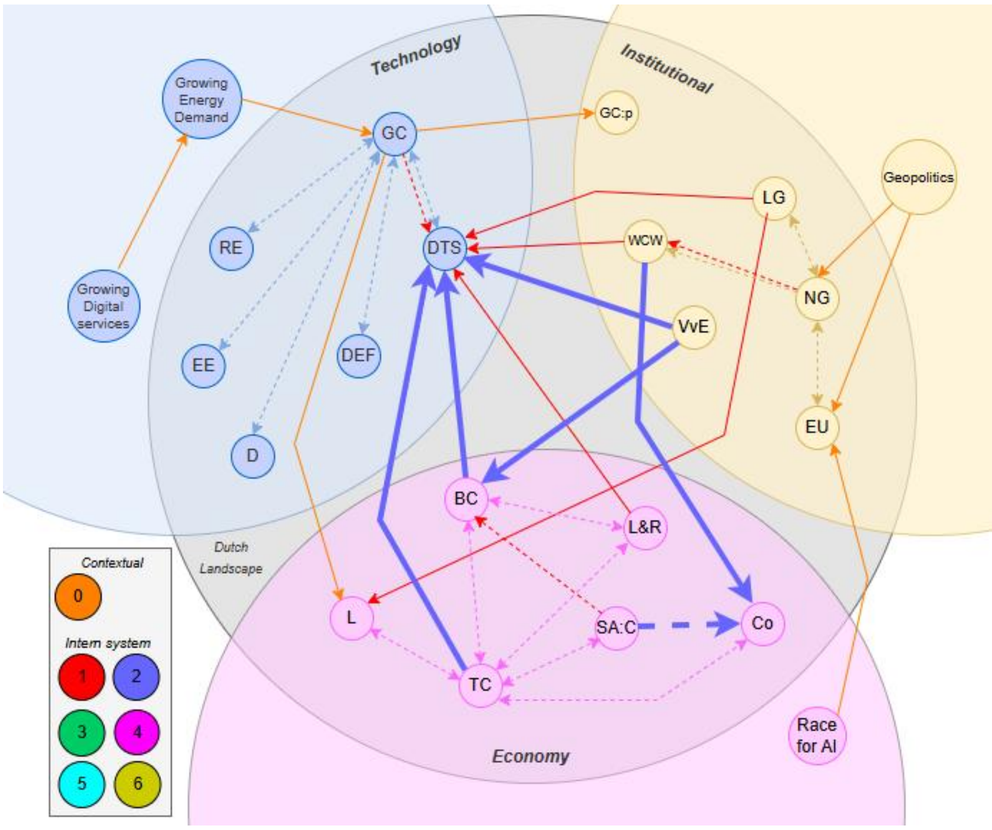

Figure 3.10 Build-up 3: adding theme 2 relations to the pattern model (purple)

Theme 3: Contributing to the Grid

Using data centres for energy flexibility has a high potential to **contribute to grid stability**, only different stakeholders have a different view on this, which can be seen in Figure 3.11. Starting with a data centre perspective, according to Van Essen (2025) (Switch Datacenters)*, energy flexibility is something they are not likely to implement. He considers it too risky to activate backup diesel generators for the grid, where control would be in someone else's hands. Switch guarantees the safety and continuity of data, and energy flexibility could jeopardize this. Additionally, they are only licensed to use backup generators for a maximum of 400 hours per year. Using backup for flexibility might lead them into trouble. From their perspective, energy flexibility isn't part of a data centre's core business and thus less attractive to implement.*

On the other hand, Oost (2025)(Liander) *sees opportunities in more flexible contract forms with customers. Currently, Liander designs the grid based on the maximum electricity customers might demand from the grid at any time. Flexible contracts, like time-based-contracts, could reduce peaks and make the grid more efficient. Liander advocates for alternative connection options, such as using disruption reserves from customers with their own emergency power supplies (like data centres) to reduce grid congestion, or customers may be connected to Liander's contingency reserve capacity rather than through a standard grid connection.Flexibly using data centre backups could largely help the grid congestion problem for Noord-Holland, showing a significant potential benefit in efficiently utilizing existing resources, supporting peak loads, and reducing dependency on fossil fuels. However,* Oost (2025)(Liander) *also points to the challenge of permitting, he elaborates that data centres cannot contribute here because of emission standards. He thinks some of the data centres would want to cooperate, but then they would simply point to the competent authority that they are not allowed to run many hours a year on their own backup generators.*

A smarter collaboration between grid operators and data centres is needed to efficiently utilize the network and to handle grid congestion[105]. A possible solution could be designing new data centres with flexible energy supplies, such as gas generators that can later switch to hydrogen, as a future solution[106]. However, transitioning data centres to gas generators might create a gas congestion problem as well[107].

While one potential solution could be to deploy data centre emergency generators earlier as a buffer for the electricity grid, Voskuilen (2025)(AMS Institute) *sees limited opportunities for data centres to help reduce grid congestion limitations due to their constant high energy demand. Under unique circumstances, grid operators could invite data centres to activate their redundant emergency generators as decentralized, flexible power sources for the electricity grid.*

Last, the ACM anticipated that data centres will be an important part of ensuring the digital position of the Netherlands. Therefore, in 2022, they amended the Data Act to enable high-quality cloud services for companies and services (Autoriteit Consument & Markt, 2022). According to Rood (2025) (consultant), *this has resulted in the has resulted that* the *current pricing model by the Dutch ACM is favourable for data centres, resulting in little incentive for them to engage in energy flexibility initiatives. He suggests that flexible data centres for electricity are likely not as profitable.* An alternative could be for data centres to generate their own energy to reduce dependency on the electricity grid. In the United States, experiments with SMRs are being conducted as a result[108].

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105 Interview Data centre branch

106 Interview Data centre branch; Event Data Could energy & ESG

107 Interview Liander2

108 Event Data Could energy & ESG

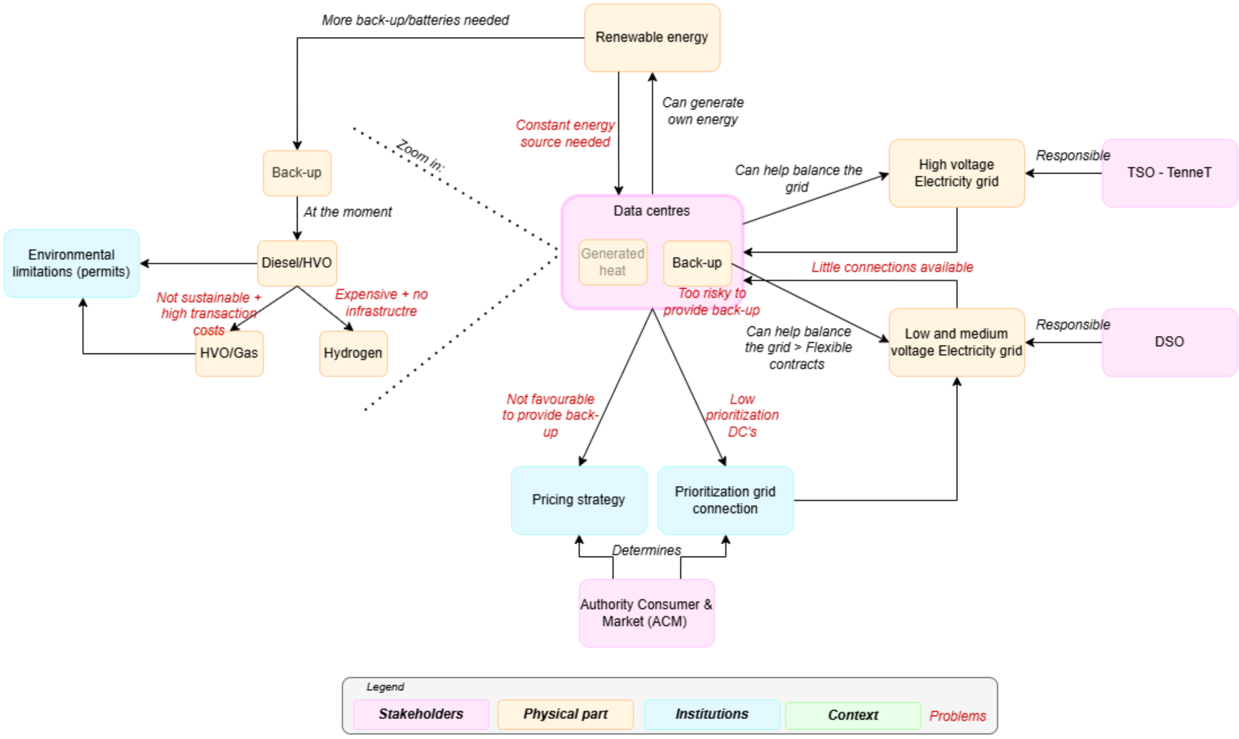

Figure 3.11 Visual representation on third theme: Contributing to the Grid

These relationships contribute to the build-up of the pattern model, adding the green lines within the figure, which can be seen in Figure 3.12. The *Contributing to the Grid* theme adds relations between Data Energy Flexibility (DEF), Transaction Costs (TC), Location (L), Land and Resources Availability (L&R), Renewable Energy (RE), Grid Congestion (GC) and Grid Congestion prioritisation (GC:p).

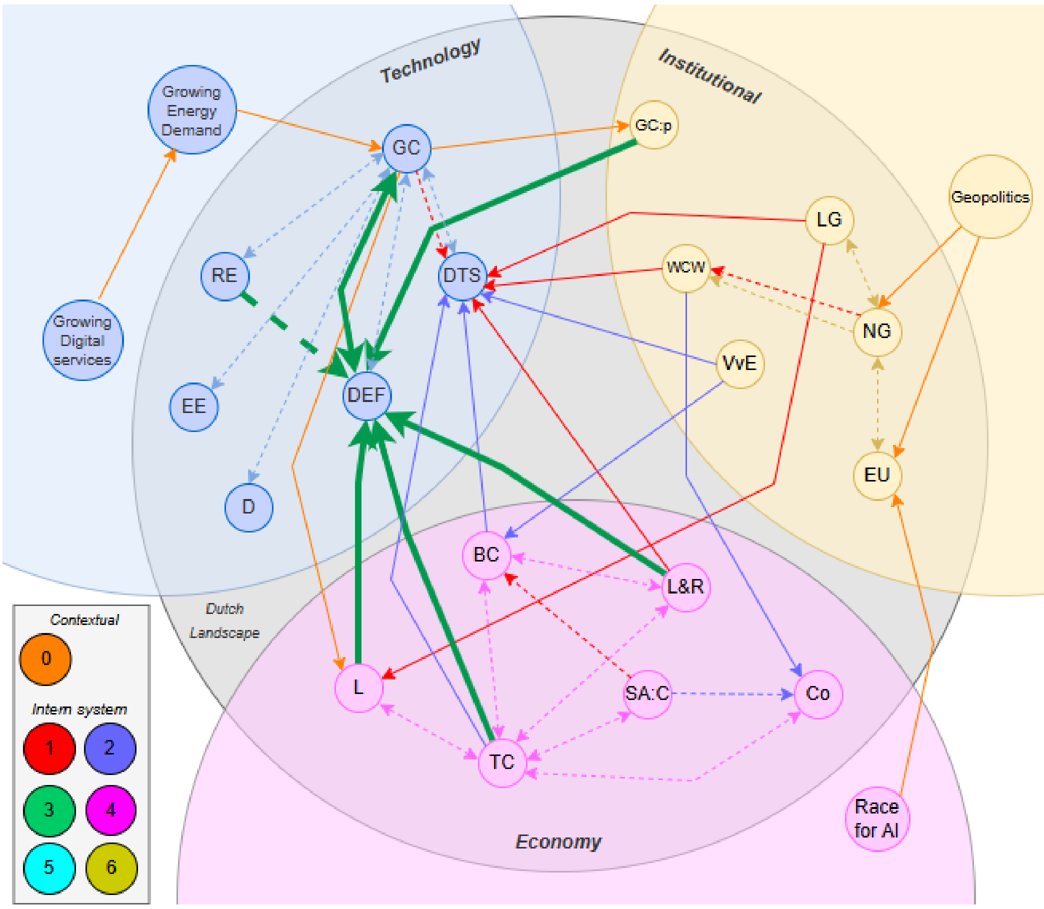

Figure 3.12 Build-up 4: Adding theme 3 relations to the pattern model (green)

Theme 4: Investment climate

The development of data centres and the possible sustainable intermediary role influences different business cases, **investment incentives** and competition positions, which can be seen in Figure 3.13. The national government and regulatory and executive bodies such as RVO and ACM determine and control the overarching laws and regulations that shape, among other things, the energy transition and the role of data centres. These include the coming Collective Heat Act (WCW), reporting obligations for data centres in the field of energy efficiency and policies on renewable energy[109]. A clear and stable policy environment is crucial to make investments in renewable projects less risky[110]. Financial institutions play a crucial role in financing data centre infrastructure and renewable energy projects. Investors consider the returns, risks and sustainability aspects of projects[111]. Within different interviews was pointed out that data centres need to better communicate their social contribution and associated risks to attract more investments in sustainable initiatives[112]. Building a heat network is costly, so the more participants, the more heat consumers and therefore the better the business case[113]. However, more and more people are currently switching to a heat pump, so for these households it is no longer attractive to be connected to the heat network[114]. Therefore, the longer to realise heat networks, the

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[109] Interview RVO
[110] Interview Investment company
[111] Interview Investment company
[112] Interview Investment company; Interview Data steward TU Delft2
[113] Interview Liander1
[114] Interview Liander2

less attractive it becomes to realise them at all. However, parties are now waiting for clarity on the Collective Heat Act (WCW) and being able to obtain an electricity grid connection[115].

The investment climate, determined by clear and stable national situations, also influences to what extent data centres will move to the Netherlands, specifically Amsterdam. Historically, the Netherlands has had good internet cable connections, which makes it attractive for establishing data centres resulting in Amsterdam as one of the first data hubs in Europe[116]. However, other European countries are also becoming increasingly popular[117]. Scandinavian countries are attractive due to their cold climate, allowing for efficient cooling and available district heating networks for utilizing heat. Ireland is particularly attractive due to tax benefits, which have made data centres one of the largest industries in Ireland at the moment. In addition to competitive European countries, Europe also needs to compete with the US and China, which are currently leaders in data and AI[118]. So far, the European Union has expressed its intention to strengthen its competitive position and to allocate more funds towards digital development[119].

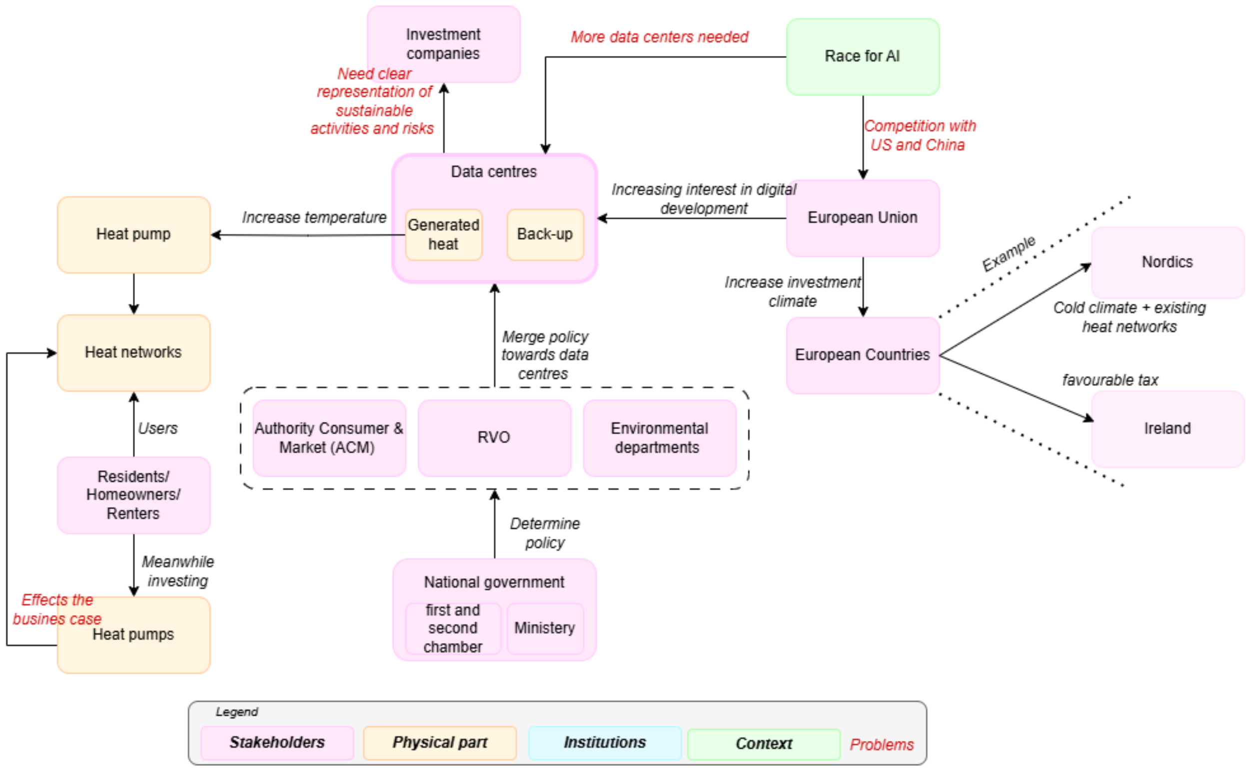

Figure 3.13 Visual representation on fourth theme: Investment climate

These relationships contribute to the build-up of the pattern model, adding the pink lines within the figure, which can be seen in Figure 3.14. The *Investment climate* theme adds relations between the Business Case (BC), National Government (NG), European Union (EU) and Data Thermal Solutions (DTS), also adding the Growing Digital services, Race for AI and the importance of location (L).

115 Interview Data centre branch

116 Interview Data centre branch; Interview Consultant1

117 Interview Investment company

118 Event Data Could energy & ESG; Event Webinear data centers in the MRA

119 Interview Asperitas

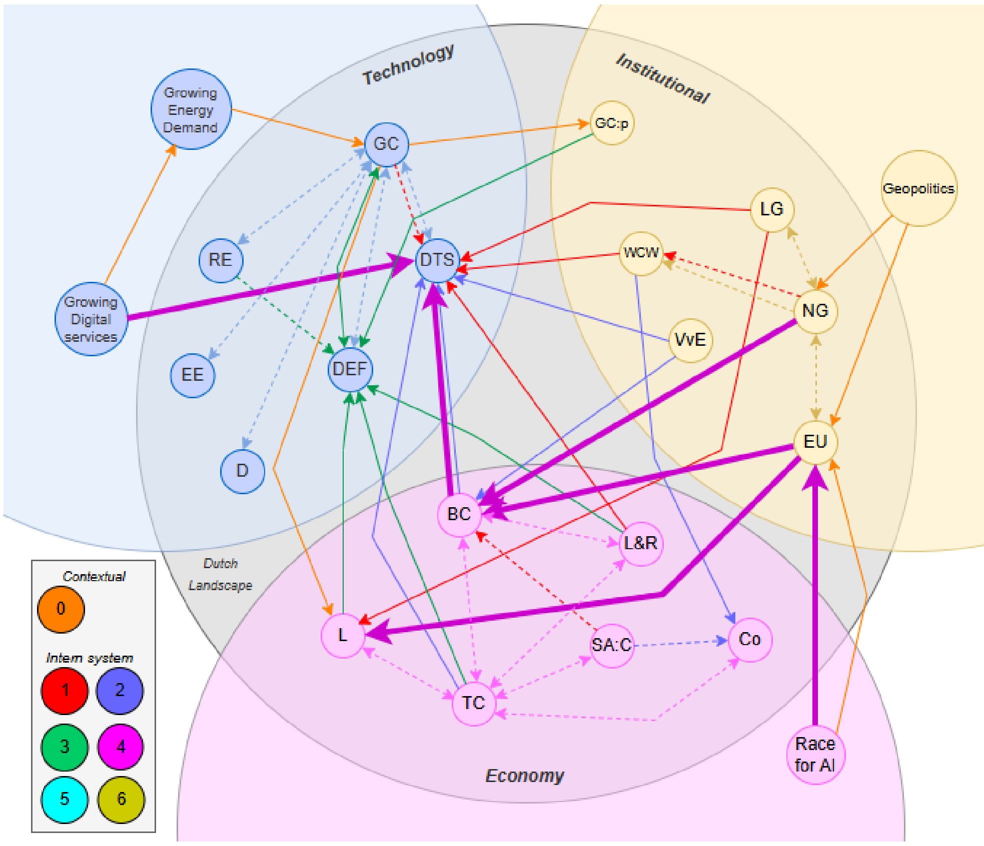

Figure 3.14 Build-up 5: Adding theme 4 relations to the pattern model (pink)

Theme 5: Decentral development

Decentralization is discussed at various levels in the interviews, as a technological trend in the architecture of AI systems[120], as a societal preference evident in the ICT sector[121], as a market development in cloud infrastructure with smaller, more dispersed data centres, and as a potential solution to the issue of network congestion by storing data closer to the source[122]. These relations can be seen in Figure 3.15. A recent technical development at Google in London, creates the idea that various data centres around the world can work with the same data[123]. This approach could be advantageous in the future by constructing multiple smaller data centres instead of larger hyperscale ones, partly due to geopolitical situations and potential was risks such as bombings[124]. However, considerations are needed regarding the maintenance of these decentralized data centres, some of which could be as small as a cupboard[125]. Within the industry, there are also developments of decentralized cloud infrastructures with smaller facilities (less than 1 MW per location) as an interesting market, strategically important for Europe to broaden its data centre capacity[126]. Besides, there is also a significant European investment program, *Europe's Next Generation Cloud Infrastructure and Services*, aimed at stimulating this development.

Additionally, several interview participants also observe that current geopolitical relations prompt reconsideration of decisions to move data to the cloud[127]. Rood (2025) (consultant) *emphasizes a technical trend*

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[120] Interview Asperitas
[121] Event EnergyLab Zuid-Oost
[122] Interview Consultant1
[123] Interview Consultant1
[124] Interview Consultant1
[125] Interview Consultant1
[126] Interview Asperitas
[127] Interview Consultant1; Interview Data steward TU Delft2; Interview Data steward TU Delft3

towards decentralization within ICT, which could reduce dependencies from foreign companies. The Dutch government has already reversed its decision to move data to the cloud and will continue to store its data in-house for the time being[128].

