Understanding flexibility in the Dutch electricity market and its adoption

An analysis of the barriers through the lens of Transaction Cost Economics

MSc Thesis CoSEM

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Preface

This thesis marks the end of my Master's degree in Complex Systems Engineering and Management at the Faculty of Technology, Policy and Management at Delft University of Technology. This six-month journey also marks the end of my time as a student - a time in which I have learnt a great deal about myself, formed new friendships and grown both personally and academically. I would like to take this opportunity to thank everyone who has helped me reach this milestone.

I am deeply grateful to my thesis committee for their valuable guidance and feedback throughout this process. My sincere thanks go to Laurens de Vries, my first supervisor, for his academic support and for helping me structure my thesis. Your expertise in the electricity market and your passion for the energy sector, which I have admired since my undergraduate days, have been truly inspiring. I would also like to thank Aad Correlje, my second supervisor, for his feedback and thoughtful perspective that helped shape this thesis.

I would like to thank Sugandha Chauhan for her continuous support, countless meetings and invaluable input. You have been a constant guide from the beginning, always available to answer questions and provide feedback. Your expertise, insights and encouragement were essential in shaping this thesis and your ability to keep me grounded and focused was greatly appreciated.

I am also grateful to all the interviewees I have had the privilege of speaking with for this research. Their insights, frustrations and visions were essential to this thesis. Without your time and willingness to share, this research would not have been possible.

Finally, I would like to thank my parents, Noortje, roommates, fellow graduates, and other close friends. Your support, whether it was during coffee breaks, words of encouragement or other moments, throughout this journey has meant so much to me. Thank you for listening, understanding and always being there.

Wessel Donkervoort
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Summary

The global transition to decarbonisation presents significant challenges for electricity systems worldwide, particularly in integrating renewable energy sources while maintaining grid stability. This challenge is also evident in the Netherlands, where increasing grid congestion and a lack of flexibility hinder optimal grid utilisation, posing obstacles to achievement of renewable energy targets. A more flexible electricity system is essential for maximising grid capacity, reducing reliance on infrastructure expansion, and enabling the integration of new energy users. However, despite the technical feasibility of flexibility measures, their adoption remains limited due to a combination of regulatory, market, and behavioural barriers.

This research investigates the factors influencing the decision-making of large electricity users in the Netherlands regarding the adoption and utilisation of flexibility options. The main research question guiding this study is:

What policy, market, and behavioural factors influence the decision-making of actors in the Dutch electricity market to adopt and utilise flexibility options effectively?

The study focuses on demand-side flexibility and examines key stakeholders, including system operators, market participants and end users. A qualitative methodology was used, consisting of an literature review, policy analysis and semi-structured interviews with industry experts. Transaction Cost Ecnomics was used as a theoretical framework to analyse how bounded rationality, opportunistic behaviour and institutional inefficiencies contribute to the barriers to flexibility adoption.

The findings reveal a persistent lock-in in the Dutch electricity sector, which divides electricity users into two distinct groups. The first group consists of those who are willing but unable to offer flexibility due to infrastructure constraints such as insufficient grid capacity. These companies recognise the benefits of flexibility but face external constraints that prevent them from participating in flexibility markets. The second group consists of those that are able but unwilling to engage in flexibility activities. These companies have the technical capacity to implement flexibility solutions but are deterred by economic barriers, operational concerns and uncertainty about profitability. For this group, transaction costs - such as high search and information costs, contractual complexity and perceived financial risks - outweigh the expected benefits of participating in flexibility markets.

A key challenge for flexibility uptake is the difference in priorities between system operators and end users. While system operators focus on maintaining grid stability, end users prioritise operational security and profitability. This divergence makes companies reluctant to adopt flexibility solutions, even when they recognise the potential benefits for the electricity system. In addition, inadequate tariff structures, regulatory uncertainty and a lack of confidence in market mechanisms further discourage participation. The study also highlights the broader systemic nature of these challenges, emphasising that flexibility uptake is not just a technological issue, but also an institutional and market design issue.

To address these barriers, the thesis proposes several policy and market interventions. First, expanding the use of flexibility scans can help assess the flexibility potential of firms and provide them with targeted recommendations. Second, reforming the grid connection waiting list system to prioritise firms willing to offer flexibility can create stronger incentives for participation. Third, introducing financial instruments to cover post-implementation operating costs would ensure that companies are supported beyond the initial investment phase. In addition, strengthening cooperation and communication between system operators and end users is essential to bridge the gap between technical feasibility and practical implementation. Finally, regulatory reforms and strategic energy planning are needed to align industrial development with grid development and ensure that flexibility solutions are integrated into broader policy objectives.