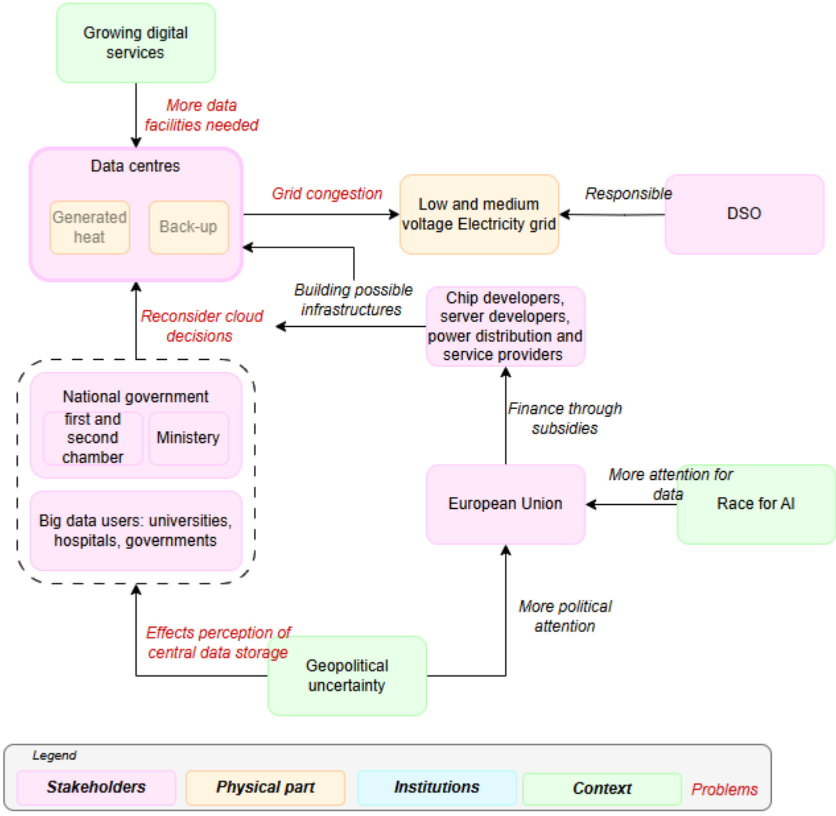

Figure 3.15 Visual representation on fifth theme: Decentral Development

These relationships contribute to the build-up of the pattern model, adding the turquoise lines within the figure, which can be seen in Figure 3.16. The *Decentral Development* theme adds relations between Decentralisation (D) and Business Case (BC), European Union (EU), the Growing Digital services, Geopolitics and influences Grid Congestion (GC).

[128] Interview Data steward TU Delft3

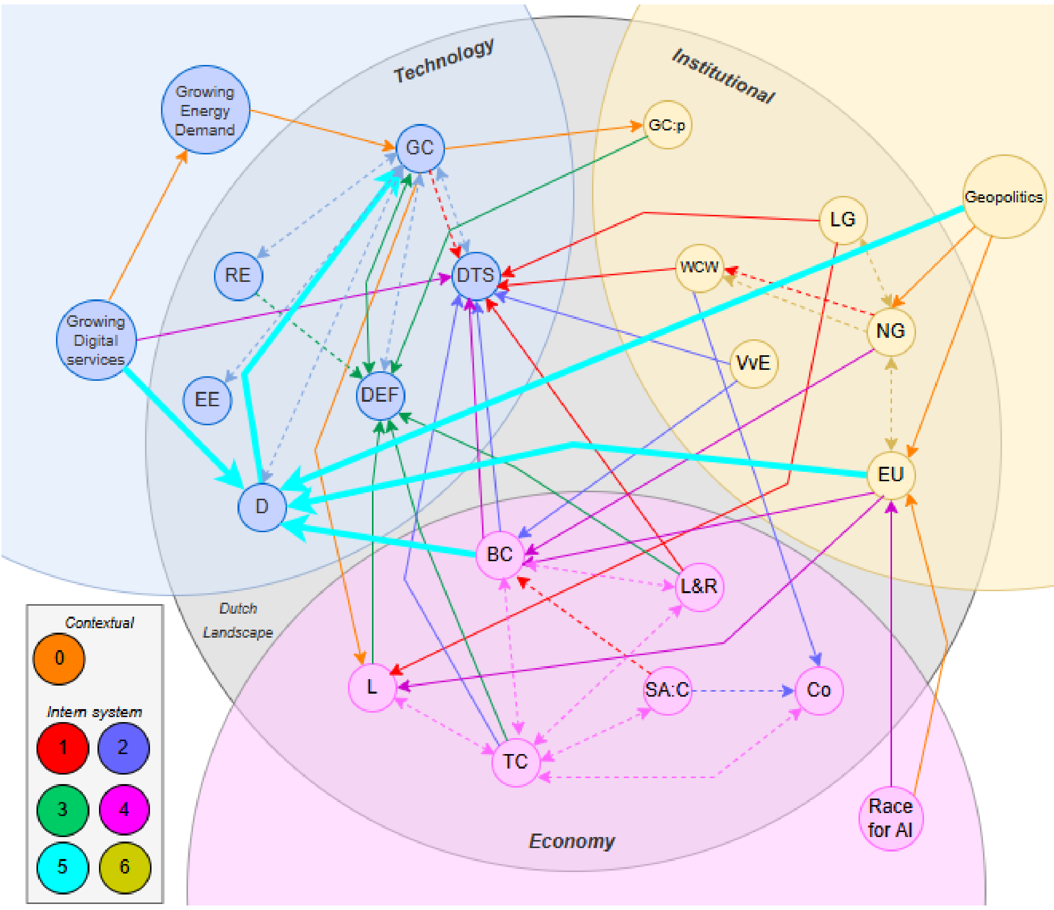

Figure 3.16 Build-up 6: Adding theme 5 relations to the pattern model (turquoise)

Theme 6: Efficiency

Within this thesis, there is looked at two aspects related to energy **efficiency** and data centres, these aspects are internal energy efficiency and system efficiency regarding heat use, of which an overview can be seen in Figure 3.17. Internal efficiency, is also discussed in Chapter 1 *Problem Definition*. This concerns the energy-saving measures that data centres themselves can take. These measures are included in the Reconised Measurements List (EML). However, there is still little knowledge among data centre operators about which measures they can easily apply themselves[129]. By focusing on higher internal efficiency, the energy consumption of the data centre could go down, thus lowering the PUE. On the other hand, the system may experience other consequences of other data centre efficiency measurements. For instance, if a higher out-put temperature can be realised, the business case for a heat network with a data centre as heat source could also increase, which could lead to a more socially efficient system[130]. So this theme is on the one hand about lowering the energy consumption to be able to lower the PUE of the data centre and on the other hand about increasing the data centre out-put temperature, which can make the data centre less efficient but creates a higher system efficiency.

[129] Interview Omgevingsdienst Noordzeekanaalgebied

[130] Interview Municipality Diemen3

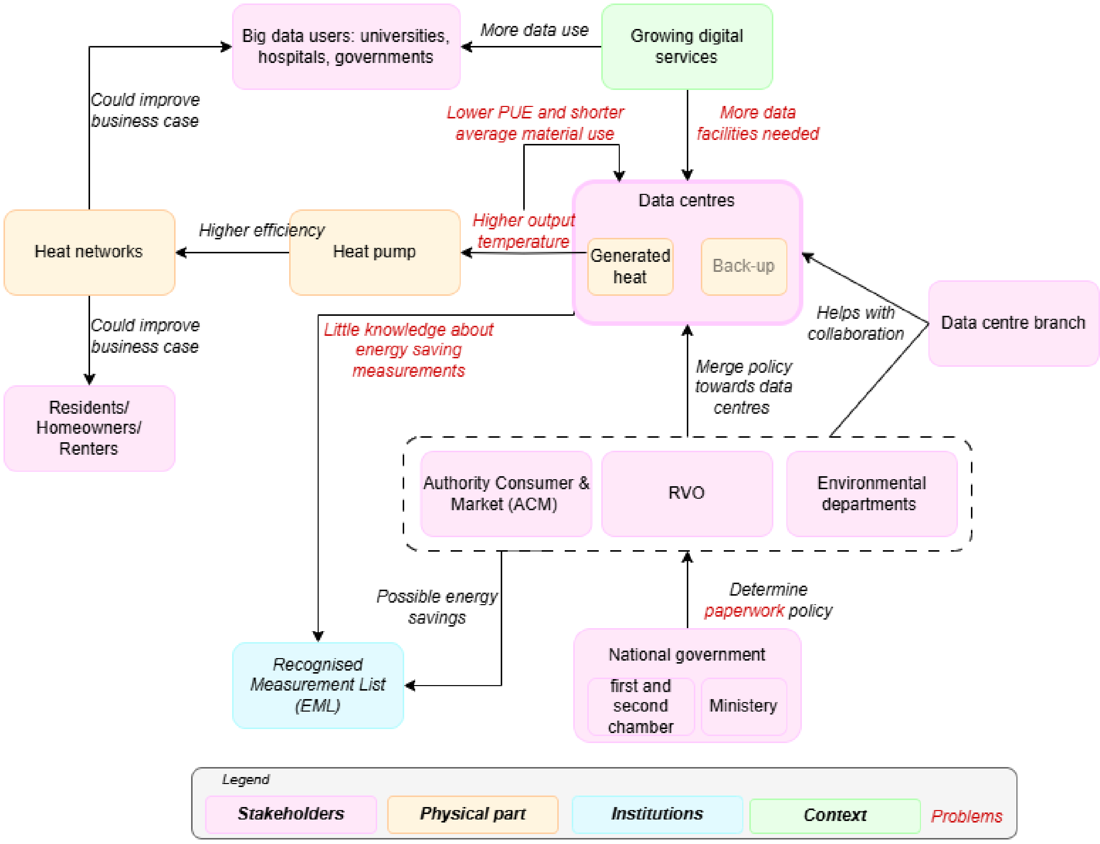

Figure 3.17 Visual representation on sixth theme: Efficiency

These relationships contribute to the build-up of the pattern model, adding the yellow lines within the figure, which can be seen in Figure 3.18. The *Efficiency* theme adds relations between Energy Efficiency (EE) and National Government (NG), Transaction Costs (TC), and Land and Resource availability (L&R).

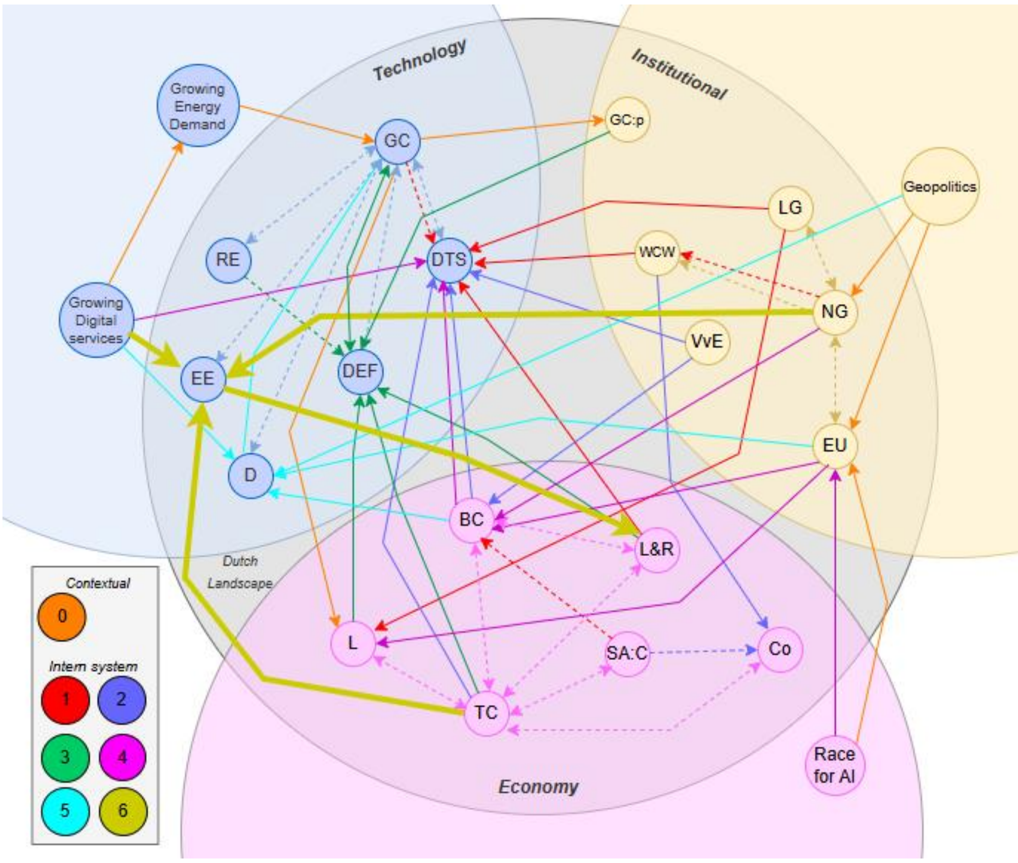

Figure 3.18. Build-up 7: Adding theme 6 relations to the pattern model (yellow)

Linking the complex themes to the pattern model figure leads to the final complex figure seen in Figure 3.19. In this figure, the blue notes are the technical aspects, as discussed in 3.1, the yellow notes are the Institutional aspects as discussed in 3.2, and the pink nodes are the economic aspects as discussed in 3.3. This Chapter has shown that the technical, institutional and economic aspects are linked, among themselves, but also with each other. The contextual relationships providing the context (0) and the internal system themes (1-6) as discussed in this section provide additional connections between the notes. This figure shows a part of the complex situation in which data centres and the other stakeholders need to operate. Important discussed themes are heat recovery, public perception, contributing to the grid, investment climate, decentral development and efficiency. These themes will be used within later Chapters, providing a basis as transition grounds. The themes help to develop potential pathways in Chapter 5 *Potential Pathways* and roles for data centres and policy incentives within Chapter 6 *Roles for Data Centres and Policy Incentives*. However, first the next Chapter *Social Acceptance,* will elaborate on Social Acceptance, which plays an additional important role for data centres.

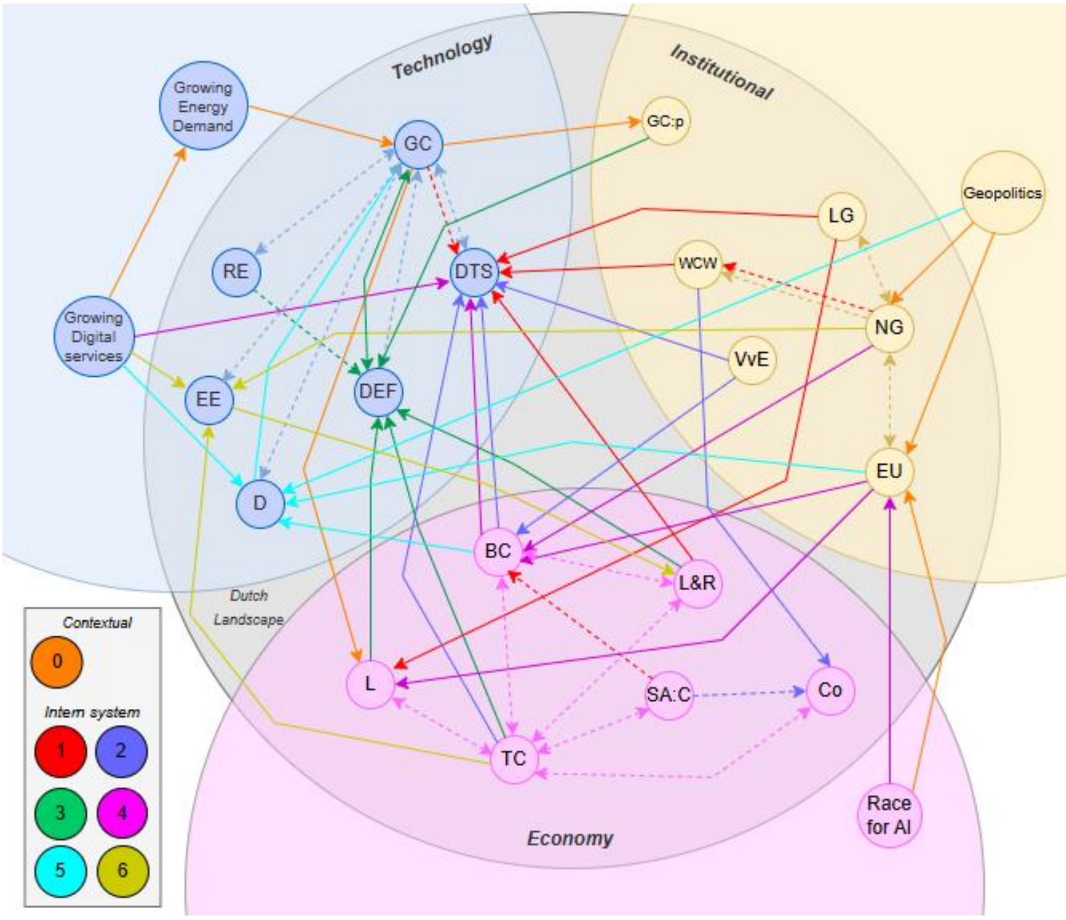

Figure 3.19 Final Pattern Model

Chapter 4: Social Acceptance

The goal of this Chapter is to determine to what extent social acceptance will influence the creation of sustainable solutions for data centres to function as intermediaries in the energy sector in the Netherlands. To provide more understanding of the social acceptance for data centres, a comparison will be made with the social acceptance for wind energy projects. This Chapter therefore will contribute to answering the second sub-question:

To what extent can the concept of Social Acceptance be used to analyse the impact of social acceptance for data centres in the Dutch energy system and the formulation of socially accepted futures?

The basis for this comparison is outlined within section 2.5 *Social Acceptance of Renewable Energy.* In which the framework is explained and applied on wind energy projects. After, the social acceptance points from Wüstenhagen et al. (2007) and Ellis et al. (2023) are discussed. Section 4.2 *Social Acceptable Future Scenarios* highlights the different ideal future scenarios per stakeholder group. Which will provide a basis for developing the future pathways within the next Chapter.

4.1 Social Acceptance for Data Centres

Section 2.5 *Social Acceptance of Renewable Energy* has discussed many different aspects of social acceptance of wind energy in the Netherlands and some nearby countries. The goal of showing this, is to provide a basis for possible aspects that will influence the social acceptance of Dutch data centres, as little literature is already available on this topic. It is likely to be assumed that some aspects of social acceptance for wind energy will be comparable as for data centres. Aspects like landscape pollution, NIMBYism, communication, financial means, etc. Therefore, the social acceptance of wind energy is used as an example so that it can be compared with the situation for data centres. Like in section 2.5, this section will be guided by the concept from Wüstenhagen et al. (2007) and the extension from Ellis et al. (2023).

The pattern model drawn up in Chapter 3 *Defining the Pattern Model,* is used as an outline of the situation in which data centres operate. From this outline, the extent to which social acceptance affects data centres is investigated. This means that aspects not included in the pattern model will not contribute to the social acceptance of data centres. However, this is a complex and yet simplified version of reality, which means that in practice other components could also play a role. The interviews, and attendant events, provide insight into several important lessons about social acceptance for data centres. A visual representation of this can be seen in Figure 4.1. This section touches upon the three aspects from Wüstenhagen et al. (2007) and Ellis et al. (2023).

First, **Social Political acceptance**, consists of a negative perception for data centres, political reluctance, policy and regulatory bottlenecks, atomising relationships and restrictions by energy policy. People are often not well-informed about what goes on in data centres and mainly see the high energy consumption[131]. Large US companies have contributed to a damaged industry's image by promises of heat utilization that were not kept[132]. In addition, politicians are reluctant, and municipalities, governments and grid operators were sceptical about data centres for a long time[133]. Policymakers sometimes seem to take a wait-and-see approach to innovations in the ICT sector when implementing policy around data centres[134]. This leads to bottlenecks in policy and regulation, currently a lot of fragmented legislation hinders sustainable solutions[135]. Political acceptance also involves shifting attitudes. Some municipalities and governments are starting to take a more positive view of data centres, seeing the potential of sustainable integration[136]. Last, there are limitations due to energy policy. Current policy can hinder the effective use of residual heat from data centres, for example the maximum energy

131 Event EnergyLab Zuid-Oost

132 Interview Consultant1

133 Interview Data centre branch

134 Event Webinear data centers in the MRA

135 Interview Province Noord-Holland

136 Interview Municipality Diemen1; Interview Municipality Diemen2; Interview Municipality Diemen3

consumption of 70MW and a maximum surface area of 10 hectares for a data centre lowers the potential of residual heat use on a larger scale[137].

Second, **Community acceptance**, this is mainly about resistance to infrastructure, lack of involvement, NIMBYism and the importance of communication. Connecting homes to heat networks meets resistance from residents, homeowners and tenants, mostly due to uncertainty about costs[138]. For projects in existing buildings, support from local residents is essential. In addition, there is a lack of involvement, renters and homeowners in VvE's are often less involved in decision-making on sustainability[139]. The complex decision-making process within VvE's makes it difficult to implement changes. Even local initiatives like MeerEnergie in Middenmeer have to work hard to get the number of participants high enough for a lucrative business case[140]. In addition, the NIMBY-problem plays a role. This was also highlighted in the analysis of wind energy, the NIMBY-problem creates an obstacle in data centres project realisation. For example, the proposed Meta (Facebook) data centre near Zeewolde was cancelled due to, among other things, the local NIMBY opposition[141].

Third, **Market acceptance**, which is influenced by an uncertain business case, high costs, competition from heat sources, financing of data centres and the potential of AI. An uncertain business case for heat networks arises from a lack of demand for heat networks from society, partly due to financial aspects and image[142]. Uncertainty about off-take and changing regulations make investment in heat networks risky. In addition, infrastructure costs are high, building heat transmission lines is costly. Uncertainty about who should pay for the costs of this development and the disconnection of heat from data centres reduces market acceptance. There is also competition from other (sustainable) heat sources such as geothermal heat, this can be seen as more attractive, because this does not depend on the high energy consumption of industry[143]. Individual heat pumps are an alternative to heat grids, which can further reduce the business case for collective heat networks[144]. Investors expect returns and contributions to green or social goals[145]. Data centres sometimes have a harder time in this than, wind farms, because their social contribution is less directly visible[146]. The negative perception of data centres as large energy consumers might hinder financing. Data centres can contribute to this by providing more factual insight into their social impact[147]. Finally, the rise of AI could lead to more and potentially higher-temperature heat, which could increase the economic attractiveness of reuse[148]. However, the business case remains a crucial factor for adoption of sustainable technologies within data centres.