The research shows that while technical solutions for flexibility exist, their implementation is constrained by socio-institutional factors, including fragmented responsibilities, high transaction costs and insuffi-

cient cooperation between stakeholders. Reducing these transaction costs through targeted interventions - such as increasing transparency, improving contractual structures and providing clear regulatory signals - will be crucial to realising the full potential of flexibility. By addressing these challenges, the Dutch electricity system can move towards a more efficient and resilient grid, supporting the energy transition while ensuring system stability and economic viability for its users.

Contents

Nomenclature

Abbreviations

Abbreviation	Definition
ACM	Autoriteit Consument & Markt
ATO	Connection and Transmission Agreement
CBC	Capaciteitsbeperkingscontract
CEP	Clean Energy Package
CSP	Congestion Service Provider
DSO	Distribution System Operator
DSR	Demand-side Response
EIA	Energie-investeringsaftrek
GHG	Greenhouse Gas
GTV-E	Gecontracteerd Vermogen voor Afname
GTV-T	Gecontracteerd Vermogen voor terugleveren
ISDE	Investeringssubsidie duurzame energie en energiebesparing
NFA	Non-firm ATO
NRA	National Regulatory Authority
RTP	Real-time pricing
RVO	Rijksdienst voor Ondernemend Nederland
SDE++	Stimuleringsregeling Duurzame Energieproductie en Klimaattransitie
TCE	Transaction Cost Economics
TSO	Transmission System Operator
VEKI	Versnelde klimaatinvesteringen industrie
vRES	Variable renewable energy

1 Introduction

After decades of fossil fuel-driven economies and energy production, the urgency to halt climate change by decreasing greenhouse gas (GHG) pollution has become clear [9]. In 2021, 60.2% of the emissions in Europe originated from the energy and industry sectors, highlighting the significant impact these sectors have on the environment [31]. As a result, the European Union has been striving to decarbonize these sectors by adopting multiple climate action strategies, including the European Green Deal, the Clean Energy Package, and the Fit-for-55 package, with the goal to achieve a carbon-neutral Europe by 2050 [27]. Recent events, such as the invasion of Ukraine and the ban on Russian fossil fuels, have further jeopardized Europe's energy security, prompting a reconsideration of its energy dependency and accelerating its commitment to becoming carbon-neutral [76, 29]. These factors rapidly transform the energy sector, introducing significant complexity and challenges for the energy system and its stakeholders.

While the broader energy sector faces multiple challenges due to decarbonization efforts, the electricity system is particularly affected. Unlike other parts of the energy system, which often benefit from more stable and predictable conditions, the electricity grid requires constant real-time control and rapid responses to fluctuating demand and supply. The increasing pace of electrification also affects this complexity, putting additional strain on the system [64]. This intensifying pressure on the grid and congestion problems in the Netherlands highlight the urgent need for innovative solutions to manage rising energy demand and balancing decentralized energy production where daily and seasonal fluctuations are central to the problem. Addressing these challenges requires a rethinking of both operational strategies and the regulatory environment to ensure a reliable and flexible electricity system that can meet current and future needs.

1.1. The need for flexibility

The conventional electricity sector was a straightforward system characterized by centralized production, predictable flows, low congestion, and simple transmission of electricity from producer to consumer. With the adoption of variable renewable energy (vRES) sources, this conventional system has transformed into a complex one, where new challenges such as intermittency, decentralized power production, bidirectional distribution, daily and seasonal fluctuations, and mismatches in energy demand patterns have led to less stable and reliable energy grids [55]. As a result, these new market characteristics reveal growing challenges in the coordination and planning of conventional and back-up generators, the predictability of the electricity market, which heavily impact the prices for consumers, and affect various stakeholders on both sides of the electricity system.

To keep the grid operational and allow for the achievement of environmental goals, the modern electricity sector requires new mechanisms to handle this decentralised production, daily intermittent patterns and seasonal fluctuations. These mechanisms are collectively described as flexibility options. This includes options like adjustable generation, demand-side management, large-scale conversion (Power-to-X), electricity storage, cross-border trade, and curtailment of renewable generation [64]. These flexibility options require a high level of utilization and a low response time in order to counter short-time disturbances on the market. Flexibility options can be integrated in different sectors and levels of the systems, such as residential, commercial, industrial, and transportation sectors [11]. These mechanisms can positively impact the system by grid balancing, the use of storage, market performance, and may potentially eliminate the need for large-scale system upgrades and reduce price fluctuations [8, 11]. It may further improve the effective use of transport capacity and support the growing intake and planned amount of variable renewable energy generation. However, even with the high amount of potential flexibility in the Dutch electricity sector, the widespread utilisation is low and congestion is high. Changes in consumption and production behaviour are needed to better utilise the electricity grid [67].

1.2. Knowledge gap & research objective

While flexibility and demand-side response (DSR) are widely regarded as solutions with few technological barriers, their effectiveness and success rely on the ability and willingness of electricity end-users to adapt their consumption patterns. Although much research has been conducted on the programme characteristics and impact of flexibility and DSR, limited studies have examined the factors that influence end-user decisions in relation to DSR programmes and the social aspects of behaviour [16, 33].

A recent study by Boston Consulting Group [14] indicates that the current deployment and utilization of flexibility options in the Dutch electricity market are insufficient to significantly alleviate grid congestion. During a recent voluntary program to use flexible capacity among large electricity consumers in the province of Utrecht, only 8% of the potential capacity was made available [25]. This highlights barriers or failures in the market that prevent actors from making their flexibility capacity accessible, resulting in social costs that could amount to tens of billions in the short term [14]. This is not limited to the Dutch electricity sector, as Stagnaro and Benedettini [58] implies that literature and research on the technical and economic potential for demand-side flexibility is large, the amount of evidence on this turning into reality is limited. To understand what influences the decision-making of these market participants, it is essential to investigate the underlying factors that influence their behaviour.

Extensive research has already been conducted on flexibility in households and the transport sector. However, there is a significant knowledge gap regarding the decision-making process of large stakeholders and industries that could provide flexibility. Industrial demand response has faced substantial resistance [64]; however, it remains unclear which barriers hinder its implementation. It is crucial to examine how voluntary participation or contributions from the industrial sector can be encouraged. This goal is further supported by researches from entities like TNO [61, 62], recurring themes in the Multi-year Mission-driven Innovation Programs (MMIPs) [34, 66], and inquiries from the Dutch government on the adoption and utilization of flexibility in the Dutch electricity sector.

Building on these studies, along with additional research by Panda et al. [47], Torriti [67], and Stagnaro and Benedettini [58], barriers to flexibility can generally be categorized into four types: technical, regulatory, behavioural, and economic. These barriers hinder stakeholders from adopting or optimizing operational flexibility. Additionally, the lack of adoption and utilization may also be attributed to the institutions governing the market, which may enforce outdated policies, including funding mechanisms, subsidies, rules, and legislation that remain aligned with a conventional energy system rather than a flexible, modern grid [50, 41]. Additionally, the lack of a clear long-term perspective from national policymakers—such as uncertainties around future subsidies or regulatory adjustments—creates hesitancy and uncertainty among market participants, making them reluctant to invest in and operationalize flexibility options [41].

1.2.1. Research objective

The growing uncertainty surrounding the integration and use of flexibility options in the electricity sector underlines the need to understand the associated policies, regulations and challenges. Market and regulatory barriers need to be identified and assessed from the perspective of different electricity market actors. For network operators, including Distribution System Operators (DSOs) and Transmission System Operators (TSOs), making informed decisions about where and when to invest in infrastructure is crucial. These decisions need to take into account the potential impact of flexibility and future market developments. However, policy uncertainty and a lack of incentives make it difficult for demand-side energy market participants to develop business cases for investing in and operating flexibility options.

Given the potential of flexibility options across different market participants and sectors - from large industrial consumers to district heating grids, supply-side curtailment, residential heat pump aggregation and battery storage - the market requires further research to identify barriers and design a regulatory framework that maximises value and aligns with the interests of these actors. Understanding how current market design influences stakeholder decisions is essential to recognising the role of active participation and operational flexibility resources in transforming the electricity system. In addition, new regulations affecting demand response could provide clearer guidelines to enable distributed resources to participate effectively in electricity markets, assist system operators in managing imbalances and congestion, and facilitate new connections for companies currently on waiting lists.

The aim of this thesis is to provide policy makers with a clear understanding of how operational flexibility can be achieved in the Dutch electricity system. It aims to analyse existing market barriers, assess the impact of market instruments on system design and identify tools for active stakeholder engagement. By addressing specific bottlenecks and providing an overview of relevant instruments, regulations and price differences, the study aims to inform strategic investments and highlight policy distortions that affect market incentives.