The big difference in **time dynamics** between wind energy projects and data centres, is the Collective Heat Act (WCW), the rise of AI, the race for AI and geopolitical relations. The acceptance of data centres and heat projects is not static and changes over time, depending on successful projects, changing legislation and public opinion. The delay in the Collective Heat Act (WCW) currently creates uncertainty and can negatively affect the acceptance of heat networks[149]. In addition, the rise of AI makes Europe want to compete with the US and China[150]. This will cause a greater or lesser degree of investments in data centres and contributing technologies. Geopolitical relations can change this. If the Netherlands, or Europe, wants to become less dependent on foreign companies, investments will have to be made to a greater or lesser extent.

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137 Interview Consultant1

138 Interview MeerEnergie

139 Interview VvE

140 Interview MeerEnergie

141 Interview Consultant1

142 Interview MeerEnergie; Interview Firan, Interview AMS Institute

143 Interview Liander2

144 Interview Liander1; Interview Liander2

145 Interview Investment company

146 Interview Investment company

147 Interview Investment company

148 Event Data Could energy & ESG

149 Interview Municipality Diemen3

150 Event Data Could energy & ESG

Scale dynamics take place at three different levels, local, mesopolitical and macroeconomic. Local acceptance is strongly influenced by concrete projects and the direct impact on the living environment. The resistance to the Meta data centre in Zeewolde is an example of this. At the level of governance and institutions, policies of municipalities, provinces and the national government play a crucial role. The lack of clarity around the Collective Heat Act (WCW) on a national level affects the realisation of local heat projects[151]. Last, the competitive position of the Netherlands as a data centre hub compared to other countries also plays a role here, a bigger scale means a mostly better competitive position[152].

Power dynamics are mostly influenced by large companies and the role from the government. Large US data centres have sometimes made decisions, which has damaged local trust[153]. Developers and investors have significant influence over project outcomes and can prioritise financial interests over community interests. Besides this, the government can influence power relations and better safeguard local interests through legislation, regulation and financial incentives. The debate on the ownership of heat networks, at least 51% owned by the government under the coming Collective Heat Act (WCW) is an example of this[154].

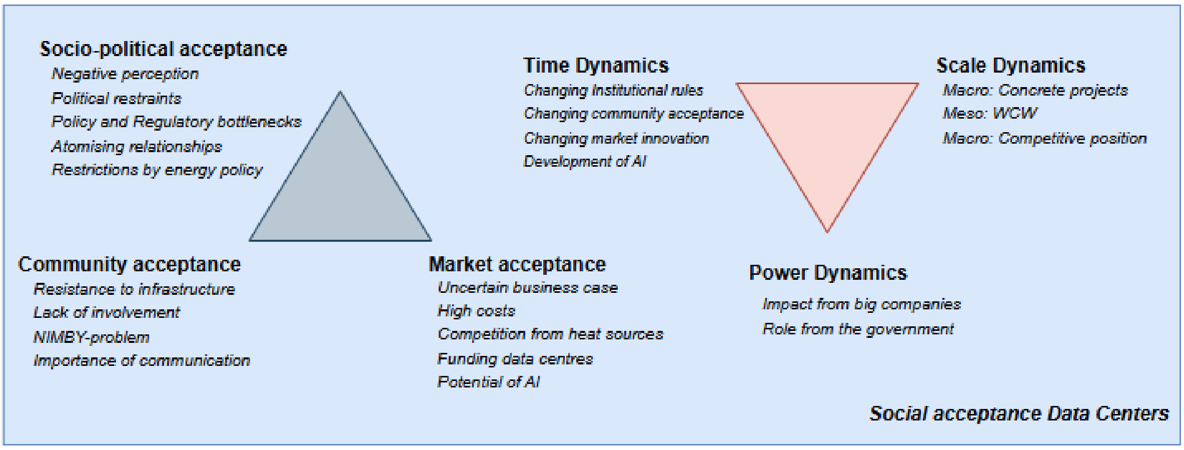

Figure 4.1 Overview Social acceptance data centres according to interviews and attended events

In short, social acceptance of data centres in the Netherlands is complex and influenced by a combination of factors at socio-political, community and market levels. As with wind energy, perceptions, policy, economic feasibility and the level of involvement of local communities play a role. In the coming years, developments around the Collective Heat Act (WCW), the growth of AI and the extent to which data centres and governments are able to effectively communicate the benefits of heat utilisation might determine the further social acceptance of data centres in the Netherlands.

This is important to take into account when developing future pathways, within the next Chapter. As seen in this analysis, creating a socially acceptable situation is complex and depends on several factors. Different stakeholders will also have different views towards what they see as socially acceptable. Therefore, the next section will look at the socially desirable situations of different stakeholder groups.

4.2 Social Acceptable Future Situations

A socially optimal situation is outlined for the following stakeholder groups: Data centre operators, Municipality and there citizens, Grid operators (heat/electricity) and the Amsterdam data hub. These groups are chosen because the interviews and events revealed the clearest differences between these groups, with regard to socially desirable situations. By starting with outlining what these different groups see as ideal, the next Chapter can outline where friction between their desired paths occur. Other important stakeholders like the national government, regulatory institutions, and the European Union and countries are left out here. This is chosen

[151] Interview Municipality Diemen3; Interview MeerEnergie; Interview Firan; Interview AMS institute

[152] Event Data Could energy & ESG; Interview Data centre branch

[153] Interview Consultant1

[154] Interview MeerEnergie; Interview Firan

because those instance determine or implement policy with the aim of creating a socially ideal situation, most of this research focuses on creating policy advice for them.

Data centre operators

Based on the interviews, an ideal future for *data centres* in the Netherlands should entail a clear government vision, recognition of societal value of data centres, sustainable energy supply to data centres, a circular economy, and ultimately, reuse of heat. In an ideal future, high demand for data centres facilitates investments, with the market calling for extensive expansion[155]. To achieve such outcome, it's essential for the government to have a clear, long-term vision integrating digital infrastructure and energy transition policies[156]. This means having clear long-term laws and regulations that promote data centre development in the Netherlands. Streamlined permit processes and stable, supportive regulations, such as a definitive and workable Collective Heat Act (WCW), encourage investments in sustainable data centre solutions and heat networks[157]. Policies should consider the growing energy needs, locations, and availability of grid connections.

With this clear government vision, the societal value of data centres is widely recognized and appreciated[158]. There's open communication about their essential role in the digital economy and their positive contribution to economic development within a sustainable society[159]. Negative perceptions regarding energy consumption and space usage are reduced through transparency and concrete actions.

One of these actions could be that data centres operate entirely on 100% verifiable, additional renewable energy. This means purchased green power genuinely contributes to building sustainable energy capacity[160]. Data centres aim for minimal energy consumption through advanced cooling techniques, resulting in a low PUE (Power Usage Effectiveness). Additionally, data centre operators adopt a circular economy approach, maximizing hardware lifespan and minimizing. They strive for optimal server capacity utilization and may adjust energy usage based on the availability of affordable renewable energy[161]. Besides this, data centres are designed and operationally set up to seamlessly integrate new technologies like AI, with flexible cooling solutions and energy management strategies adapted to increasing power density and heat generation[162]. There may be a shift toward a more decentralized digital infrastructure with smaller, strategically placed data centres[163].

Once these ideal future conditions are met, data centres explore large-scale utilization of heat for heating homes, businesses, and sectors like horticulture. This is facilitated by strategically locating data centres near heat demand areas, well-developed and reliable heat network infrastructure, and clear legal and financial frameworks that facilitate cooperation between data centres and heat companies[164]. Efficient cooling systems raise the heat to a higher temperature, reducing the energy needed to upgrade it for heating purposes.

Municipality and its Citizens

An ideal future for data centres based on the views of a municipality and its citizens means that data centres are a sustainable and integrated part of the community[165]. These facilities, which are essential for our digital lives to powering the internet, hospitals, and social media, will operate with a strong focus on environmental responsibility. First, Data centres will be powered by 100% renewable energy, directly contributing to a greener

155 Event Data Could energy & ESG

156 Interview Data centre branch

157 Interview Switch Datacenters1

158 Event Data Could energy & ESG

159 Interview Investment company

160 Event Workshop EML

161 Event Data Could energy & ESG

162 Interview Asperitas

163 Interview Consultant1; Interview Data Steward TU Delft3

164 Interview Municipality Diemen3

165 Event Workshop EML

future. This means purchased green power directly contributes to building sustainable energy capacity[166]. Data centres aim for minimal energy consumption through advanced cooling techniques, resulting in a low PUE (Power Usage Effectiveness). Besides this, data centres operators will be careful with resource availability to lower their energy consumption and minimize water use. With that said, the growth of new data centres is small, only attracting smaller scale data centres for Dutch purposes with economic opportunities[167]. The presence of innovative and sustainable data centres can attract further investment and create new jobs in the region[168]. Adding that data centres will be transparent about their operations and benefits, fostering greater understanding and acceptance within the community. Projects will be developed with consideration for the local environment and community needs[169].

A key benefit for citizens will be the large-scale reuse of heat generated by the data centres to warm homes, schools, and local businesses through efficient district heating networks[170]. This can potentially reduce reliance on traditional heating methods and contribute to lower energy bills. Initiatives like the MeerEnergie in Middenmeer will be explored more often and provide community faith in potential heating projects[171]. All these projects contribute effectively to a more affordable and sustainable energy system within the municipality[172].

Last, national government is actively involved in realising projects with a clear vison of sustainable and affordable energy[173]. This can be seen in a realised Collective Heat Act (WCW) and financial resources used to get projects off the ground.

Grid Operators (Heat Operators/Electricity Gird operators)

The ideal future envisions data centres as key partners in a stable and sustainable energy system. This collaboration offers significant opportunities for lowering grid congestion at the moment and collaboration for future grid stabilization and an increasing energy demand[174]. The rise of AI will significantly increase the electricity demand of data centres. Careful energy planning and efficient grid infrastructure will be needed to accommodate this growth[175]. Besides this, the grid operators also face much grid congestion nowadays, meaning that there is little to no space and energy left to create additional grid connections and extensions. This is the first problem that needs to be fixed for grid operators[176].

While the current core business from data centres prioritizes data continuity, there is a potential for data centres with significant backup power capacity to contribute to electricity grid stability. This can be obtained by providing flexibility during peak demand or when renewable energy supply fluctuates[177]. This would require adapted regulations and economic incentives that ensure the reliability of the data centre's primary operations[178]. The possibility of using backup power to prevent grid congestion in regions like Noord-Holland highlights this potential[179]. However, current regulations often restrict the use of backup generators for grid services.

When this problem is dealt with, data centres will become reliable and significant sources of low-to-medium temperature heat suitable for district heating networks. Technologies like liquid cooling in AI-driven

166 Event Workshop EML

167 Interview Data Steward TU Delft2

168 Interview Data Centre Branch

169 Interview MeerEnergie

170 Interview MeerEnergie

171 Interview Firan

172 Event EnergyLab Zuid-Oost

173 Event Webinear data centers in the MRA

174 Interview Liander1; Interview Liander2

175 Interview consultant2

176 Interview Liander1; Interview Liander2

177 Interview Liander1; Interview Liander2

178 Interview consultant1; Interview consultant2

179 Interview Liander1; Interview Liander2

data centres might provide higher temperature heat, increasing efficiency for heat pumps[180]. Strategic location of data centres near heat demand and a well-developed heat infrastructure are crucial for maximizing this potential. The development of clear legal and financial frameworks, like the upcoming Collective Heat Act (WCW), is essential to facilitate these partnerships[181].

The Amsterdam Data Hub

The *Amsterdam Data Hub,* is not one stakeholder but represents the economic position of the data hub in Amsterdam as many data centres are located here and Amsterdam is well known for this. The ideal future for the Amsterdam data hub builds upon its existing strengths as a crucial digital infrastructure hub while embracing sustainability and addressing current challenges. Amsterdam can maintain its position by becoming a global leader in sustainable data centre operations[182]. This involves a strong commitment to energy efficiency through advanced cooling technologies and powering facilities with verifiable renewable energy sources. Adding that there is a strong need for more land and resources availability[183]. Data centres need to be prioritized for grid connections, the electricity grid needs to be expanded and reliable[184]. Collaboration with grid operators is essential to find solutions for net congestion, which currently limits growth. Exploring alternative connection models, like the closed distribution system implemented by EdgeConneX, and advocating for strategic grid upgrades are important steps[185]. Also, the development of a hydrogen backbone delivering clean and cheap hydrogen can contribute to creating more sustainable back-ups within the region[186]. The hub can drive innovation in flexible energy management and potential grid services, while ensuring the reliability of data centre operations. Exploring solutions like on-site renewable energy generation, which can contribute to a more resilient and sustainable energy footprint[187].

Besides this, the Amsterdam data hub can large scale implement heat utilization to become a more sustainable data hub. This requires strategic planning for data centre locations near heat demand, collaboration with grid and heat network operators, and advocating for supportive regulations and infrastructure development. Overcoming past challenges with heating projects, such as those in Amsterdam Zuid-Oost[188].

Last, the public perception needs to be enhanced. The Amsterdam data hub needs to actively communicate its essential role in the digital economy and its commitment to sustainability to the public[189]. Demonstrating tangible benefits like heat use might help improve public perception and secure social acceptance.

These four ideal situations already hint that there are aspects where stakeholders think alike, but there are also aspects where stakeholders have different interests. The next Chapter will elaborate on this while developing future pathways.

[180] Interview Municipality Diemen3

[181] Interview consultant2

[182] Interview Data centre branch

[183] Event Data Could energy & ESG

[184] Interview Data centre branch

[185] Interview EdgeConneX

[186] Interview Province Noord-Holland

[187] Event Data Could energy & ESG

[188] Interview AMS institute

[189] Interview Investment company

Chapter 5: Potential Pathways

With this Chapter, research phase two starts. Phase one created a complex pattern model in which technical, institutional and economic aspects as well as stakeholders interactions between them are presented. This Chapter explores possible future developments by outlining extreme contrasting pathways for the integration of data centres into the Dutch energy system. These pathways are not intended as exact predictions, but rather as structured explorations of what could happen under different conditions. They are based on findings from interviews, attended events, and literature analysis, and reflect current trends (pathway 1) and plausible shifts in governance, technology, and market dynamics (pathway 2,3,4). This will contribute to answering the third sub-question:

How can insights into the complex system contribute to the formulation of future pathways to obtain a sustainable energy system?

The purpose of creating these paths is to give insights into socially desirable pathways and the contradictions in the different stakeholder interests. Therefore, scorecards are created for each path showing how the different stakeholder groups, discussed in section 4.2 *Socially Acceptable Future Situations,* value the outcomes.

The paths are developed from a stakeholder perspective, as discussed in section 2.6 *Scenario Study,* incorporating the seven themes developed in section 3.4 *Stakeholder Interactions.* The themes are used to show where future transitions can take place. Besides this, the two stakeholder groups with the biggest disparity in interests, *data centre operators* and *municipality with their citizens*, will shortly be explained separately for their most accepted future path to highlight the differences.

In addition, a distinction is made between *desirable* situations and *feasible* situations. This Chapter will discuss the desirability of the future paths. Chapter 6 *Roles for Data Centres and Policy Incentives* will comment on this and further discuss the feasibility of the presented desirable pathway. This was chosen because the most desirable situations will have fewer restrictions in developing a future path. Including fewer constraints leaves more room for the complexity explained in the pattern model. However, it is not realistic for these future paths to be realised in this way, which is why the following Chapters will focus more on the feasibility of the future paths. Together, these pathways help to identify the key drivers, challenges, and opportunities for data centres to act within the Dutch energy system, attention to these opportunities will be paid in the next Chapter.

Pathway 1: Limited Integration and Continued Challenges

This first future pathway assumes a scenario in which the role of data centres within the Dutch energy system develops only to a limited extent in the coming years. Despite the technical potential and social opportunities, structural obstacles continue to hinder the integration of data centres into the energy system. Legal bottlenecks, slow policymaking and reluctance among both public and private parties ensure that existing challenges persist. This pathway thus reflects a continuation of the current situation, in which data centres mainly operate as large energy consumers, with limited social embedding.

The path shows what happens when essential preconditions for sustainability fail to get projects off the ground, cooperation fails, and innovative solutions remain small-scale or are not realised at all. This pathway serves as a reference point, not so much as a desirable outcome, but as a warning of what may happen if concrete action and policy direction fails to be implemented. A storyline of how this pathway looks like, can be read in figure 5.1.

*The first pathway entails fragmented policy and regulation, Limited heat recovery, a challenging public perception, data centres that cannot contribute to balancing the grid, remaining grid congestion, an unattractive investment climate, a niche decentral development, an average PUE for data centres above 1.2 and more AI use, that doesn't contribute to a higher output temperature of data centres. Within this pathway, the government is not taking any directing role in determining an energy planning for sustainable solutions, contributing to a **fragmented policy** and **regulation**.*

*Besides this, the technical potential of **heat recovery**, **remains limited**. Due to legal, financial, infrastructural, and logistical obstacles hindering large-scale deployment of heat recovery projects. The low temperature of residual heat in many existing data centres necessitates costly upgrading with heat pumps, which further complicates the business case and feasibility. The absence of heat networks, a connection to heat networks, and uncertainty about demand make investments risky. Slow decision-making regarding the Collective Heat Act (WCW) and the risk of monopolies delay projects.*

*Next, **public perception remains challenging**, data centres are still seen as major energy consumers with limited societal contribution. The lack of large-scale, successful sustainability projects reinforces this perception.*

*Additionally, **grid congestion** remains a bottleneck, the growing demand for electricity, partly due to the rise of AI, exceeds the capacity of the electricity grid. New data centres face challenges in connection, and existing data centres can be limited expanded. Alternative energy sources such as nuclear energy and hydrogen have long implementation times or are not yet cost-effective. Data centres remain hesitant to use their backup generators for **grid stabilization** due to continued risks. Which leads to little further development of data centre projects, and therefore to an **unattractive investment climate** for new data centres.*

***Decentral development** remains a niche, even with a possible societal trend towards decentralization of data, a potential for decentralized AI systems and smaller cloud infrastructures, large-scale colocation and hyperscale data centres remain dominant. Decentralized data storage in places like hospitals and universities remains a limited market.*

*The government tries to support **energy efficiency** measures by providing regulations to adhere to sustainability measures from the Recognised Measurements List (EML), However, this mainly creates paperwork, resistance from data centre operators, and little concrete action to sustainable innovations.*

*Last, AI leads to higher energy consumption and more complex cooling, the increase in AI applications requires more computing power and generates more heat. This results in higher energy demand and the need for more efficient cooling techniques such as liquid cooling. However, implementing liquid cooling in existing data centres is costly and complex. The higher residual heat temperatures from AI chips could potentially benefit heat networks, but it is uncertain whether this will actually lead to higher **output temperatures** in practice.*

Figure 5.1 Storyline Pathway 1

Different stakeholders will value certain aspects of these pathways differently, of which an overview can be seen in the scorecard in Figure 5.2. In green is indicated that the stakeholder likes the outcome, the stakeholder values it as an *important aspect*. Yellow indicates that a stakeholder values it as a *nice to have,* but does not see it as a main point. Orange states that the stakeholder does not care much about this aspect, and red means that the stakeholder face additional challenges in implementing this aspect. These scores are given based on interviews and events that were attended. Most of these relations are already described within Chapter 3 *Defining the Pattern Model.* Interesting from this figure is that all stakeholders groups experience additional challenges regarding grid congestion, and fragmented policy and regulations[190]. Besides this, data centres, grid operators, and the Amsterdam data hub value it as positive that decentralisation remains a niche. This is a two-piece result, on the one hand, decentralisation may cause more connections for relatively smaller data centres, creating a higher dependency on the low and medium voltage grid. In addition, decentralisation might not benefit the

[190] Event EnergyLab Zuid-Oost

business case for colocation and hyperscale data centres. Therefore, these stakeholder groups might benefit from the absence of large-scale decentralisation.

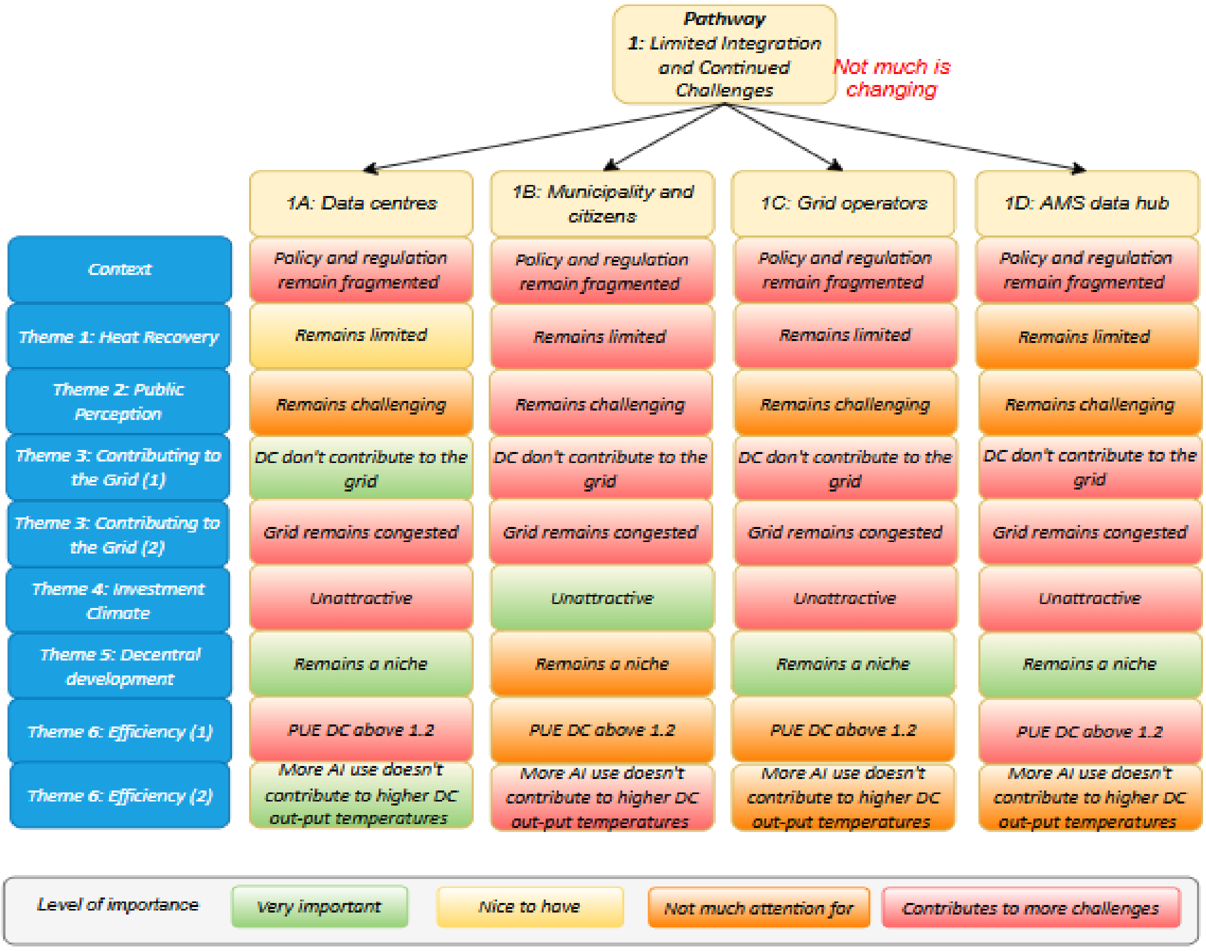

Figure 5.2 Scorecard pathway 1

The way stakeholder groups value pathway one shows that there is room for improvement, many stakeholders are dissatisfied with this outcome. Through the interviews with different stakeholders, it was possible to find out what stakeholder groups would like to see as an ideal future. For the stakeholder group *data centres* and *municipality and their citizen*, the differences between their ideal situations are the most apart. Therefore, additional attention will be paid to the differences between these two groups.