1.2.2. Main research question

This research will examine the impact of institutions and instruments that influence the integration of flexibility options from the perspective of large electricity consumers and associated key stakeholders. By ensuring that any regulatory changes are aligned with market needs and provide the necessary guidance to decision makers. By using market analysis, policy analysis and insights from expert interviews and relevant stakeholders to gain a deeper understanding of the behavioural and decision-making dynamics in the Dutch electricity market. This approach forms the basis of the research and can be formulated into the main research question, which guides the thesis towards generating new insights and contributing to the field with the aim of understanding how actors can behave efficiently. The main research question, derived from the knowledge gap, is as follows

What policy, market, and behavioural factors influence the decision-making of actors in the Dutch electricity market to adopt and utilise flexibility options effectively?

1.3. Relevance

1.3.1. DEMOSES

This research is part of an overarching NWO research project named *Designing and modelling future systems of energy systems* (DEMOSES). The overall goal of the DEMOSES-project is to develop decision support models and tools for the redesign of the Dutch energy system [68]. The project aims to combine and improve existing energy models from different stakeholders and integrate them to optimise the heat, electricity and gas distribution networks. By integrating and refining existing energy models, the project aims to optimise the interactions between electricity, heat and gas distribution networks, incorporating interdependencies and flexibility mechanisms to improve decision making.

Flexibility plays a crucial role in this optimisation process, in particular in reducing grid congestion and supporting the integration of renewable energy sources. This thesis contributes by investigating the institutional, market and behavioural factors that influence the uptake of flexibility and provides empirical insights into the role of end users in the energy system. The findings will help the project partners to assess whether regulatory interventions, financial incentives or infrastructure investments are the most effective strategies to address short and long term energy challenges. In addition, the integration of real-world flexibility profiles into decision support models can enhance the ability of energy markets and system operators to make informed decisions under evolving regulatory and market conditions.

1.3.2. Societal and academic

The transition to a low-carbon electricity system requires a fundamental shift in the behaviour of stakeholders in the electricity grid. Increasing shares of variable renewable energy sources (VRES), the electrification of demand, and decentralised electricity production are putting pressure on the existing infrastructure in an increasing degree. While technical solutions such as grid expansions and storage technologies exist, their effectiveness depends on the willingness of end-users to adopt and utilise them.

From a societal perspective, flexibility is increasingly seen as a necessity rather than an option. Without sufficient flexibility, grid congestion can lead to higher system costs, inefficient electricity allocation and a potential slowdown in the energy transition. Addressing these challenges requires an integrated approach that takes into account technical feasibility, economic incentives and institutional frameworks. This study examines how current policy mechanisms fit with the practical realities of energy system actors, and identifies where incentives and market structures may need to be adjusted.

From an academic perspective, this work contributes to the study of flexibility deployment, market design and regulatory economics. While there is an extensive literature on the barriers to flexibility adoption in electricity markets, the willingness to adopt flexibility in the Dutch electricity sector remains underexplored. By combining theoretical insights with empirical findings, this research bridges the gap between economic theory and real-world implementation. In particular, it examines how transaction costs, regulatory constraints and behavioural factors shape the decision-making process, providing insights that can inform both future research and policy development.

Ultimately, this study aims to improve understanding of how institutional and market structures affect the uptake of flexibility and what interventions may be needed to align policy objectives with system realities or to identify areas where market failures occur. By addressing key barriers and identifying opportunities for improvement to support a more resilient, efficient and sustainable electricity market.

1.3.3. MSc program

This thesis is part of the Complex Systems Engineering and Management (CoSEM) programme, which focuses on addressing complex challenges in socio-technical systems. As outlined in the societal relevance, this research examines a key issue within the Dutch electricity sector, where market design, policy and institutional structures influence the adoption of flexibility. Using a holistic approach, this study integrates technical, economic and policy perspectives, in line with the interdisciplinary focus of the CoSEM programme.

The research aims to identify how policies and regulations create barriers to the adoption of flexibility by limiting incentives for market participants. To achieve this, a stakeholder, policy and institutional analysis will be conducted, complemented by interviews with key stakeholders. Through this analysis, the study will provide insights into institutional barriers, stakeholder interactions and regulatory frameworks to support policy recommendations that can improve market efficiency and enhance the integration of flexibility into the energy system.

1.4. Thesis outline

This thesis is divided into eleven chapters, beginning with an introduction in Chapter 1. Chapter 2 provides the necessary background information to set the context for the theoretical framework outlined in Chapter 3. Chapter 4 details the research approach and the sub questions that form the basis of the analytical framework used in this study.

Chapter 5 examines the market structure and institutional framework of the Dutch electricity sector, while Chapter 6 examines the instruments that influence the decision-making of market participants. The findings from these analyses, combined with the theoretical framework, form the basis for the interviews, the results of which are presented in chapter 7.