Pathway 2: Best Case Data Centre Operators

First, Figure 5.3 shows the most ideal future situation for *data centres*. This is also a scorecard showing how the other stakeholder groups value the ideal future path from the data centres. It can be seen that all stakeholders would like to see a *proactive government with integrated policies.* In addition, *more space on the grid,* where new initiatives can have a grid connection, is important to all stakeholders as well, as this ensures new (sustainable) projects. However, there are three points where fiction occurs with other stakeholder groups. First, *data centres contributing to balancing the grid*, is helpful for most stakeholders providing more room for adjustments and a better reputation[191]. However, currently this is not possible for data centre operators[192]. Second, data centre operators like to see an attractive investment climate with cheap energy, easy permits and a trusted governmental policy. On the other hand, citizens see this differently, they like to see a decrease in data

[191] Interview Liander1
[192] Interview Switch Datacenters1

centre growth[193]. Last, municipalities also like to see a higher out-put temperature from data centres, which can help to increase the business case for heat networks. However, this provides friction with a decreasing data centre efficiency and thus higher a PUE, and shorter product lifecycle[194].

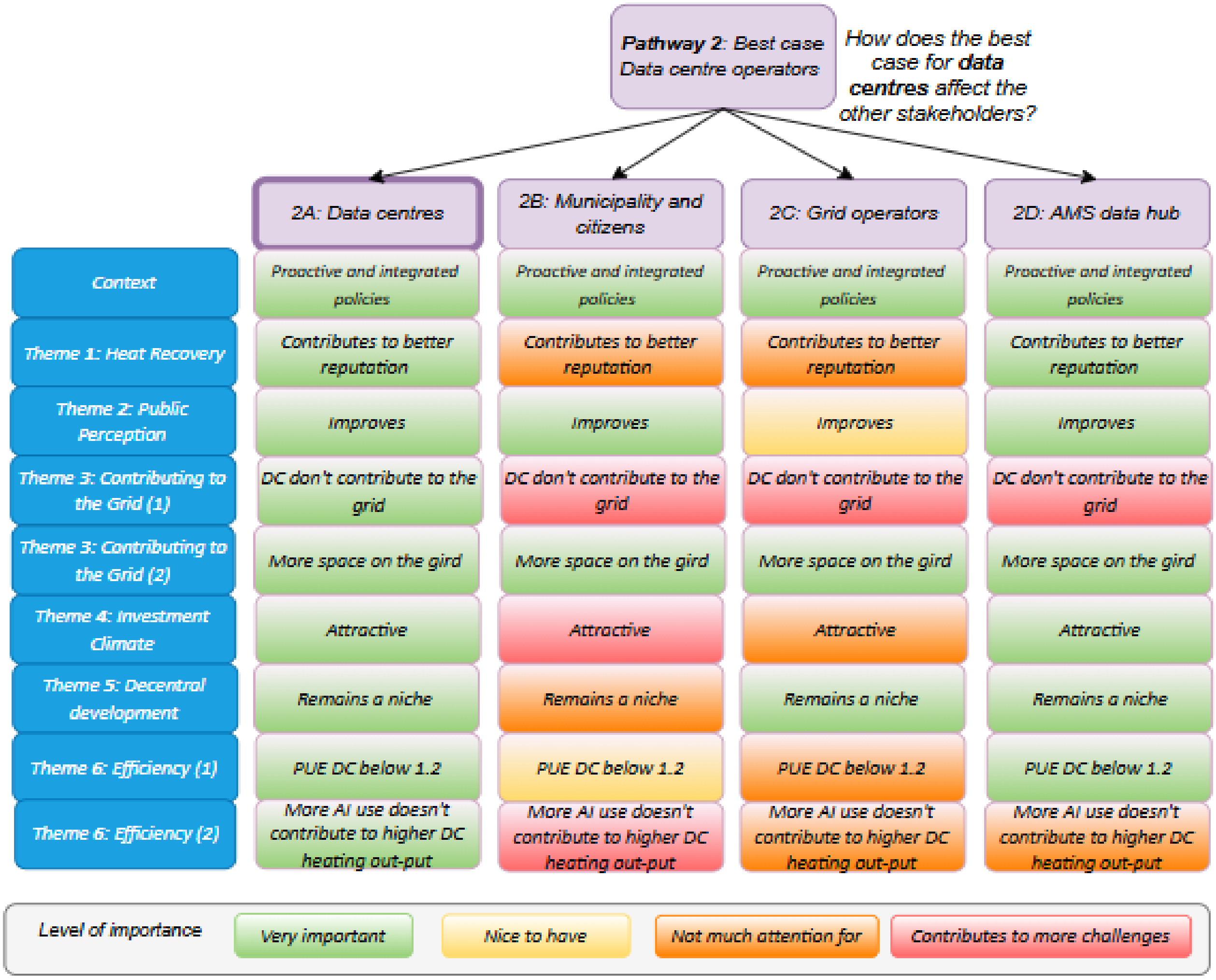

Figure 5.3 Scorecard best case data centres

Pathway 3: Best Case Municipalities and Citizens

Figure 5.4 shows a scorecard for the most ideal future situation for *municipalities and their citizens.* It can be seen that all stakeholders would like to see a *proactive government with integrated policies*, *more space on the grid*, and value an improved public perception. However, there are also points of friction within this pathway, like municipalities that are in favour of data centres to contribute to grid stability, which data centres currently cannot provide[195]. Municipalities that want to limit the growth of new data centres, which other stakeholders, not admire. Municipalities and citizen might be in favour of a decentral development leading to fewer dependencies on foreign companies. The current geopolitical situation can contribute to increase this incentive. Last, municipalities like to see an increased temperature from data centres, providing a better business case for heating networks. However, this can be suboptimal for data centre operators.

193 Event EnergyLab Zuid-Oost
194 Event Workshop EML
195 Interview Switch Datacenters1; Interview Municipality Diemen3

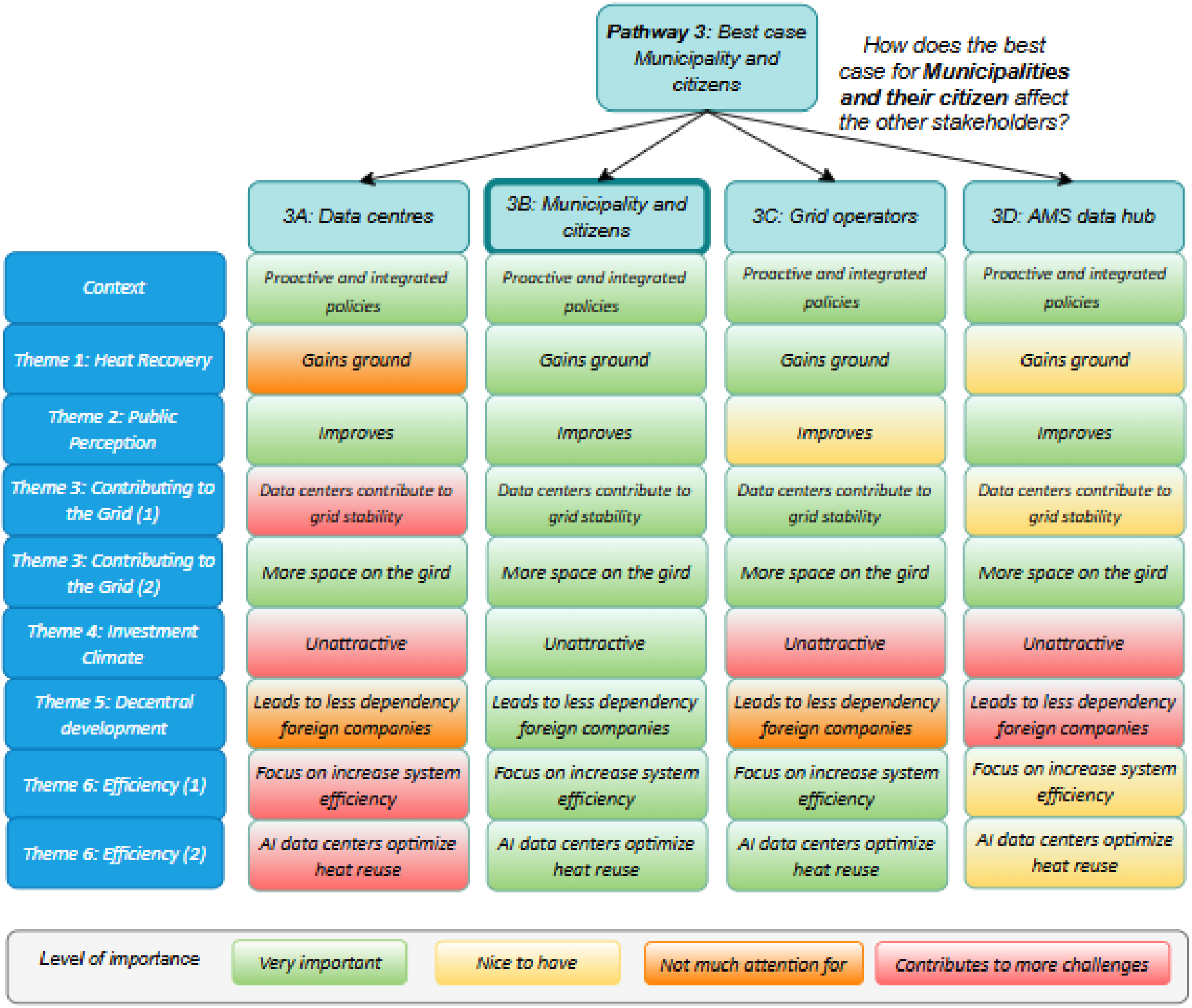

Figure 5.4 Scorecard best case Municipality and their citizens

Pathway 4: Socially Desirable Situations

In this final pathway, a future is envisioned in which data centres have successfully become an integral and accepted part of the Dutch energy system. The transition towards sustainability is not only technically enabled but also actively supported through consistent, long-term policy, improved cooperation among stakeholders, and growing societal awareness of the role data centres can play. In this pathway, data centres contribute significantly to multiple aspects of the energy transition.

The combination of different desirable situations lead to the overall socially desirable situation. Because different stakeholders have different perceptions of what is socially desirable and what is not. This pathway is based on the four preferences per stakeholder group as described within Chapter 4.2 *Social acceptable future situations*. To be able to create this, the optimal future scenarios, are used as a basis for the desirable situations. This creates the overall socially desirable situation of which a storyline can be read in figure 5.5.

Within the Socially Desirable pathway, government pursues a proactive and integrated policy, heat recovery gains significant grounds, public perception improves, data centres contribute to grid stability, there is more space on the grid, an attractive investment climate, more decentral development, and higher intern and system data centre efficiency. Within this pathway, the government is taking a directing role, providing a ***proactive and integrated policy****. This leads to less risks and uncertainties among stakeholders, providing guidelines for stakeholders to act sustainable within the energy sector.*

Besides this, ***heat recovery,*** *gains significant ground. This is made possible by clear legal frameworks, financial incentives from the government and a new Collective Heat Act (WCW) effective since January 1st, 2026, facilitating the development of heat networks. Municipalities take a more active role in energy planning and coordinate the construction of heat infrastructure near data centres. Innovative collaboration models emerge between data centres, heat companies, and consumers. Technological developments in liquid cooling lead to higher and more constant residual heat temperatures, increasing the efficiency of heat pumps. Data centres and heat companies find feasible models for heat guarantees and cost sharing.*

Resulting in an improved, ***public perception.*** *Active communication and greater transparency from the data centre sector regarding its contribution to the digital economy and sustainability efforts are critical. Successful data thermal projects and a more active role in* ***stabilizing*** *the* ***energy grid*** *contribute to a more positive image.*

By stabilizing the energy grid, ***more space on the grid*** *becomes available. Data centres contribute to grid stability, due to changing legislation that enables flexible deployment of backup power, diesel generators with HVO or hydrogen, from data centres for grid balancing. Clear compensation mechanisms are introduced for data centres providing these services. Smarter collaboration between grid operators and data centres leads to more efficient use of the existing energy network. Additionally, data centres invest in local energy generation, like the investigation of SMR, wind, solar, or hydrogen cells, to reduce their dependence on overloaded networks and contribute to local energy supply.*

These developments lead to an ***attractive investment climate*** *for new data centres. A good investment climate means that companies like to establish themselves in the Netherlands, which strengthens the Netherlands' economic position. In addition, the investment climate is sustainable in the longer term, meaning that the growth in the number of data centres is not at the expense of sustainability goals that the government wants to achieve. This is due to energy saving efforts and sustainability projects getting off the ground.*

Thus, data centres grow, but not only in size, ***decentralization gains ground*** *as well. The development of decentralized AI systems and the market growths for smaller, regional cloud infrastructures leading to a more dispersed data centre landscape. This could reduce pressure on the central electricity grid and increase opportunities for local residual heat utilization. Cooperative models for local data centres emerge, and research continues on how their heat can be reused on a small scale.*

Last, besides an ***improvement*** *of* ***internal energy efficiency*** *from a data centre,* ***AI data centers optimize heat temperature****. An optimal energy efficiency from data centres together with a higher temperatures from AI chips enables more efficient heat utilization. New data centres are efficiently designed with maximum heat recovery in mind. Heat networks, together with heat pumps, can handle the temperature profiles of AI data centres to actively use the heat from data centres.*

Figure 5.5 Storyline Pathway 4

It is likely that the actual future will be a combination of scenarios, with some aspects of integration and sustainability making progress while others are hindered by persistent challenges. The pace of technological developments, the effectiveness of new policies and regulations, such as the Collective Heat Act (WCW), and the willingness to cooperate among various stakeholders will determine the ultimate direction. Since this future situation would be socially desirable, the points where friction may occur will be discussed in more detail.

Figure 5.6, shows a scorecard of how the stakeholders value this pathway, as can be seen, all stakeholders benefit from a *proactive government with integrated policies* and *more space on the gird.* This means that the government takes a leading role, implementing clear and long-term policies so that stakeholders know what to expect and how they can respond effectively. Besides this, the gird is effectively expanded, creating room for additional projects.

On the other hand, for municipalities and grid operators, it is advantageous if *heat, from industry, becomes an important heat source*, as this can reduce costs and help to prevent grid congestion. Data centres are willing to contribute to this, as long as it does not negatively affect their business model. Therefore, the development of higher-temperatures could be beneficial, allowing the temperature of the heating network to be raised without, or with minimal, additional heat sources or heat pumps.

Decentralisation is an emerging development, and it remains to be seen how it will unfold in practice. If it helps counter the "*big black box*" culture, municipalities are likely to be in favour[196]. However, it also brings increased complexity in terms of connections, logistical arrangements, and maintenance.

From a technical perspective, data centres could contribute to *grid stability*, which would help solve issues for grid operators. However, at present, data centres see few real opportunities to contribute effectively, due to supply risks and regulatory restrictions[197].

Improving *public opinion* about data centres is important for all stakeholders in order to build greater support for business cases, whether for the expansion of data centre projects or for the use of district heating networks.

Finally, most parties benefit from a lower intern energy efficiency from data centres (determined by the PUE), as this means that data centres consume less energy, this contributes to sustainability goals. However, the use of technologies such as heat pumps or increasing temperature due to more AI use, can potentially increase a data centre’s PUE.

[196] Event EnergyLab Zuid-Oost

[197] Interview Equinix

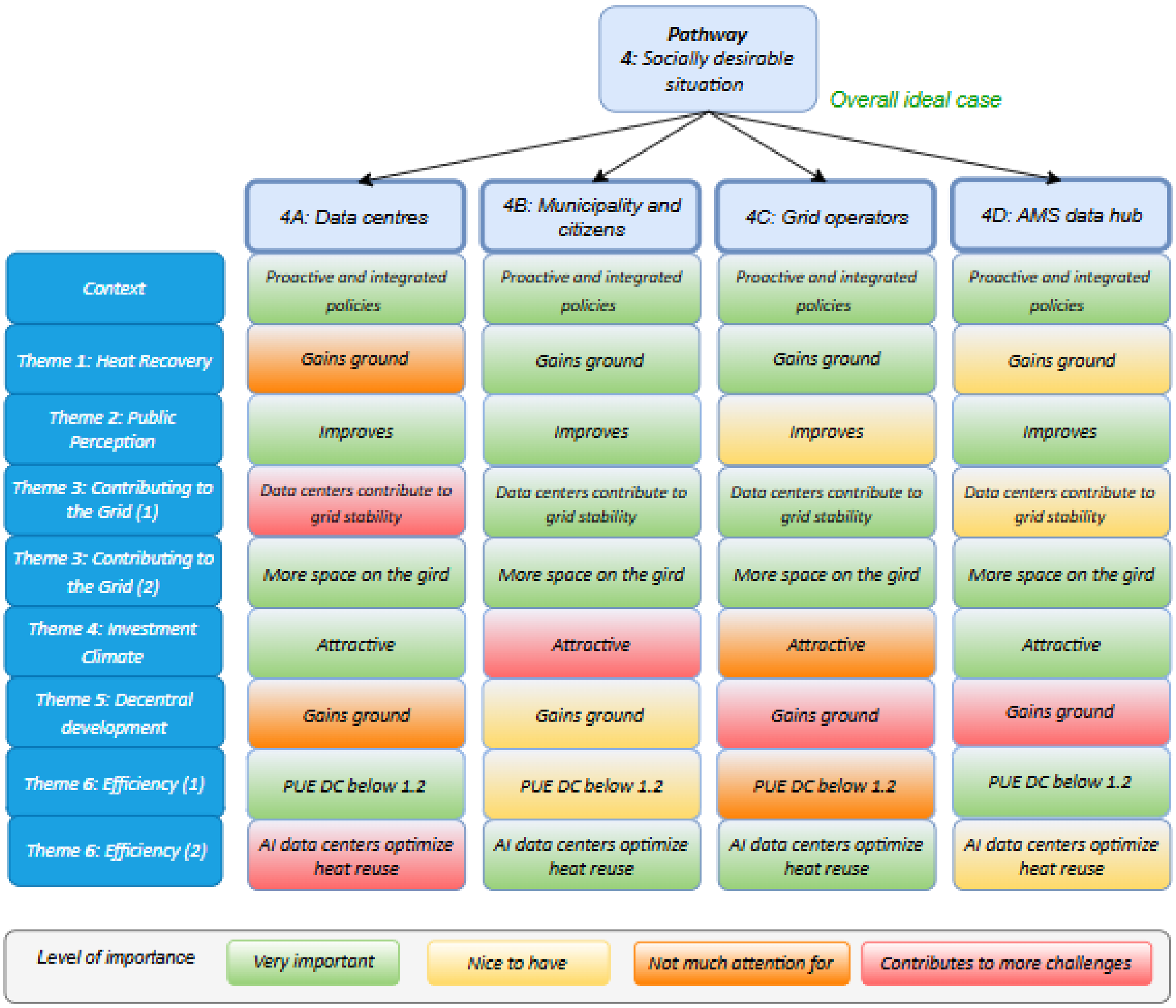

Figure 5.6 Scorecard Pathway 4

This Chapter has shown two main contrasting future paths, of which a summary can be seen in figure 5.7. The pathways were based the themes discussed in section 3.4 *Stakeholder Interactions.* These themes provided a basis of where transitions could occur. It is shown that pathway 1 weakens the themes and thus ensures that sustainable solutions are not or little realised. On the other hand, pathway 4 shows how the themes can be strengthened, allowing sustainability projects to be developed. Different stakeholders can play crucial roles to realise certain themes. The explanation of the different themes, in section 3.4, already shows that different stakeholders are involved in different ways. Because of time and resource constraints, this research only focuses on the role of data centres. However, it is also interesting to investigate how the other stakeholders can take steps to realise sustainability projects.

Given the complexity of the problem, no single pathway is optimal, as multiple stakeholders are unlikely to be entirely satisfied. Pathway 4: *Socially desirable situation*, is the most socially optimal situation, to achieve this, several stakeholders will have to make concessions. The next Chapter will therefore discuss what *data centres* can do to contribute as an intermediary within this future pathway, and how policy incentives can stimulate this.

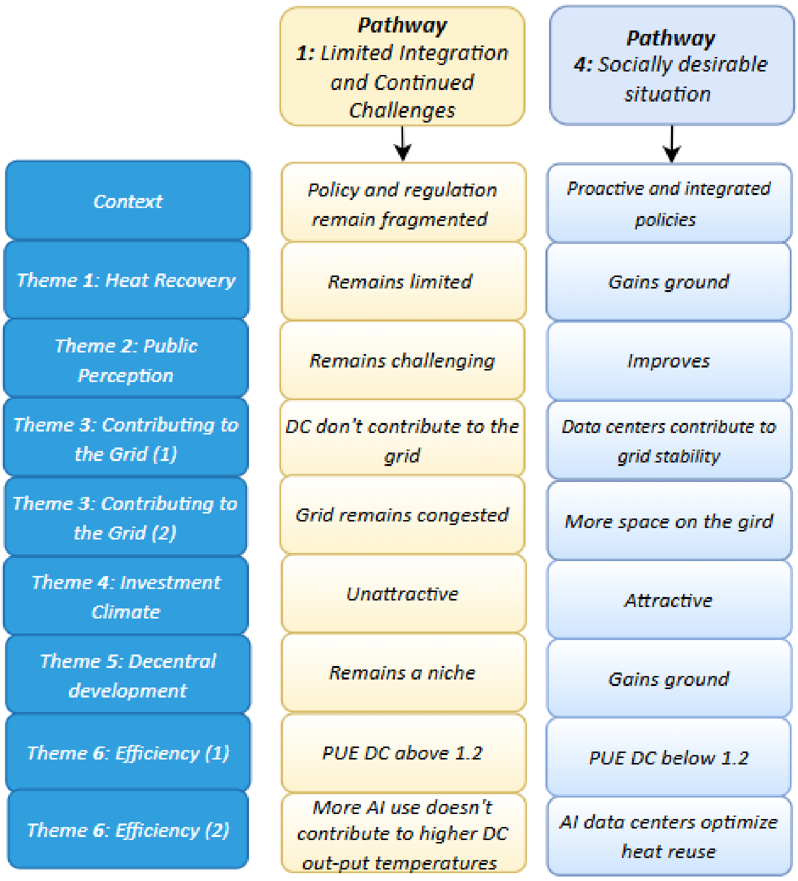

Figure 5.7 Summary of the differences between pathways 1 and 4

Chapter 6: Roles for Data Centres and Policy Incentives

Building on the socially desirable future pathway outlined in Chapter 5 *Potential Pathways*, this Chapter addresses the last research phase. Attention will be paid to how data centres in the Netherlands can contribute more actively as an intermediary in the energy transition, and the policy incentives needed to create these roles. While investigating this, the fourth and fifth research questions will be answered.

Data centres are often viewed primarily as large energy consumers, but they hold a unique potential to support sustainability goals through energy efficiency, flexible electricity use, residual heat recovery, and even decentralised digital infrastructures. Whether or not this potential is realised depends on technical capabilities, institutional support, regulatory frameworks, and public perception.

This Chapter first addresses the intermediary role for data centres in section 6.1 *Potential Roles for Data Centres*. The role for data centres within the energy sector lies mainly in the energy consumption of data centres and passing on residual products such as heat or unused energy. However, the role is not just about energy but also intermediate with regard to information and collaboration. This aims to answer the fourth sub-question:

Which possible intermediary roles can be foreseen for Dutch data centres to contribute in the future Dutch energy system?

This is done by presenting seven intermediate roles that data centres could play. These roles aim to reach data centres to optimize energy efficiency, contributing to grid stability, supplying residual heat to heating networks, improve public perception, supporting decentralised data processing, advocating for integrated policymaking, and taking measurable steps towards sustainability. Each role is described in terms of its added value and obstacles which needed to be overcome before implementation. Although discussed individually, these roles should not be seen in isolation.

By outlining these future roles, data centres face technical, institutional and economic limitations, like grid congestion, uncertain policies and business models, knowledge gaps, or negative attention. However, there are specific opportunities for data centres to add system value and help to address shared energy challenges. This is why section 6.2 *Policy Incentives,* explains eight designed interventions to realise the intermediary roles for data centres. This will help answer the fifth sub-question:

What policy instruments can be useful to create an acceptable Data Centre role within the Dutch energy system?

To give thorough and clear advice, research needs to be done on how these policy incentives are handled in different governmental bodies. However, this is not possible within the time span of this study. Based on what is discussed in the previous sub-questions, advice is given on the *directions* for further research on policy incentives.

These interventions are designed to improve social acceptance of data centres, framed through the three dimensions identified by Wüstenhagen et al. (2007) over the dynamics from Ellis et al. (2023). Aiming to support the transition toward the socially desirable pathway (4) presented in Chapter 5 *Potential Pathways*. Therefore, this Chapter ends with an explanation of how the roles and policy incentives might influence social acceptance for data centres in section 6.3 *Connection to Social Acceptance.*

6.1 Potential Roles for Data Centres.

This section provides a detailed overview of the seven different roles data centres could play within the Dutch energy sector. These seven roles are connected to the different themes, discussed in section 3.4 *Stakeholder Interactions.* Table 6.1 gives an overview of the seven different roles, the gaol of realising this role connected to the different interaction themes, advantages, and obstacles. Together, the obstacles, are the reason why these roles are currently not being fulfilled. Therefore, the next section will look at the policy incentives needed for the roles to be applied.

First role, aiming to optimising energy efficiency and sustainable energy use

The first step towards sustainability lies in data centres continuously striving to reduce their PUE by implementing energy-saving measures. This can be done through a diverse set of actions already included in the Recognized Measurements List (EML), which continues to evolve with advanced techniques[198]. The benefit is clear, lowering the PUE also reduces overall energy consumption, thereby directly improving the environmental footprint of the data centre. However, data centres are still hindered in this regard, often lacking clarity on cost-effective ways to contribute, and limited by paperwork, which prevents them from actually taking action[199].

Purchasing sustainable energy is a next step, data centres can utilise available space for on-site generation, like implementing solar panels on the rooftop or parking-lot. Even though this seems beneficial, this will only marginally support total sustainability goals[200]. An impactful approach is investing in large-scale renewable projects, which stimulates broader energy investment through increased demand[201]. Unfortunately, many projects are currently on hold due to grid connection limitations[202].

In addition, data centres could contribute to renewable energy integration by actively buying energy which increases the production of green energy[203], by taking part in renewable energy projects or by generating their own green energy[204]. For example, combining renewables with energy storage, such as batteries or hydrogen, can allow for a more autonomous energy supply. Although technically feasible, the current costs are significantly higher than traditional grid power[205]. Small-scale pilots involving hydrogen as a sustainable backup are ongoing, but the lack of national hydrogen infrastructure makes large-scale implementation unfeasible for now[206].

Second role, aiming to improve public perception and social acceptance

After taking the initial steps toward sustainability, data centres can communicate more actively about their critical role in the digital society and their sustainability efforts. It is important to highlight their broader societal value, such as enabling digitalisation and reducing emissions in other sectors[207]. Public awareness of what data centres are and what they do is still limited, leaving a major opportunity for the sector to better communicate its function. A large-scale (online) campaign might help familiarise the public with the concept. Besides this, successful heat projects can help shift the negative perception from data centres being seen as heavy energy consumers. However, in practice, restoring public trust can be challenging (Greenberg, 2014).

Third role, aiming to apply heat recovery into district heating networks

Data centres can contribute to a sustainable district heating systems by providing heat, reducing dependence on fossil fuels. This requires investment in technologies that can increase the heat temperature, such as heat pumps. However, this may increase the PUE of the data centre[208], something that is currently being actively opposed. Collaboration with heat providers and municipalities is necessary to build the infrastructure, pipes, transfer stations, residential connections, and to arrange agreements for heat delivery and uptake. Uncertainty surrounding the Collective Heat Act (WCW) and concerns over monopolies must be addressed before this will be realised[209]. Besides this, the location from the data centre, is crucial, for heat recovery. Future location decisions

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[198] Event Workshop EML

[199] Event Workshop EML

[200] Interview Equinix; Interview Switch Datacenters1

[201] Event Workshop EML

[202] Interview Province Noord-Holland

[203] Interview Omgevingsdienst Noordzeekanaalgebied

[204] Event Data Could & ESG

[205] Interview Province Noord-Holland

[206] Interview Liander1; Interview Liander2

[207] Interview Investment company

[208] Interview Switch Datacentres1

[209] Interview MeerEnergie

should consider proximity to district heating networks[210]. Data centres must also provide clarity on the continuity and temperature levels of their heat output, possibly by combining heat with other sources or implementing backup systems. Increased reuse of residual heat could also help relieve grid congestion, as fewer electrical connections would be needed if heating demands are met via district networks[211].

Fourth role, aiming to contribute to grid stability

While continuity of IT services remains the primary focus, data centres could, under specific conditions, support grid balancing by leveraging their backup generators[212]. Current regulations restrict such participation[213]. Legislative changes are needed to allow flexible use of backup capacity without compromising its emergency function. Additionally, there must be a viable business model to compensate data centres for providing this service. Some are already exploring sustainable backup alternatives, such as hydrogen fuel cells, which could offer greener contributions to grid stability in the future[214].

Fifth role, aiming to advocate for an integrated policy

Data centres should actively collaborate with governments, grid operators, heating companies, and other stakeholders to co-develop solutions for the energy transition[215]. The sector can advocate for a proactive government, that aligns energy infrastructure, spatial planning, and economic strategies. This includes a clear long-term vision for the role of data centres in the future energy system. While this kind of collaboration is already occurring, politics need to deal with different visions, which prevents the government from providing an energy planning role[216].

Sixth role, aiming at enabling decentralised data processing and AI training

Although data management is still highly centralised, technological developments point to a future with more decentralised solutions[217]. New systems enable AI processes to be executed in collocated data centres, allowing workloads to be widely distributed. This opens the door to decentralised AI training and data processing in smaller, possibly regional, centres. Studies even suggest potential performance improvements for training decentralised AI models (Wahab et al., 2024). On-site data centres could appeal to businesses seeking independence from large, centralised or foreign providers. However, decentralisation is not yet widely adopted, as it introduces logistical complexity due to data dispersion[218]. Moreover, the sector currently pays little attention to it, and research on the technical and economic implications remains limited.

Seventh role, aiming at taking measurable steps towards sustainability

Data centres can support a sustainable investment policy by taking measurable steps in energy efficiency, utilising heat and contributing to grid stability. In addition, it is essential to be transparent and actively communicate about these contributions and the role of data centres in the digital and energy transition, in order to increase public and political support and convince investors of the social value of their investments. By attracting investments that enhance sustainability, a sustainable investment climate might be created. However, data centres are currently limited by grid congestion that limit renewable energy projects, and competition with others that keep the focus on providing a cheap and reliable service. Even as the need for capacity for data that keeps expanding.

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[210] Interview Province Noord-Holland

[211] Interview Liander1; Interview Liander2

[212] Interview Liander1; Interview Liander2

[213] Interview Switch Datacentres1

[214] Interview Province Noord-Holland

[215] Event Data Could Energy & ESG

[216] Interview consultant2; Event Webinear data centers in the MRA

[217] Interview consultant1

[218] Interview consultant1

Although the possible roles of data centres in the future Dutch energy system have been worked out separately, it is important to recognise that in practice these roles are not separate. It is precisely the synergy between different functions, that offers opportunities to contribute within the energy transition. A data centre that generates sustainable energy, stores it, supplies residual heat to a heat network and offers flexibility to the electricity grid creates far greater system value than if these roles were approached separately. However, before these data centres roles can be realised, some obstacles need to be overcome. This means that different stakeholders need to take steps to remove uncertainties or bottlenecks. The next section will therefore address the question of policy incentives, which are needed to be researched, so that data centres can ultimately achieve an intermediary role in a sustainable energy system.

Table 6.1 Overview data centre roles

Role	***Goal** (+ addresses theme)*	***What a data centre can do:***	***System advantages:***	***Obstacles for data centres to realise the role:***
1	Optimization of energy efficiency and renewable energy use (Theme 6: Efficiency)	Reducing energy consumption, increasing the use of sustainable energy sources, and own energy generation	Lower energy costs; Lower PUE; Lower environmental foodprint; more investment in renewable energy	Little knowledge about possible savings; lots of paperwork; grid congestion for Renewable energy projects; High cost and lack of infrastructure for hydrogen back-up
2	Improving public perception and societal acceptance (Theme 2: Public Perception)	Active communication about societal contributions	More knowledge about what a data centre is and does; Stronger overall support for future projects	Lack of societal knowledge about the function of a data centre; negative (online) attention
3	Active involvement in heat recovery (Theme 1: Heat Recovery)	Supplying residual heat to district heating networks	Decarbonization of heating supply; reducing dependence on fossil fuels for heating	Increase in DC PUE with higher temperatures; lack of investment in heat pumps, new cooling technologies, and heat networks; lack of collaboration between stakeholders; uncertainty with WCW
4	Contributing to grid stability (Theme 3: Contributing to the Grid)	Flexible deployment of back-up power for grid balancing	Relief of grid congestion	Permits restrict connection of back-up to grid; back-up must remain available to the data centre; no financial incentives; diesel generators are not environmental friendly
5	Collaboration and advocacy for integrated policy (Context)	Promoting proactive government action by actively collaborate	Faster implementation of sustainable infrastructure	Government does not want to take a directing role; Government has not clear visions; Government does not listen to the branch
6	Facilitating decentralized data processing (Theme 5: Decentral Development)	Supporting local AI training and data hubs	Reducing central grid pressure; fewer dependencies on foreign big tech companies; Higher performance	Still little research; logistics challenges; little attention to it from the industry and government
7	Taking measurable steps towards sustainability (Theme 4: Investment Climate)	Measurable steps in terms of energy efficiency, utilising heat and contributing to grid stability; be transparent and actively communicate about these contributions	Increase public and political support; convince investors of the social value of their investments to reach a sustainable investment environment	Grid congestion limit renewable energy projects; competition with others; more data capacity needed

6.2 Policy Incentives

This section provides a detailed overview of the eight different policy incentives, which could be addressed. These incentives are divided into four technical, two institutional, and two economic incentives. Table 6.2 gives a summary of the incentives, their desired outcomes and actions that need to be taken.

Technical incentives for overcoming barriers

Four technical opportunities can be identified to overcome some of the barriers identified in the previous section. These entail incentives providing, an optimizing energy efficiency for data centres, an optimized temperature in data centres, conditions for data centres to contribute to grid stability and, less reliability on foreign companies. First, ***optimal energy efficiency*** (TI1), this needs to help data centres in lowering their energy consumption. To be able to realise this, more knowledge needs to be spread about possible savings, paperwork regulations need to be prevented and support needs to be created for alternative back-up generators. Different organisations such as environmental departments, the RVO and branch organisations are already actively contributing to this by providing energy saving information sessions like the workshop EML[219]. However, more support from the government could be needed to realise active change. Besides this, as discussed in subsection 3.3.3 *Current Policy*, there are many regulations in place that mainly involve paper work and do not provide actual actions. This causes the morale regarding sustainable options at data centres to be low[220]. Lastly, some data centres currently use a lot of diesel as back-up, by supporting the transition to HVO or hydrogen, energy efficiency could be further increased. The best way to integrate this technical incentive, *optimal energy efficiency*, will be open for further investigation.

Second, ***optimize the temperature from data centres*** (TI2). As discussed in subsection 3.1.2 *Data Thermal Solutions,* data centres are currently providing a 30 degrees heat, which might increase when more AI will be generated. If a higher data centre temperature can be achieved, this temperature will be more efficiently applied in a heat network. However, currently, regulations are prioritized to get the PUE (Power Usages Effectiveness) as low as possible. This works against a higher data centre temperature. Therefore, this technical incentive, *optimize the temperature from data centres*, should further investigate which regulations are needed for data centres to reach the highest possible temperature to ultimately create a significant heat source into a district heating network.

Third, ***data centres contribute to grid stability*** (TI3). To be able to realise this, two technical obstacles need to be overcome, currently there are permits that restrict data centres to support the grid with their back-up and the back-up must remain available to the data centre when needed. Data centres are mostly using diesel or HVO back-up generations, which are not environmentally friendly. Therefore, there are some limitations in the time that the back-up is allowed to be used. These limitations limit the possibility for contributing to grid stability. Besides this, the back-up needs to be available to the data centre at all times, because, data centres guarantee 24/7 power. Some data centres have additional back-up which they are not likely to use, some efforts can be made to investigate if there is a potential in using these[221]. Finances might help as well, which is addressed in economic incentive *Financial incentive flexibility* (EI1).

Last, ***promote less reliability on foreign companies*** (TI4). Decentralization can lower the dependency on foreign countries and companies which can be obtained by addressing the following three obstacles, create attention, increase research and investigate logistic challenges. Decentralization can have potential, however, not much attention is already paid to this, by investigating this, and create attention to the industry more decentralized alternatives might be accomplished. However, decentralized alternatives, can also contribute to more logistic challenges, which could be useful to investigate and optimize as well[222].

Institutional incentives for overcoming barriers

Two institutional incentives lies in the development of proactive government policy and improving collaboration across the sector. First, a ***proactive policy approach*** (II1) is essential. The current lack of overarching frameworks and fragmented legislation hampers the development of sustainable solutions. Delays in decision-making, particularly regarding the Collective Heat Act (WCW), which creates an uncertain investment environment. In many cases, the government does not provide a clear vision or take a guiding role[223]. This signals the need for further research and development of a long-term, strategic vision for the energy transition, in which the role of data centres is explicitly addressed. An integrated policy that aligns energy infrastructure, spatial planning, and

219 Event Workshop EML

220 Event Workshop EML

221 Interview Liander1; Interview Liander2

222 Interview Consultant1

223 Event Webinear data centers in the MRA

economic development from the branch, is critical for moving forward. Several specifics actions could support this, starting with an implementation of the Collective Heat Act (WCW) to establish regulatory certainty and provide appropriate incentives for residual heat projects. In addition, legislation must be changed to allow for flexible use of backup capacity from data centres for grid services. Furthermore, the interviews highlighted the importance of energy planning, at local and national levels[224]. Municipalities could develop clear district heating transition plans, while provinces could require that new data centres are prepared for future heat delivery. National policy coordination could support and align these efforts across scales.

Second, ***improved collaboration*** (II2). Although collaboration among stakeholders, including data centres, governments, grid operators, heating companies, and residents, is essential, it is often hindered by differences in speed, expectations, and institutional structure. Businesses often develop faster than public stakeholders can respond. Therefore, an opportunity exists to stimulate active, solution-oriented collaboration between all involved parties. This requires jointly developed policy frameworks, shared responsibility, and mutual trust. Innovative collaborative models could emerge between data centres, heating companies, and consumers. Industry organisations already play a role in connecting members with relevant regulation and initiatives[225]. A potential sector deal between data centres and grid operators could also be explored to improve strategic alignment between these stakeholder groups. Besides this, the spread of knowledge based on facts is essential to increase the common knowledge about data centres and to contribute to fair public opinions. Therefore, this institutional incentive, *improved collaboration,* might contribute to all desired outcomes determined in pathway 4, Chapter 5.

Economic incentives for overcoming barriers

Two economic incentives can be identified, providing a financial motivation for flexible energy usage and create acceptance for heat networks such that, data centres can become a significant heat source. First, ***provide financial motivation for flexible energy usage*** (EI1). This is one additional step after technical incentive *Data centres contribute to grid stability* (TI3), besides permits and collaboration, a financial compensation might increase the likelihood of data centres providing their backup to the grid. The current pricing model regulated by the ACM provides limited financial motivation for data centres to engage in flexible energy consumption[226]. This presents an opportunity, for instance, tariff structures and compensation mechanisms could be adapted to reward data centres for grid-balancing contributions. However, further research is needed to determine how such incentive should be designed and implemented effectively.

Second**, *acceptance for heat networks*** (EI2). Whether the business case for heat networks gets off the ground depends to a large extent on the acceptance of heat networks and whether there is also enough investment in heat pumps, techniques for disconnection, and heat networks themselves. As discussed in subsection 3.3.1 *Collaboration*, stakeholders are hesitant to make investments because the business case is uncertain. By being able to actively stimulate this, the business case can be increased and stakeholders might take certain steps. Ultimately, this should lead to data centres that can be implemented as a significant source in a district heating system.

Table 6.2 Overview of proposed policy incentives, desired outcomes, actions needed, and impact on social acceptance

Domain	***Incentive***	***Desired outcome (+ addressing DC role)***	***Actions needed***	***Impact on Social Acceptance***
Technical	(TI1) Energy efficiency	Optimized Energy Efficiency for data centres (addressing role 1)	Provide knowledge about possible savings; prevent paperwork regulations; support the transition away from diesel backup generators	Reduces the perception of data centres as mere 'high energy users' by actually using less energy and improves operations by reducing costs.
	(TI2) Heat utilization	Optimized temperature in data centre (addressing role 3)	Create regulatory possibilities for higher DC PUE's when heat is provided	When data centres create higher temperatures, less additional energy is needed to incorporate in a heat network

[224] Interview Province Noord-Holland

[225] Interview Data centre branch

[226] Interview Consulatant1

	(TI3) Energy flexibility	Data centres contribute to grid stability (addressing role 4)	Revision of permits that restrict a back-up availability to the grid; ensure that back-up is still available to the data centre	When data centres contribute to grid stability, relations between data centre operators and grid operators intent to increase providing more market acceptance
	(TI4) Decentralisatio n	Less reliable on foreign companies (addressing role 6)	Attention to the development of decentralisation; investigate logistic challenges; finance more research for decentralisation	When more data is stored and processed decentral, the Dutch data industry will become less reliable on foreign companies which might increase social acceptance.
Institutional	(II1) Proactive government	Overcome fragmentation and create sustainable investment environment (addressing role 1,3,5,7)	Prevent paperwork regulations; decide about the WCW; Lisen to data centre branch; create clear vision till 2050; provide a clear directing role; ensure more data capacity	Reduces uncertainty for investors and developers. Creates clear frameworks for sustainable projects.
	(II2) Improved collaboration	Needed to obtain all discussed goals (addressing role 2,3)	Increase collaboration between stakeholders; transfer knowledge about the importance of data centres; provide information based on facts to determine public opinion	Builds trust, ensures shared responsibility and enables more inclusive planning, which is essential for community acceptance.
Economic	(EI1) Financial incentive flexibility	Provide financial motivation for flexible energy usage (addressing role 4)	Reform energy pricing; adjust tariffs and compensation models	Creates financial motivation for flexible energy use
	(EI2) Acceptance heat networks	Can contribute to data centres becoming a significant heat source (addressing role 3)	Increase incentives to invest in aspects needed to create data thermal solutions like heat pumps, new cooling technologies, and heat networks	Created more sustainable alternatives which can increase social acceptance

6.3 Connection to Social Acceptance

The technical, institutional, and economic incentives discussed in this Chapter directly contribute to strengthening the social acceptance of data centres in the Dutch energy system. As outlined in Chapter 4 *Social Acceptance*, in which social acceptance is divided based on the framework by Wüstenhagen et al. (2007) and Ellis et al. (2023). Addressing the key obstacles impacts the social acceptance across all dimensions. An updated social acceptance framework can be seen in Figure 6.1. The above policy incentives can provide improvements in certain aspects of social acceptance. Three important aspects are highlighted out of this figure.

First, **transparent and proactive communication** about the essential role of data centres in the digital economy and their efforts in sustainability is essential to improving their public image. Demonstrating successful examples of energy efficiency, heat reuse, or grid flexibility can help to reshape the perception, from high energy consumers to contributors of the energy transition. This might affect the resistance to infrastructure and a more positive public perception.

Second, **inclusive planning and community involvement**, particularly in projects related to heat networks or spatial planning, might help strengthen community acceptance. Engaging local residents in co-developing solutions reduces NIMBY problems and builds trust (Wolsink, 2012). The visible contribution of data centres to local heating supply, for example, can shift their identity from "high energy users" to "heat providers" in the eyes of the public, improving community acceptance.

Third, **contributing to the problem of grid congestion**, currently a widely recognised societal issue. In which data centres can restore their reputation by actively being part of a solution rather than the problem. Flexible power use, support for decentralised infrastructure, and cooperation with grid operators signals institutional responsibility and system awareness, further reinforcing socio-political acceptance.

Ultimately, the realisation of a socially desirable pathway (Pathway 4) is not only dependent on technology, institutional of economic isolation but emerges from the successful alignment of incentives and opportunities across all domains.

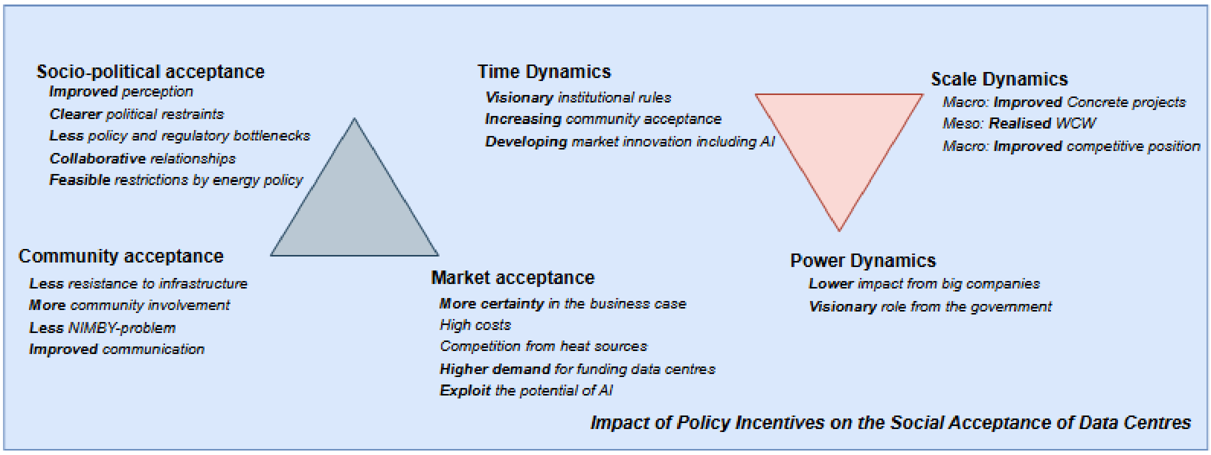

Figure 6.1 Updated version Social acceptance framework

Chapter 7: Finalizing: Towards an Acceptable Role for Data Centres

The aim of this thesis was to explore the complex position of data centres within the Dutch energy system, with the goal to identify what insights can support the development of policy instruments to facilitate an acceptable role for data centres as intermediaries in the system. So far, the research findings can contribute to answer the central research question:

What insights can support the development of policy instruments aimed at facilitating an acceptable role of data centres as intermediaries in the future Dutch energy system?

In answering this question, section 7.1 *Recommendation,* provides a policy recommendation creating a prioritization of policy incentives. After this, section 7.2 *Synthesizing and Translation to the Energy Transition,* touches upon the academic contributions of this research and the impact to the broader Dutch energy transition.

7.1 Recommendation

Supporting the development of an acceptable role for data centres asks for a multi-faceted approach. Enabling data centres to become true intermediaries in the energy system requires several steps, this recommendation will though upon the prioritization of these steps. This prioritization was determined based on the findings within this research. A visual representation of the impact from the policy incentives can be seen in Figure 7.1. A version which can be read better is shown in Appendix G. The left site of this figure shows the obstacles when realising the roles for data centres as resulted from the developed roles in section 6.1 *Potential Roles for Data Centres.* The right side of this figure shows the ultimate goals developed from pathway 4 in Chapter 5 *Potential Pathways.* In the middle, the policy incentives discussed in section 6.2 *Policy Incentives* are shown.

This figure shows which incentives can reduce the obstacles to obtain several system goals. As can be seen in the figure, three obstacles are not addressed with these incentives. These are likely to required other incentives, which are, due to limited time and resources, out of the scope of this thesis. The order of goals, shown on the right side of the figure, shows the **prioritization** of **policy incentives,** of which an overview is given in Table 7.1.

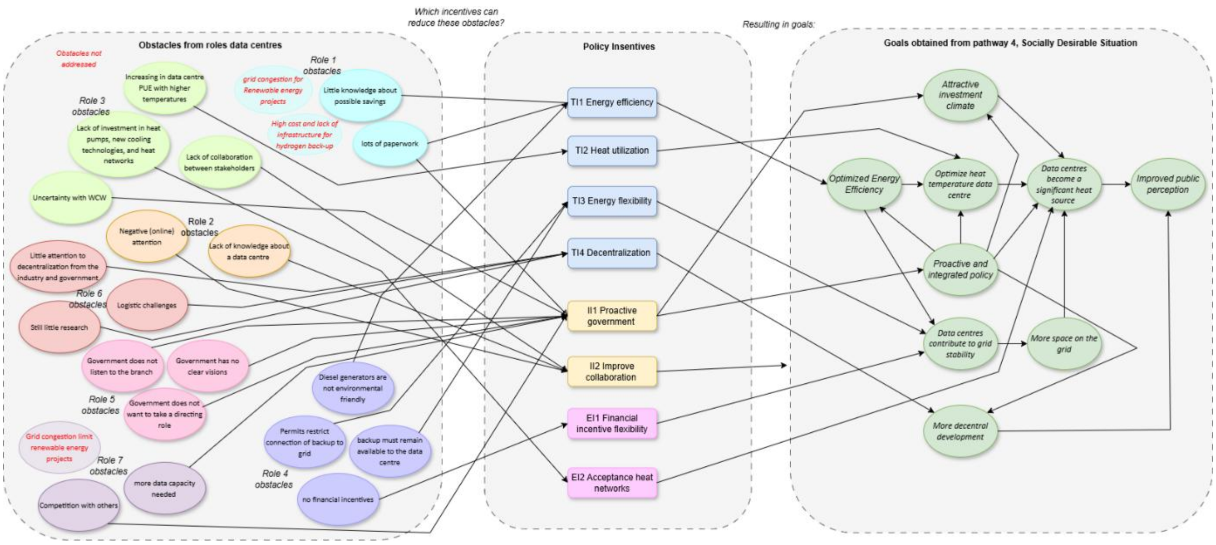

Figure 7.1 Impact policy incentives

The order reflects a combination of immediate feasibility, urgency for energy transition, and the extent to which a policy incentive is needed for various measures. (II2) ***Improve collaboration*** is placed first because it is a prerequisite for almost all other measures. Without collaboration between actors, technical and economic measures remain ineffective or delayed. Next, (TI1) ***Energy efficiency*** is technically feasible and immediately implementable, it is therefore given priority two. Most of the measures are given shared priority three, because they are highly interconnected and need to be taken up simultaneously. Each of these policy incentives contributes in its own way to achieving the desired future, but none of them can independently carry the system transformation. For example, (TI3) ***Energy flexibility*** and (EI1) ***Financial incentive flexibility,*** both encourage the contribution of data centres to balancing the grid. The last priority goes to (TI4) ***Decentralisation***, this is strategically relevant, especially in light of geopolitical independence and data sovereignty. However, there is a lower urgency or implementation readiness. Decentralisation requires in-depth research, fundamental system changes and possibly new infrastructure, making the impact visible only in the medium to long term. In addition, it has a lesser impact on short-term problems such as grid congestion, energy consumption or public perception.

Table 7.1 Overview of Policy Incentive prioritization and reasoning

Priority	***Incentive***	***Reasoning***
1	(II1) Improve collaboration (*Institutional*)	Cooperation is the basis for effectively implementing the other measures. Without better cooperation between governments, grid operators and data centres, system optimisation remains impossible.
2	(TI1) Energy efficiency (*Technical*)	Energy efficiency is an immediate and technically feasible measure that quickly contributes to reduced energy consumption and CO_2 emissions, crucial given societal pressures.
3	(II1) Proactive government *(Institutional)*	Policy certainty and a long-term vision are needed to encourage investment from data centres and partners. This can create trust and increase acceptance.
3	(TI2) Heat utilization (*Technical*)	Heat utilization has great potential for sustainable interconnection with heat networks. A higher output of temperatures can even strengthen the business case.
3	(TI3) Energy flexibility (*Technical*)	Flexibility helps with grid congestion and renewable energy integration, this requires cooperation and adaptive policy frameworks.
3	EI1 Financial incentive flexibility (*Economic)*	New financial incentives can make contributing to grid balancing more attractive for data centres.
3	EI2 Acceptance heat networks (*Economic)*	Without sufficient local acceptance and business cases for heat networks, heat utilization will remain limited. This requires attention to social acceptance of heat networks.
4	TI4 Decentralisation (Technical)	Decentralisation might contribute to reduced dependence on foreign tech companies and increased data sovereignty. As this requires structural change and has been little researched, it has been given lower priority.

7.2 Synthesizing and Translation to the Energy Transition

The *Problem Definition,* in Chapter 1, provided a short literature review of the findings into the technical possibilities of sustainable data centres development, economic feasibility, policy status, and lack of societal implementation. It was highlighted that, sustainability is not purely technical any more, heat utilization is technically possible via heat networks using heat pumps and storage. Besides this, geographical location is crucial and clustering of small data centres promote optimisation of both data and heat capacity. In addition, it highlighted high investment costs, unclear business models for operators, and limited knowledge about the energy market among data centre operators. On the other hand, positive aspects were also outlined, a possible short payback period for heat projects, success stories on transparent cooperation, supportive policies and availability of heat networks. Finally, the lack of specific EU regulations for data centre heat utilization, the importance of financial incentives such as tax benefits and lower electricity costs, and the need for cooperation to counter competition, were highlighted.

However, large parts of these researched studies provided examples from abroad where different conditions apply than in the Netherlands. In addition, there was insufficient research into how data centres in cooperation with other stakeholders can be integrated into a sustainable energy system in the Netherlands. Which resulted in this research filling a gab, by explorative research taking the technical, institutional and economic aspects even as stakeholder interactions into account. To obtain insights into the possible future intermediary roles for data centres in the Netherlands and which policy incentives should be needed to determine this. Through this research, four findings were observed that provide academic contributions. These focusing on the link between complexity, acceptance and feasibility of pathways, the importance of social acceptance, the tension between stakeholders, and the role of policy.

The Link Between Complexity, Acceptance, and Feasibility of Projects

While doing the interviews, it was noticed that each interview brought new information and nuance to the complex sociotechnical system. In addition, adding the importance of social acceptance also adds to the complexity of the system. The more complex the system becomes, the more difficult it is to sketch feasible future paths, as more and more parts seem to gain obstacles. Therefore, some parts are not discussed, these are explained later in section 8.2 *Reflection*. The more complex the problem the greater the differences between the two developed future paths, this is explained by also showing future paths of individual stakeholder groups in Chapter 5, pathway 2 and 3. As complexity increases, transaction costs also increase, as discussed in section 2.4 *Transaction Costs Economics*. Investigating previous Dutch heat and sustainability projects, showed that higher transaction costs, causes stakeholders to eventually drop out of projects. Stakeholders want to contribute to sustainable projects, however, become hesitant when costs and uncertainty become too high.

Social Acceptance as a Crucial Factor

Social Acceptance is described in a broad way by including the three different aspects of Wüstenhagen et al. (2007) and the dynamic change of Ellis et al. (2023). This was, according to the researcher's knowledge, not done before and highlights that there are several components of importance that ultimately lead to the overall social acceptance of data centres in the Dutch energy system. In some cases, social acceptance is assumed as a logical consequence (Wüstenhagen et al., 2007). However, this is not to be taken for granted. During the various events attended, it was evident that social acceptance is difficult to obtain and plays a very important role in the realisation of projects. The Dutch researcher, Maarten Wolsink, has already done a lot of research on social acceptance, in different projects and approaches. Besides this, more recent studies on social acceptance are available as well. For example a study from, Onencan et al. (2024), they investigated the social acceptance of district heating networks in Haarlem, the Netherlands, crucial for using heat from data centres. These more resent studies about social acceptance can be an inspiration for follow-up research about social acceptance from data centres.

Within this thesis it was found that, especially in the informal contact moments with stakeholders, perceptions can be different from when there is an on-record interview. To the outside world, many parties have big words to do sustainability, but when it really comes down to it, it remains difficult to realise projects. A lack of policy intentions, other than paperwork, is still causing few projects to get off the ground.

Tensions Between Stakeholders

That different stakeholders have different interests, is already known, but what became clear during this study, is that these different interests created specific friction points in realising sustainable data centre projects, as discussed in Chapter 5 *Potential Pathways.* With the interviews and attended events, it was possible to create a system overview and identify these friction points, which led to an overview of obstacles showing in Chapter 6 *Roles Data Centres and Policy Incentives.* Despite the fact that all stakeholders want to implement sustainable alternatives, there are major differences in interests that prevent stakeholders from aligning. Therefore, this research provided topics for further investigation on policy incentives, which might be useful to get data centres into the right direction. This leaves a research gap for investigating how other stakeholders can be pushed into the right direction.

The Role of Policy

The research identifies various obstacles hindering the realization of the potential roles for data centres. These obstacles are addressed by the suggested policy incentives. For example, the obstacle of uncertain business cases for flexibility is addressed by the need for financial incentives and compensation models. The complex regulation around heat recovery is addressed by the need for final and clear implementation of the WCW and defining rules for heat guarantees and cost allocation. The research thus clearly indicates *what* areas require attention, which is a crucial step, even if a detailed plan for *how* these policy incentives should be implemented requires further research.

Through this study, various policy incentives were generated that can be further investigated to better integrate data centres in the Dutch energy system. It was found that in the Netherlands, too, sustainability is no longer purely technical but requires a multidisciplinary approach. The use of heat from data centres is technically possible in the Netherlands, but is currently hampered by a lack of governmental directions, the Collective Heat Act (WCW), the yet-to-be-developed heat networks, grid congestion, and financial incentives. However, the high population density, despite the slightly warmer climate, can strengthen the business case of the Netherlands. The development of small decentralised data centres could be further explored, as this could contribute to a more sustainable energy system and less dependence on others. Finally, this research has contributed to uncovering opportunities for the Netherlands, which lie in boosting cooperation to realise energy flexibility, setting up an infrastructure for heat use and exploring decentralisation.

Development within the Dutch Energy Transition

The prioritized policy incentives can contribute to realise an *acceptable role for data centres as intermediaries* in the future Dutch energy system. While the policy incentives outlined in this thesis, are primarily focused on optimizing the role of data centres in the energy system, their impact might extend beyond the sector itself. In fact, these measures align closely with key objectives of the broader Dutch energy transition, such as increasing energy efficiency, enhancing system flexibility, accelerating the shift to sustainable heat, and strengthening institutional coordination.

From a technical perspective, the proposed incentives focus on continuous improvement of energy efficiency (TI1), directly supporting national goals to reduce energy consumption and carbon emissions. In addition, promoting higher temperatures of residual heat from data centres (TI2) contributes to the transition away from natural gas in the built environment by supplying sustainable heat to district heating systems. The enhancement of energy flexibility (TI3) plays a critical role in stabilizing an electricity grid that increasingly relies on intermittent renewable sources like wind and solar. Lastly, the introduction of decentralisation as a long-term possibility (TI4) supports the development of a more resilient and sovereign digital infrastructure, reducing dependence on large foreign providers and might develop local energy solutions.

From an institutional standpoint, strengthening a proactive government (II1) and fostering collaboration among stakeholders (II2) contribute to alignment across various actors, an essential condition for coherent and integrated energy system planning. These elements are vital to overcoming the fragmented responsibilities currently hindering progress in infrastructure development and sustainable investment.

Last, economically, the introduction of flexible financial incentives (EI1) promotes market mechanisms that reward adaptable energy consumption and investment in smart technologies. This helps build a more dynamic energy market that can respond efficiently to supply and demand fluctuations. At the same time, improving the acceptance of district heating systems (EI2) supports long-term decarbonization efforts by creating a more robust and investable heat infrastructure.

In essence, by following this path, data centres can evolve from high-energy consumers into trusted, efficient, and collaborative players in the Dutch energy transition. Their role as intermediaries might not only be acceptable, but essential, contributing to a leading position on AI, data capacity stability, preventing grid congestions and contributing to a sustainable Dutch energy system.

This Chapter has brought to attention how the eight constructed policy incentives can contribute to a more sustainable energy system in the Netherlands. However, there are some points that can be questioned in this research, therefore, the next Chapter will provide topics for further research and reflect on the research limitations.

Chapter 8: Advise for Further Research and Reflection

Chapter 7 *Finalizing: Towards an Acceptable Role for Data Centres,* provided *a* recommendation, and translation of this research into academic contributions and the Dutch energy transition. Which leads to this last Chapter with advice for further research, and a research reflection.

8.1 Advice for Future Research

Aspects that could be investigated further are a validation with stakeholders, determining the effectiveness of policy incentives, an impact assessment for data centres, exploring specific Dutch case studies, effective communication, and decentralisation. A first follow-up step could be to check whether stakeholders can validate the outlined desirable future paths developed in section 4.2 *Social Acceptable Future Situations* and Chapter 5 *Potential Pathways*. This can be done by presenting the stakeholders with the results and asking them for feedback where necessary, which might affect the nuances or alter the complexity of the issue. However, this can contribute to development of even more realistic future pathways.

Next, Chapter 6 *Roles for Data Centres and Policy Incentives,* can be extended with a detailed policy study. An investigation on how the identified policy incentives can be effectively designed and implemented within the different Dutch governmental departments. For example, research on successful or failing policy implementations in similar sectors. This could give the policy incentives more back-up to actually be realised. It will require a new set of research topics, for example with interviews, to provide a clear understanding of how policy incentives are implemented within the different governmental departments.

A quantitative impact analysis, for data centres acting within the energy sector, could be helpful to determine the effectiveness of certain policy incentives. A study of the actual impact from data centres at the level of energy consumption versus the potential contribution to flexibility or residual heat. This might be helpful in determining the costs and efforts to put into sustainability projects with data centres and the environmental gains that result from these costs. When comparing this study with the impact from making other industries more sustainable, it can be determined, which industry would be most effective to gain environmental benefits.

Also, a specific Dutch case study of residual heat or flexibility projects could contribute to understand the success and failure factors on a technical, institutional, economic, and social level. These could contribute to even more insights into where projects come to a standstill. This has already been looked at with the case in Amsterdam Zuid-Oost. However, using techniques like pattern modelling could contribute to find more points of friction, here as well.

Another research field that could be discovered is the specific research into effective communication strategies and participation models for increasing community acceptance of data centre projects. This research could contribute to best address the '*fear of the unknown'* describes by local stakeholders as one of the bottlenecks that projects will not be realised[227].

A final recommendation for potential follow-up research lies in decentralisation and AI. Deeper research into the technical, economic and social feasibility of decentralised data processing and the role of AI, within the Dutch context. This can give Dutch governments advise, if they should put more attention to this.

8.2 Reflection Methodology and Research Limitations

This study started with a contextual understanding (Chapter 1 *Problem Definition*) of the current situation in which data centres operate. This included focus on the increasing use of digital services, increase of energy use, and the race for AI. All these contextual aspects result from a prosperous economy, which despite geopolitical tensions, is currently attracting many new investments. However, the conjecture may change due to various external factors which may cause the outcomes of this study to change. Therefore, this reflection approaches, how future changes can be taken into account while using the pattern model, and why there are certain limits to the research.

227 Interview Firan

This section reflects on the methodological choices made in the study. Discussing the strengths and limitations that shaped the scope, depth, and reliability of the findings. Considering how the chosen qualitative approach, including stakeholder interviews and event participation, contributed to a understanding of the complex situation in which Dutch data centre operate. This section acknowledged the strong points of this research as well as the areas where the research design faced constraints, such as time, stakeholder access, and subjectivity.

Reflection Frameworks: Pattern Modelling, Social Acceptance and Transaction Costs Economics

During this research, environmental factors have changed that influence the outcomes of the study. An example of one of these changes is the (potential) import tariffs which were announced on April the 2nd, 2025. These tariffs create uncertainty among investors and can make commodities more expensive, delaying new investments in data centres (Goldman, 2025). The development could change the business case for data centres for the short or long term, and therefore impact the development in the Dutch energy system.

However, the pattern model is capable of accommodating such dynamic change, as the import tariffs. Using this example, this can be implemented in three steps. First, it will have to be determined in which domain this change falls, in the case of import tariffs, this falls in the contextual economic domain. Meaning that this is an economic aspect which will influence the situation from outside the system boundary (the Dutch Landscape). After which this aspect (node) can be added to the pattern model, this is shown in Figure 8.1. Then, the relationships between *import tariffs* (IT) and the other aspects can be determined. In this case will, *import tariffs*, depend on *geopolitical* relationships, therefore adding an arrow to import tariffs. In addition, import tariffs are likely to affect the *Business Case* (BC), and *land and resource availability* (L&R), which also adds two arrows. Now an updated pattern model emerges showing that through existing aspects, import tariffs can also have technical and institutional consequences.

This example shows that pattern modelling is a suitable method to represent the complexity of data centres in the Dutch energy system. What the consequences are for the pathways and roles for data centres, cannot be said based on this small amount of information. A next step could therefore be to do interviews with experts who can tell more about the consequences of import tariffs, after which the pathways, roles, and policy incentives could be adjusted.

Additionally, this shows that the social environment in which data centres find themselves is constantly changing. Highlighting the strengths of the social acceptance framework from Ellis et al. (2023), which included time, space and power dynamics, based on the framework from Wüstenhagen et al. (2007). Together, both frameworks help to show how changing system dynamics change the social acceptance of data centres within the Dutch energy system. However, one changed aspect can affect social acceptance in different ways. The combination of these frameworks gives room to include these changes. The example of *import tariffs,* does not yet have enough information to give a clear change, for that further research will have to be done on the effects. This research used an example application of the social acceptance frameworks on wind energy, which was helpful to create an outline on how the social acceptance framework could be applied for on data centres.

On the other hand, *import tariffs,* are also likely to change the transaction costs, as described in section 2.4 *Transaction Costs Economics*. Transaction costs include expenses related to gathering information, negotiating contracts, and enforcing agreements (Williamson, 1998). This means that when system conditions change, parties will go back to the table to reach agreements. This in turn, can affect development costs not directly related to the actual costs, the transaction costs. Because this type of cost will increase as the system becomes more complex, it has been an appropriate addition to this study, providing a clear distinction.

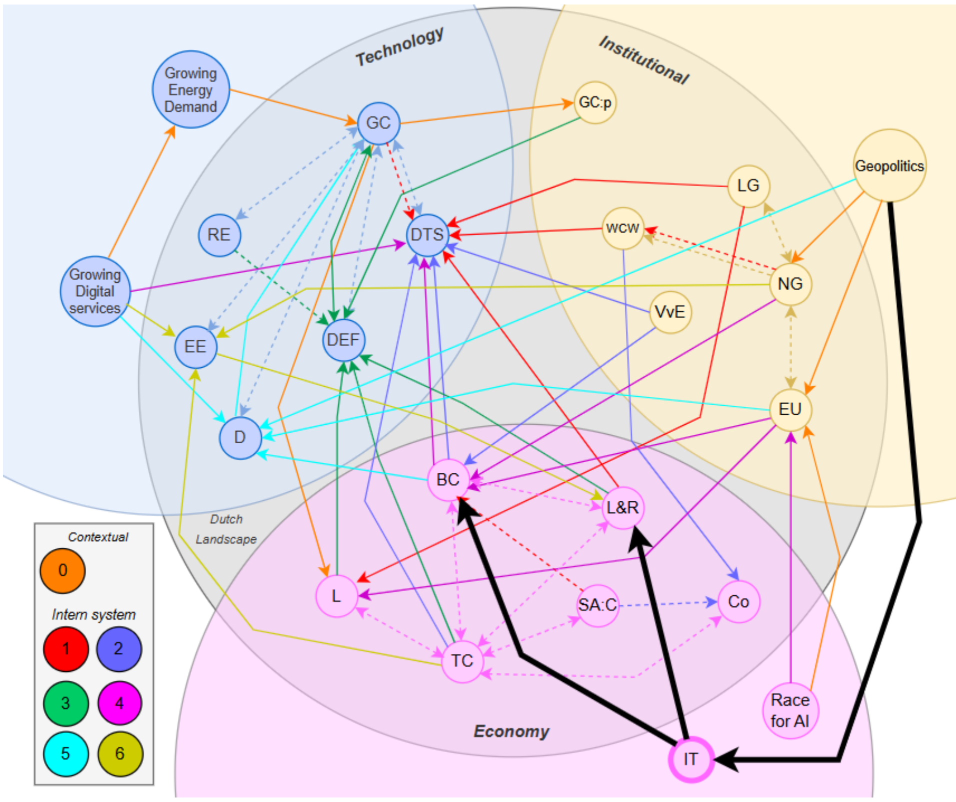

Figure 8.1 Updated patten model with import tariffs (IT)

Reflection on the Interviews

Numerous interviews were conducted with diverse stakeholders, which caused a wide-range understanding of the system's complexity and supported the development of well-informed trade-offs. The interviews covered many key actors. However, some important perspectives were missing, which presents an area for improvement.

The interviews were arranged using a snowball method, with the process ending once participants began referring to individuals who had already been interviewed and when the thesis period ended. While efficient, this method may have reinforced a certain network of perspectives, potentially overlooking voices outside that circle. Additional outreach beyond snowball referrals could have broadened the dataset. Even though this takes more time and effort to realise. In developing the pattern model, only themes that were mentioned frequently or discussed in depth, within the interviews of participated events, were included. Topics that arose only once or twice during the interviews were excluded to simplify, though these may still hold significance and could influence the system if further investigated. The lack of interviewing all stakeholders could contribute that some points or important aspects are missing.

One significant limitation was the absence of a non-governmental organisation representation. Although efforts were made, it was not possible to include participants from organisations such as Greenpeace Netherlands, Milieudefensie, Bits of Freedom, Waag Futurelab, or local citizen initiatives like *Land van Ons* and *Meten = Weten*. These actors could have contributed valuable insights, particularly around social concerns and ethical implications of data centre projects.

Moreover, while the study included interviews with three data centre operators, the inclusion of additional operators, especially those engaged in alternative sustainability initiatives, such as Iron Mountain or NorthC, might have offered greater diversity in views and practices. The study also did not engage with enterprise data centres, which are often smaller, internally managed facilities run by individual companies. While some perspectives were gathered from individuals at TU Delft with relevant experience, these smaller players were not a primary the focus, as attention was directed toward larger colocation centres. Similarly, hyperscale providers were only approached informally during events, as time constraints prevented formal interviews.

Last, in terms of government stakeholders, the research included input from municipalities and provinces, but missed views from Ministries (Economic Affairs, Climate and Green Growth). Although these ministries were considered, small contact could only be established during the events. However, due to the research timeframe, representing a limitation in capturing national policy perspectives within the interviews.

Reflection on the technical, institutional, and economic aspects as well as themes connecting them

Chapter 3 *Defining the Pattern Model,* led to the final pattern model (figure described above, figure 8.1), which describes part of the complex situation in which data centres find themselves. To build the figure, various technical, institutional and economic aspects were identified while doing the interviews and attending the events. In addition, seven themes were developed in which the complexity of the situation was tried to capture. However, it was not possible to include all the complexity, therefore choices were made during the research to omit or simplify parts. In further research, this could be extended further. An example of a simplified situation is in the internal theme 6: *Efficiency*. In this research, this theme is about two things: (1) the internal efficiency of data centres and (2) system efficiency with the focus on heat utilisation. However, when talking about *efficiency*, there are still many aspects that also affect this or can change the definition. For example, analysing the system efficiency when looking at the entire CO_2 footprint. When including this, other optimal outcomes could arise. A ground for further research can be to identify which aspects need to be taken into account while determining the efficiency of the system in which data centres operate. The last paragraph of this Chapter, *Other Research Limitations,* discusses more research limitations that were left out in the complex pattern model.

Reflection on the pathways

The pathways, discussed in Chapter 5 *Potential Pathways*, have been drawn up as structured explorations of possible future developments for the integration of data centres into the Dutch energy system. They are explicitly not meant to be exact predictions for a specific time frame. Instead, they are based on findings from interviews, expert meetings and literature, and reflect both current trends and plausible shifts in governance, technology and market dynamics. The study presents two main contrasting pathways, with the goal to show significant differences. Pathway 1, outlines a future in which the role of data centres in the energy system develops only to a limited extent. It also outlines a socially desirable future in which data centres actively and visibly contribute to a more sustainable and resilient energy system (pathway 4). These paths were developed based on subjective findings gained during the interviews and events. When other stakeholders were included in the interviews or had other events been attended, other paths could have emerged due to different views. The consideration to formulate the paths this way is based on what came up a lot in the interviews. Two limitations of this approach are that they have been formed on a subjective basis and there was no time to validate these future pathways by going back to the interview participants to ask for feedback and possible additions. This could have added further complexity and validation in future research. However, there were many interviews done that it is possible to say with some certainty that these future paths largely correspond to what stakeholders advocate.

Reflection on the Potential Roles for Data Centres

Building on the socially desirable future pathway (Pathway 4) outlined in Chapter 5, Chapter 6 identifies seven potential intermediary roles that data centres could play in the future Dutch energy system. These roles are also not presented as definitive predictions, but rather as potential contributions determined from the research findings. The seven roles represent specific areas where data centres could potentially add system value and help address shared energy challenges. The development of these roles was directly based on the analysis of the complex system (Chapter 3), the insights into social acceptance and differing stakeholder preferences (Chapter 4), and specifically the vision presented in the socially desirable pathway (Pathway 4, Chapter 5).

A limitation in the development of these specific roles, similar to the pathways, is that while they are based on a broad understanding gained from interviews and events, there was limited time to validate these exact defined roles with the interview participants. Presenting the stakeholders with these specific roles and their associated obstacles and potential synergies could provide valuable feedback and further refine the understanding of their feasibility and acceptability in practice. Such validation, potentially through follow-up discussions or targeted workshops, could be a valuable area for future research.

Additionally, this study only focused on the potential role for data centres and leaves out the roles for other stakeholders. Other stakeholders also contribute to the development of a sustainable energy system.

However, due to limited time and resources, this study only looked at the role of data centres. In further research, the role of municipality, grid operators or connecting organisations could be interesting to be investigated.

Nevertheless, the outlined roles represent a crucial step in translating the theoretical potential of data centres in a desirable future scenario into concrete actions and areas for policy focus. Which was useful to determine the topics for policy incentives.

Reflection on the Developed Policy Incentives

Following the identification of potential roles, data centres could play in a socially desirable future energy system. The second half of Chapter 6 shifts the focus to the necessary policy directions that require action to enable these roles. It explicitly outlines policy incentives across technical, institutional, and economic domains designed to overcome the obstacles identified in designing the data centre roles to move towards the desired future scenario.

The proposed policy incentives fall into the three main categories, these categories were chosen to give structure to the research as these domains were also investigated within Chapter 3. However, it was also possible to categorise these incentives differently, for example on openness to change or feasibility. This is why there has been chosen to do an additional prioritization within the final Chapter 7.

It is important to acknowledge that, while these policy incentives are proposed to facilitate the socially desirable future, different stakeholders may value these incentives differently. As highlighted in the analysis of desirable futures in Chapter 4 and the pathways in Chapter 5, stakeholders like data centre operators, municipalities and citizens, and grid operators have divergent priorities and ideal outcomes. For instance, while grid operators might highly value incentives for grid stability contributions, municipalities might prioritize incentives for residual heat utilisation for local heat networks, and data centres might focus on incentives that simplify permitting or support business cases for growth. The policy incentives, while aiming for an overall optimal societal outcome (Pathway 4), will likely require mutual concessions from various stakeholders to be realised. The prioritization of policy incentives implicitly reflects this, suggesting that foundational institutional clarity is needed before more specific technical or economic incentives can be fully effective.

Adding that some obstacles could not be captured within the policy incentives, some of these were shown in red within Chapter 7, figure 7.1. However, due to the complexity of the problems and the time limitations of this thesis, it was not possible to develop policy incentives for every obstacle. Therefore, it was chosen to create incentives for the ones that were mostly mentioned within the interviews and attended events.

Last, it should also be noted as a limitation in the development of these incentives that, due to time constraints, more detailed research on *how* these policy incentives would be effectively designed and implemented within different governmental bodies was not possible to investigate. The advice in this chapter focuses on the *direction* of necessary actions and highlights areas for future research. This contributed to the reflection on *pathways* and *roles*, where validation with stakeholders was also identified as an area for further exploration.

Reflection on the Prioritization of Policy Incentives

The prioritization of the policy incentives is included to distinguish the relative importance of certain steps over others. This prioritization is based on observations made during interviews and events, and is therefore subjective in nature. Follow-up research could reveal that certain incentives may be better addressed earlier or later, or implemented in different ways. Furthermore, there are limitations to the types of incentives that governmental bodies can realistically guarantee, and many developments will largely depend on political dynamics and external factors. For these reasons, it is difficult to fully validate the proposed order. Due to time constraints within the research, the presented incentives should be seen as recommendations for further investigation rather than firm policy advice.

Besides this, Figure 7.1 shows that some data centre roles need several incentives to be realised while other roles only need one. This is an example of another reasoning why certain incentives have to be prioritized before others. For example, based on easiness to implement, one could start with pushing the role for data centres where the least incentives are needed for.

Other Research Limitations

While conducting this research, there were some additional limitations, which include time, subjective nature, the demarcated research of social acceptance and some aspects that were left out of this research. Time was one of the most significant constraints in this study. As a result, the research could not investigate the practical implementation or real-world effectiveness of the identified policy instruments in depth. Instead, it focused on exploring directions for policy incentives rather than evaluating their actual outcomes.

Another limitation comes with the subjective nature of the data, which was largely based on stakeholder perceptions and insights collected through interviews and events. Despite the attempt to reach a wide range of actors, not every relevant stakeholder could be included. Additionally, it was not possible to validate the findings through follow-up interviews, nor to explore in detail how proposed policies might be embedded within governmental frameworks or administrative practice. Also, the pattern model developed in this study represents the complexity as observed within the specific scope and context based on available data. Another researcher might identify different themes if conducting the study at another time or under different circumstances. Nonetheless, through engagement with a diverse stakeholder group, the research tries to capture as much of the systemic complexity as possible.

The topic of social acceptance is itself a large research field. Although central to this study, the treatment of social acceptance and resistance was necessarily limited by the available time and resources. Resistance can take many forms and emerge from various causes, ranging from the NIMBY problem to financial concerns or communication failures, making it difficult to generalize without all the details. Each case of resistance is context-specific and may differ per analysis.

Last, some relevant themes were initially considered but ultimately excluded from the final analysis due to insufficient data from interviews. For instance, interactions with horticultural stakeholders, water use from data centres, comparisons with other countries, selling heat business-to-business, computing vs storage applications, using energy hubs and the impact of spatial planning. While horticultural stakeholders were acknowledged as potentially valuable sources, given their experience with heat and thermal storage, it was not possible to include them in the interview pool. Also, the issue of water usage was left out, since it was rarely mentioned in the interviews and, relative to other industrial sectors, this was not seen as a pressing concern. Besides, international comparisons were explored to some extent within events, contextual differences led to a reduced focus on them. However, this remains a promising direction for future research, as international case studies may yield transferable insights. There was also limited attention given to the use of heat from data centres in business-to-business applications, such as supplying heat to pools, greenhouses, or nearby industries, despite the existence of early-stage examples. This line of inquiry could form the basis of a possible business case in future studies. The emergence of quantum computing and AI-driven high-performance computing was recognized in the problem definition as part of a broader trend of digitalization. However, the research did not explore in depth how different computing applications, like storage vs. compute, influence energy consumption on a large scale. Even though this was raised in some interview, due to time and resource constraints of these projects, this was left out. Additionally, the integration of data centres into Energy Hubs was only briefly addressed. Although this concept has potential, it is still considered a niche and was therefore not explored further. Nonetheless, it represents an opportunity for future research. Finally, the impact of spatial planning was not taken into account, the importance of spatial planning is great and this is also partly referred to as ‘energy planning’ as discussed is the earlier chapters. However, spatial planning is again a very new component, so due to a time and resource shortage it could not be looked at further. For future research, however, it is recommended to include this. It requires a fundamental shift in perspective and a collective willingness to make concessions to unlock the potential of data centres as valuable intermediaries in the energy transition. Future research could start with building on these insights by validating the pathways with stakeholders and investigating the practical implementation of the identified policy incentives.

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B. AI statement

To write this thesis, AI was used in various ways. This statement clarifies how AI was used to provide a fair insight into the areas where it contributed. Four different AI software were used: ChatGPT, Perplexity, NotebookML, and DeepL.

ChatGPT (free version) was first used during the brainstorming phase of the research to generate ideas for further exploration. This was helpful in exploring alternatives and checking when I, as a researcher, was stuck in a loop. For example, I asked ChatGPT questions like: "*Can you explain what a data centre is and what it does?*" I also asked Chat to summarize small pieces of text to determine whether the text was worth reading further. For example, by asking about a newspaper article: "*Hi Chat, can you give me a two sentence summary of this text?*" Besides this, I used ChatGPT to translate my texts at times. In some cases, I wrote parts in Dutch and then asked ChatGPT to translate them: *Hi Chat, can you translate this text to Englisch for me?".* I then reviewed the translations myself to ensure I agreed with them and made adjustments as needed. Last, I used ChatGPT to give me feedback on some parts I had writing, for example uploading Chapter 4 and asking questions like: "*Hi Chat, Can you give me feedback on the written text I have uploaded?".* I have used this feedback to improve my texts or to get new suggestions on how I could better address some points. Sometimes, I thought that the feedback was not so useful, in that case I didn't implemented it.

Perplexity (free version) works similarly to ChatGPT but also provides example articles showing where it found its information. This was helpful at the beginning when I needed to gather a lot of information. However, I quickly noticed that it mainly referenced to American sources, which were less relevant to my Dutch research. Therefore, as the research progressed, I stopped using Perplexity.

NotebookML (free version) is an AI tool that can compare sources or summarize them into a single text. I used it in some cases to look for comparison between the materials of two reports, articles, or interviews. This form of AI sometimes inspired me with ideas on how to compare certain parts. For example, I uploaded five documents about increasing energy efficiency measures and asked, "*Can you explain to me which energy efficiency measures are most frequently discussed within these documents?".* The tool gave me a list and I checked the sources again if this did align. This was helpful to generate ideas, however some logics were not sufficient to my understanding, therefore I meanly used it as inspiration.

Last, I used *DeepL* (free version) to make some translations to English when I didn't know how to make the English translation. This AI technology works similar to Google Translate.

Concluding this AI statement, despite using these AI tools, to the best of my knowledge, all information has been verified and cited where necessary. Therefore, I stand by the written texts.

Appendix

Appendix A. Different Dutch Data Centres

Table A. Overview of different types of data centres.

Type of data centre	*Enterprise*	*Colocation*	*Hyperscale*
Single or multi-tenant	Single-tenant	Multi-tenant	Single-tenant
Definition	The main purpose of an enterprise data centre is for an instance to have internal IT and business applications	These data centres provide space, power, and cooling for servers owned by different organizations. They range in size from small facilities to large complexes, depending on client needs (Zhang, 2024).	This is a data centre from one owner with a built-up floor area of more than 10 ha and an electrical connection capacity of +70 MW (de Jonge, 2023).
Ownership	One company	Third-party provider	Big tech companies
Active companies in the Netherlands	The Dutch government, Hospitals, educational instances	Switch, Equinix, Digital Realty, EdgeConneX, Iron Mountain, Eurofiber	Microsoft, Google, Amazon
Locations in the Netherlands	In all provinces	In all provinces, best with a 10km span radius from each other.	Middenmeer 2x (Noord-Holland), Eemshaven 1x (Groningen)
Scalability	Limited – depending on company's capacity	High – space can be leased	Very high – mega and superscale data centres.
Efficiency	Average, A PUE between 1.2 – 1.4 (Rijksdienst voor ondernemend Nederland, 2025b)	Average, A PUE between 1.2 – 1.4 (Rijksdienst voor ondernemend Nederland, 2025b)	Highest system cost and energy efficient

Appendix B. Interview Participants and Attended Events

The participants, participating within the interviews have signed a consent from, all interviews are summarized and checked by the interview participant and all interviews (except the group interview) are recorded and transcribed, an overview can be seen in Table B1. The transcripts of these interviews are not publicly available, if someone wishes to have access to them, the researcher can be contacted. All materials are located on the TU Delft one drive. In addition to the interviews, four extern events were attended, which are also added in Table B1. Besides this, some interview participants were cited, these references can be seen in Table B2. It is checked with the participants if the citations have been correctly adopted.

Webinear data centers in the MRA (Metropool region Amsterdam) – 15th of January 2025

This was an online webinar which I attended, the webinar data centres in the Amsterdam metropolitan region was an online event organised by the Amsterdam metropolitan region (MRA). During this online session, various stakeholders discussed their perspectives on the development of sustainable data centres in the Netherlands. Organizations telling their perspectives were the MRA itself, the province of North Holland, the province of Flevoland, the municipality of Amsterdam, the Ministry of Economic Affairs and Climate, Dialogic (research institution) and Stratix (IT consultant).

Data Could energy & ESG - 5th of March 2025

The Data Could Energy & ESG congress took place on the 5th and 6th of March in Brussels, Belgium. This is a two-day congress connecting industry partners and for information exchange. This included speakers, workshops and networking moments. During this event, it was possible to talk informally with people in the data centre industry. In addition, the various speakers gave an overview of the general development of sustainability in European data centres. This event was organised by a European data centre branch, so data centres were representative in high numbers, but also industry partners were present to highlight the status of sustainability projects. This event contributed to a broader base knowledge of the industry currently and some future developments.

EnergyLab Zuid-Oost annual seminar - 27th of March 2025

The Energy Lab southeast annual update event took place on March 27, 2025 in Amsterdam. During this event there were speakers, workshops and the opportunity to network. Several stakeholders from Amsterdam southeast were present at this event. Sustainability projects in the region were discussed, including a number of projects involving data centres and heat. This event contributed to a broader base of knowledge of social obstacles to realizing heat network projects in Amsterdam.

Workshop EML duty to investigate for data centres – 23rd of April 2025

This workshop was organized by the Omgevingsdienst Noordzeekanaalgebied (environmental service of the region of Amsterdam) in collaboration with the branch organisations DDA (Dutch Data Centre Association) and NL digital, the goal of this workshop was to brainstorm with data centre owners about energy efficiency measures they could take. Several data centres and a number of other interested parties were present at this event. It was interesting to see the dynamics between the data centre operators, the industry organisations and controlling organisations such as the environmental department. During this workshop, a clearly different composition could be seen, projects were made less 'pretty' and there was more reality than what people say in 'on-record' interviews.

Table B1. Overview of interviews and events as references

Reference in text (Interview)	***Expertise***	***Info***
Interview Consultant1	Consultant - ICT	One-on-one Online
Interview consultant2	Consultant – Energy transition	One-on-one Online
Interview Data centre branch	Data centre branch – Dutch Data Center Association	One-on-one Online
Interview AMS institute	AMS institute – Heating networks in Amsterdam	One-on-one Online
Interview Switch Datacenters1	Data centre - Switch Datacenters	Group interview
Interview Switch Datacenters2	Data centre - Switch Datacenters	Group interview
Interview Municipality Diemen1	Municipality Diemen - Policy Officer	Group interview
Interview Municipality Diemen2	Municipality Diemen - Policy Officer	Group interview
Interview Municipality Diemen3	Municipality Diemen - Heat transition expert	One-on-one Online
Interview Equinix	Data centre - Equinix	One-on-one Online
Interview EdgeConneX	Data centre - EdgeConneX	One-on-one Online
Interview VvE	VvE-bond	One-on-one Online
Interview Province Noord-Holland	Province Noord-Holland - Heat transition expert	One-on-one Online
Interview Data steward TU Delft1	TU Delft - Data steward	One-on-one Online
Interview Data steward TU Delft2	TU Delft - Data steward	One-on-one Online
Interview Data Steward TU Delft3	TU Delft - Data ICT expert	One-on-one Online
Interview MeerEnergie	Local heat cooperation - MeerEnergie	One-on-one Online
Interview Firan	Heat operator - Firan	One-on-one Online
Interview Liander1	DSO - Liander	Two-to-one Online
Interview Liander2	DSO – Liander - Data centres expert	Two-to-one Online
Interview RVO	RVO	One-on-one Online
Interview Asperitas	Data centre cooling technology - Asperitas	One-on-one Online
Interview Investment company	Investment company - PGGM	One-on-one Online
Interview Omgevingsdienst Noordzeekanaalgebied	Omgevingsdienst Noordzeekanaalgebied (environmental service of the region of Amsterdam)	One-on-one Online
Reference in text (Event)	***Event and Expertise***	***Info***
Event Webinear data centers in the MRA	Webinear data centers in the MRA – Data Centres in the Netherlands	Online Webinar
Event Data Could energy & ESG	Data Could energy & ESG – Sustainable Data Centres in Europe	Conference
Event EnergyLab Zuid-Oost	EnergyLab Zuid Oost annual Seminar – discussion session with involved stakeholders	Annual seminar
Event Workshop EML	Event to explain EML duty for data centres	Workshop

Table B2. Overview Interview citations

Reference in Text	***(Sub)section***	***Interviewee***	***Role/working at***
Rood (2025)(Role) citate	3.4.2; 3.4.2	Hendrik Rood	Consultant
Van der Woude (2025)(Role) citate	3.3.3	Dirk van der Woude	President of a Dutch VvE Association
Brandligt (2025) (Role) citate	3.3.3	Stephan Brandligt	Consultant
Van Essen (2025) (Working at) citate	3.1.2; 3.3.2; 3.3.4; 3.4.2	Edgar van Essen	Switch Datacenters
Voskuilen (2025) (Working at) citate	3.4.2	Paul Voskuilen	AMS Institute
Goede (2025) (Working at) citate	3.3.4	Siem Goede	Municipality Diemen
Grove (2025) (Working at) citate	3.1.2; 3.3.4	Stijn Grove	Data centre branch
Schelvis (2025) (Working at) citate	3.3.1	Hans Schelvis	Equinix

Schaart (2025) (Working at) citate	3.3.3; 3.4.1	Leonie Schaart	Firan
Nicolaï (2025) (Working at) citate	3.3.3	Ardine Nicolaï	Neighbourhood cooperative
Barendsen (2025) (Working at) citate	3.1.5	Erik Barendsen	Province of Noord-Holland
Oost (2025) (Working at) citate	3.3.4; 3.3.4; 3.4.1; 3.4.2	Maurice Oost	Liander
Dintzner (2025) (Working at) citate	3.1.4	Nicolas Dintzner	Data steward, TPM, TU Delft
Newton (2025) (Working at) citate	3.3.3	Arthur Newton	Data TU Delft
Boonstra (2025) (Role, Working at) citate	3.1.4	Lolke Boonstra	Research ICT Expert, TU Delft
Lambregts (2025) (Working at) citate	1.1	Marlies Lambregts	Omgevingsdienst Noordzeekanaalgebied

Appendix C. Consent Document Interviews

Participant information Interviews Master thesis – Suzanne Meijer:

Opening statement:

You are being invited to participate in a research study titled *Balancing growth and sustainability – Mapping the future of data centres in the Netherlands*. This study is being done by Suzanne Meijer, a student from the TU Delft.

The purpose of this research study is to create an overview of the Dutch digital landscape in which Data Centres might act as intermediary between the electricity and heat sector and will take you approximately *45 – 60* minutes to complete. The data will be used to get a better understanding of the current situation in the Dutch digital landscape, to create effective policy recommendations within this master thesis project. I will ask you to answer questions about your views and ideas on the Dutch digital landscape.

Besides your answers, the only additional information needed for this research is: name, email and working position. Only the last (working position) will be used in the final rapport, the other personal information will be used for contact with the researcher, this information will not be shared with others. The interview will be recorded and transcribed via Microsoft Teams and saved at the TU Delft. The data will be stored in such a way that only the researcher can see it. Within a maximum of one month after the graduation (expected 1 July), all personal data will be deleted [recording and transcript].

I will create a summary of the interview and send it back to you so you can give feedback on the information that will be seen in the thesis, which will be made publicly available.

Your participation in this study is entirely voluntary, and you can withdraw at any time. You are free to omit any questions. Once you wish to remove any data later, you can let the researcher know this any time and then this part of the data will be removed.

If you have any questions you can contact Suzanne Meijer or Responsible researcher Aad Correljé

I have read and understood the information, and I give consent to participate and to the data processing described above.

Signature

____________________________	___________________________	________
Name of participant:	Signature	Date

Appendix D. Example of Interview Preparation (Dutch)

Beste …,

Aanstaande [datum] om [tijd] uur hebben we ons geplande interview via Teams. Je kunt deelnemen via deze link, die ook in de eerdere uitnodiging staat. [Link]

Met jouw toestemming zou ik graag het interview opnemen om het later te kunnen terugluisteren, te transcriberen en samenvatten. Een paar dagen na het interview stuur ik je een samenvatting toe. Ik heb ook een toestemmingsformulier toegevoegd in de bijlage; zou je dit willen ondertekenen? Dit is nodig voor de ethische goedkeuring van de TU Delft.

Ik verwacht dat het interview ongeveer 45 minuten zal duren, afhankelijk van hoe onze discussie verloopt.

Wat betreft mijn onderzoek: ik doe een afstudeeronderzoek van zes maanden aan de TU Delft - Faculteit Techniek, Bestuur en Management, van februari tot juli. Mijn focus ligt op de rol van datacenters in Nederland in de energietransitie, waarbij ik kijk naar technische mogelijkheden, wet- en regelgeving, economie en sociale acceptatie.

Op dit moment onderzoek ik duurzame technologische opties die datacenters kunnen toepassen om bij te dragen aan de energiesector. Een van de aspecten waar ik me op richt, is hoe datacenters kunnen bijdragen aan de energietransitie door gebruik van restwarmte of het inzetten voor energie flexibiliteit.

Ik geloof dat jouw expertise hierbij van waarde kan zijn. Daarom heb ik een aantal gesprekspunten opgesteld voor het interview, als leidraad. Dit zijn suggesties en het gesprek kan natuurlijk anders verlopen:

1. Kun je kort vertellen wat je huidige rol is en waar je dagelijks mee bezig bent?
2. Heb je eerder ervaring gehad met datacenters in je werk?
3. Wat denk je dat momenteel de grootste uitdagingen zijn rond om net congestie in Amsterdam en/of data centers daar een rol in kunnen spelen?
4. Hoe gaan jullie om met sociale acceptatie in de regio? Merk je daardoor dat projecten belemmerd worden?
5. Wat zijn volgens jou succesfactoren die een project nodig heeft om gerealiseerd te kunnen worden?
6. Momenteel wordt veel gesproken over restwarmte gebruik, maar hoe om te gaan met koeling? Wanneer AI-chips meer warmte gaan genereren en vanuit consumenten ook een vraag naar koeling komt?
7. Denk je dat er toekomst is om waterstof te integreren in het systeem van datacenters en energie?

Ik kijk ernaar uit om hierover verder met je te praten tijdens het interview. Mocht je vooraf nog vragen hebben of iets willen bespreken, laat het me gerust weten.

Met vriendelijke groet,

Suzanne Meijer

Appendix E. Additional Background Information

This appendix provides additional background information which can be helpful for readers who do not have complete knowledge regarding some aspects discussed in Chapter 3. Appendix E.1 provides additional technical background information, and appendix E.2 gives additional information regarding EU policies and regulations.

E.1 Technical Background

Additional technical background information from Chapter 3.

The Dutch electricity grid (subsection 3.1.1 Grid Congestion)

Briefly, the Dutch electricity grid consists of the following components, electricity is generated, by a power plant running on conventional energy such as gas or coal, but this can also be wind or solar energy. This energy is then transported via a high-voltage line to a high-voltage substation owed by the Dutch transmission operator (TSO): TenneT. There, it is further distribution via a local high-voltage line to a transformer station, which all happens above ground. For the next stage, the ownership is changed from TenneT to a local power distribution company, called the distribution operator (DSO), like Liander, Enexix or Stedin. From the transformer station, an underground medium-voltage cable transports the electricity further to a transformer house and from there, as a final step, an underground cable goes to the consumers (Kennisplatform, n.d). When more energy flows across the grid than the grid can handle, a traffic jam is created, which is called *grid congestion*. This can be caused on all levels, high-voltage, local high-voltage, medium and low voltage. When grid congestion occurs, the power will be cut off, so the grid operators, try to avoid this as much as possible (Rijksdienst voor Ondernemend Nederland, 2025a).

Short term grid congestion solutions (subsection 3.1.1 Grid Congestion)

A key initiative is GOPACS, a congestion management platform developed by Dutch grid operators (Netbeheer Nederland, 2025). It connects grid operator demand with market participants offering flexible capacity (GOPACS, n.d.). GOPACS helps identify congestion issues, specifies required volumes, and aggregates flexible bids from multiple platforms. It enhances efficiency by combining bids of different durations (15, 30, or 60 minutes), thereby expanding participation and improving grid utilization.

Cable pooling is another collective solution, allowing multiple users to share a single grid connection. This maximizes use of existing infrastructure, especially where new connections are difficult to establish. Under the new Dutch Energy Act, this is legally permitted with notification to the Authority for Consumers and Markets (Authority for Consumers & Markets, 2024; Netbeheer Nederland, 2024).

Higher energy efficiency due to reuse of heat (subsection 3.1.2 Data Thermal Solutions)

Reusing heat is a promising approach to increase the overall efficiency of a data centre (Yuan et al., 2023). Terenius et al. (2022) has underscored the value of the Energy Reuse Effectiveness (ERE) score, which is similar to the PUE but takes heat reuse into account, which can be shown by this equation:

$$ERE = \frac{Total\ Facility\ energy - Reused\ energy}{IT\ Equipment\ energy}$$

**Equation by Terenius et al. (2022)*

Yuan et al. (2023) has investigated different data centre reuse possibilities which can increase the ERE. They recommend the next five rules to take into account to obtain the highest ERE scores. First, using heat nearby, by increasing the transportation distance, the ERE will go down. Second, heating can be most effectively reused for heating supply of the data centre itself. Third, heat pumps can increase the heat temperatures and heat storage systems are needed to balance the mismatch in supply and demand of heat. Last, optimization methods and economic analysis differing per data centre will obtain the best ERE.

Other data centre heat applications (subsection 3.1.2 Data Thermal Solutions)

Ebrahimi et al. (2014) has analysed nine different technologies based on economic and technological possibilities, among them reusing heat in district heating networks. They conclude that using heat in absorption refrigeration and the organic Rankine cycle is the most effective. Absorption refrigeration is a cooling process that uses heat energy instead of mechanical energy to provide cooling. In the context of data centres, this can utilize the heat generated by servers to power the cooling cycle. This system replaces the need for electricity-driven compressors in traditional cooling systems, reducing overall energy consumption. The organic Rankine cycle is a thermodynamic cycle that converts low-temperature heat into electricity. Data centres can harness the low-grade heat to generate additional electricity. Which can be used to power other data centre operations or fed back into the grid. According to Ebrahimi et al. (2014) both technologies can be more beneficial for data centre heat applications by improving energy efficiency, and reducing costs, environmental impacts and needed cooling space. However, the effectiveness in practice, need to be further investigated.

E.2 Institutional Background

Main EU level policy regulations regarding data industry (subsection 3.3.3 Current Policy)

These are the different policy regulations regarding the data industry at the moment: First, *the Corporate Sustainability Reporting directive* (CSRD), big companies (companies with a net turnover of €50 million, over €25 million on the balance sheet or over 250 employees) are required to have a sustainability report and need to review this by an auditor (Rijksdienst voor Ondernemend Nederland, n.d.). This CSRD effects hyperscale data centres most, but there are also more legislation that effect colocation and enterprise data centres as well. The *Enhanced Energy Efficiency Directive* (EED) is a regulation from the European commission to help reduce the overall energy consumption, Dutch data centres must comply with this directive (European Commission, n.d.). The *EN 50600 standard* is the first international standard for data centres within Europe. The EN 50600 series of standards consists of ten standards and two standards available as drafts. These standards are set to provide a standard determining many of the aspects of a data centre (NEN, 2024). The *NEN-ISO 22237*, is a standard as of the first of October 2021, which is created for data centres to meet desired levels of availability, security and energy efficiency. This standard entails: a business risk and operational costs analysis, determined availability, security and energy efficiency over the lifetime of the data centre and sets some design principles (NEN, 2021). The *Codes of conduct* (CoCs), which are European voluntary programmes for the ICT sector that have been introduced since 2000. Currently, there are four CoC for ICT products in place: External Power Supplies, Digital TV Systems, Broadband Equipment and UPS. All the CoCs set specific efficiency requirements for specific products on a voluntary basis, but once a company participates, they have to meet the performance levels and report the energy consumption of their products annually (Avgerinou et al., 2017). Last, the European AI Act, in place since the first of August 2024, constitutes the world's first comprehensive legal framework for artificial intelligence (AI). This legislation aims to promote reliable and human-centred AI, protect citizens' fundamental rights and foster innovation in the EU. The European AI Act includes some provisions on sustainability, but these are often considered insufficient by experts. The legislation recognises the need to regulate the environmental impact of AI, but imposes only limited obligations and largely relies on voluntary measures and future standardisation (Bakker, 2025).

Appendix F. Overview Abbreviations in the Pattern Model

Table F. Overview of abbreviations pattern model (figure 2.2, 3.2 till 3.19, 8.1)

Domain	*Abbreviation*	*Meaning*
Technical	*D*	*Decentralisation*
	DEF	*Data centre Energy Flexibility*
	DTS	*Data Thermal Solutions*
	EE	*Energy Efficiency*
	GC	*Grid Congestion*
	RE	*Renewable Energy*
Institutional	*EU*	*European Union*
	GC:P	*Grid Congestion: Prioritisation*
	LG	*Local Government*
	NG	*National Government*
	VvE	*Vereninging voor Eigennaren (Association of Owners)*
	WCW	*Wet Collective Warmte (Collective Heat Act)*
Economic	*BC*	*Business Case*
	Co	*Collaboration*
	IT	*Import Tariffs*
	L	*Location*
	L&R	*Land & Resource*
	SA:C	*Social Acceptance: Community*
	TC	*Transaction Costs*

Appendix G. Zoom-in Figure 8.1

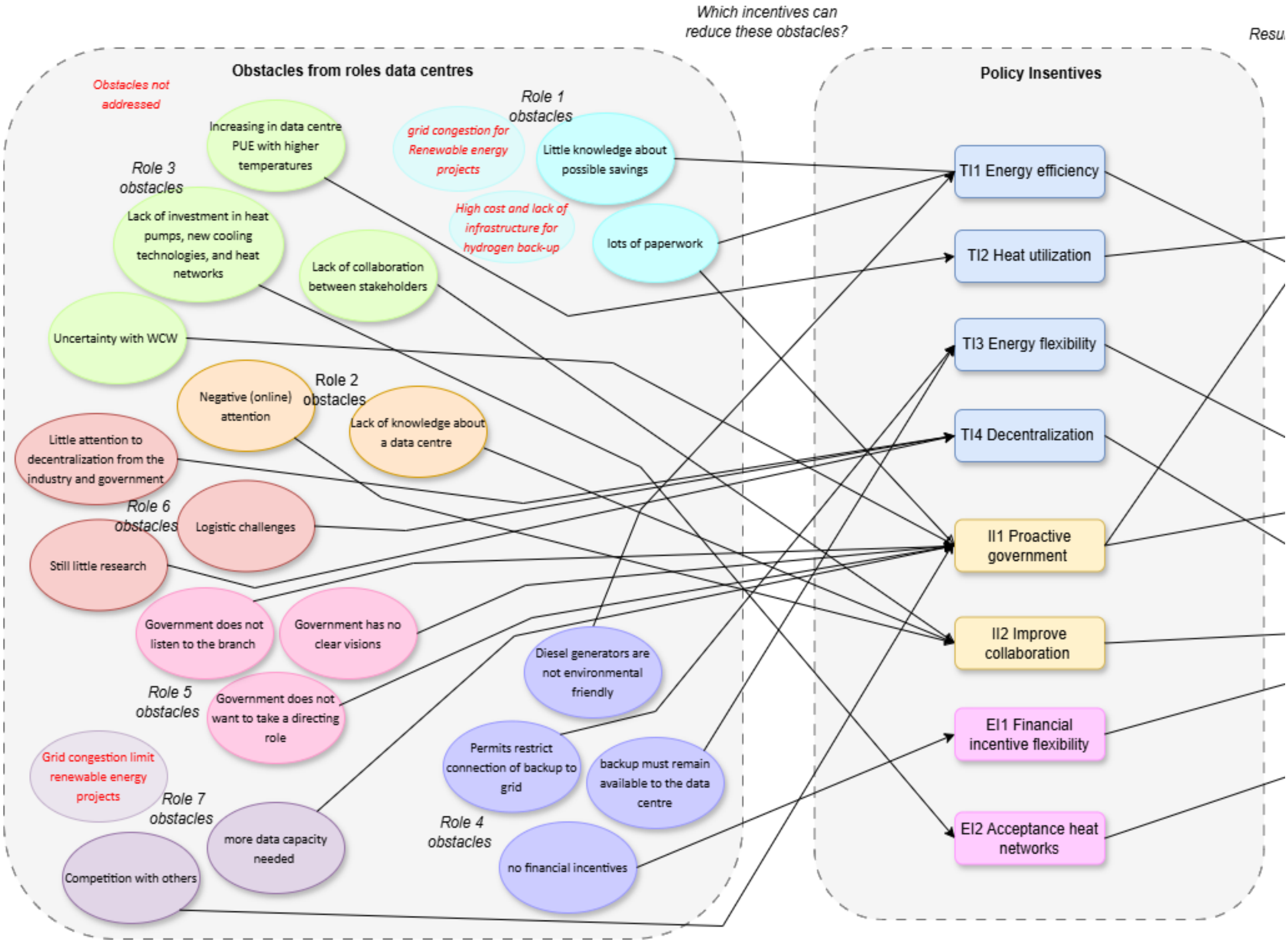

Figure G.1 Zoom in figure 8.1 (left and middle part)

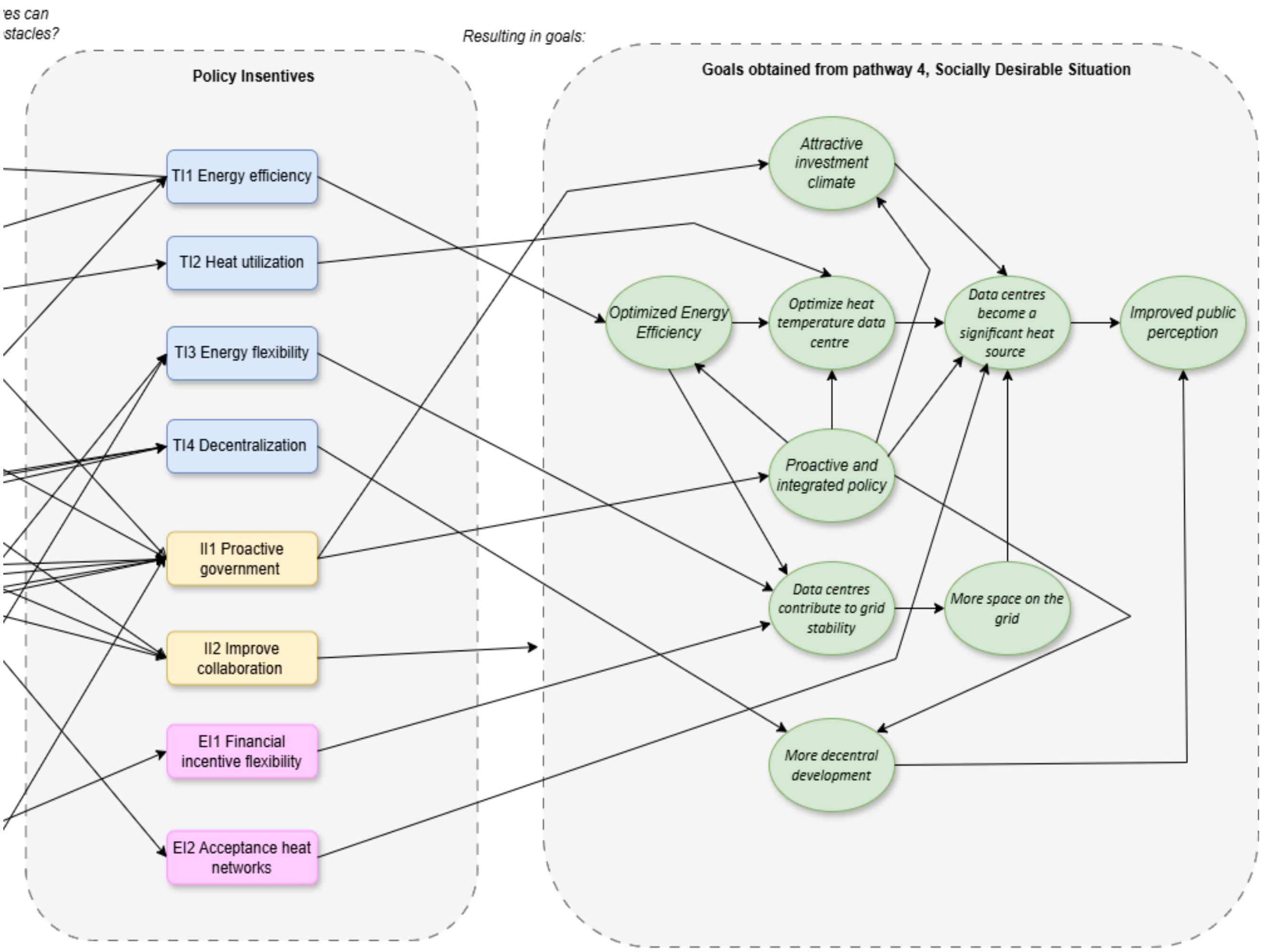

Figure G.2 Zoom in figure 8.1 (middle and right part)