Chapter 8 integrates the findings from the analyses and interviews into the theoretical framework and provides an in-depth analysis of their implications. Chapter 9 presents a discussion of the findings, reflecting on their wider significance, limitations and future research. The final conclusions and policy recommendations are presented in Chapter 10, followed by a personal reflection in Chapter 11.

2 Background information

This chapter provides the necessary background information on flexibility in the electricity system and lays the foundation for the theoretical framework outlined in Chapter 3. Section 2.1 introduces the concept of flexibility and its importance in the electricity system, followed by an examination of spatial flexibility in section 2.2. Section 2.3 categorises different types of flexibility, with a particular focus on demand-side flexibility, which is central to this research. Finally, Section 2.4 summarises the key findings and links them to the broader context of this thesis.

2.1. Flexibility in the power system

Power systems are engineered to balance electricity generation and consumption both spatially and temporally at all times. Flexibility refers to the capacity of a power system to adjust generation and consumption as necessary to maintain stability in a cost-efficient manner. This flexibility ensures the system can continue providing service even when there are rapid or significant shifts in supply or demand. Until now, flexibility was mainly sourced from large fossil power plants at the supply-side [35]. However, the focus of enabling flexibility is increasingly placed at the demand-side in the industry, commercial, and residential sectors.

Flexibility options can impact various parts of the electricity grid, influencing the entire system. As described in the introduction 1, the electricity network originally functioned with a traditional one-way flow from generation to end-users. In the conventional system, fossil fuels were converted into electricity and transported through national and local transmission lines to consumers. However, with the integration of variable renewable energy sources (vRES) and flexibility options, this linear flow has evolved into a more complex, multi-directional system [57]. High vRES integration brings two major impacts: it increases variability and uncertainty on the supply side, which heightens the need for different flexibility options, while also reducing the profitability of conventional generators due to the low marginal costs associated with renewable sources, which may lead to the shut down of flexible generators that are currently operational. This shift is represented in Figure 2.1, which illustrates how flexibility options integrate into the evolving grid structure.

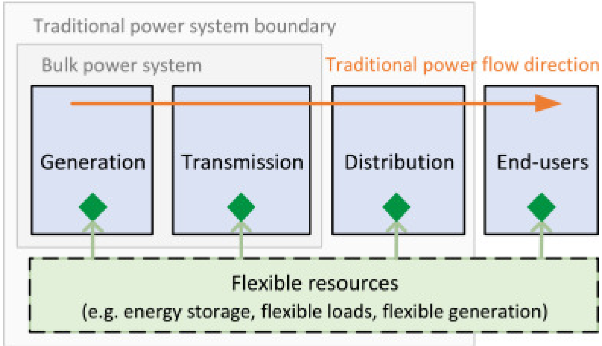


Figure 2.1: Traditional electricity system and integrated flexibility options (source: Sperstad, Degefa, and Kjølle [57])

The integration of different flexibility resources has a cascading effect throughout the grid, affecting local, low, medium and high voltage transmission levels. Each level of the grid can therefore adjust its operation or energy balance to meet the needs of balancing the system. Figure 2.2 shows that the current system can no longer be divided into clear system boundaries, but is deeply integrated. With flexibility, resources can have an impact on the adjustments they initiate at lower levels, which in turn affect higher levels within the network. This simplified illustration shows how flexibility helps to stabilise the grid by enabling rapid responses to fluctuations and changes in supply and demand.

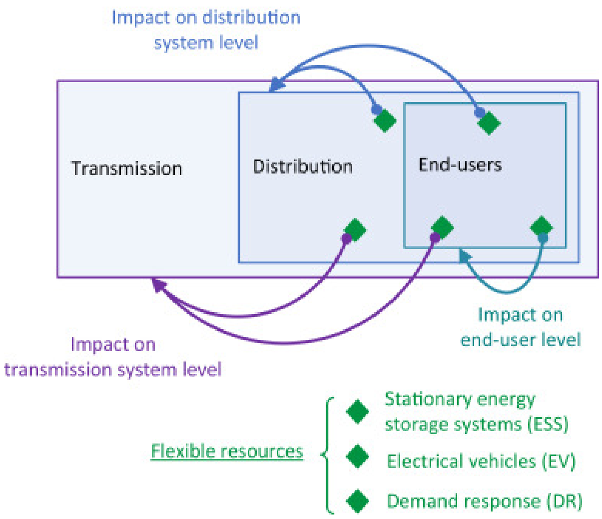


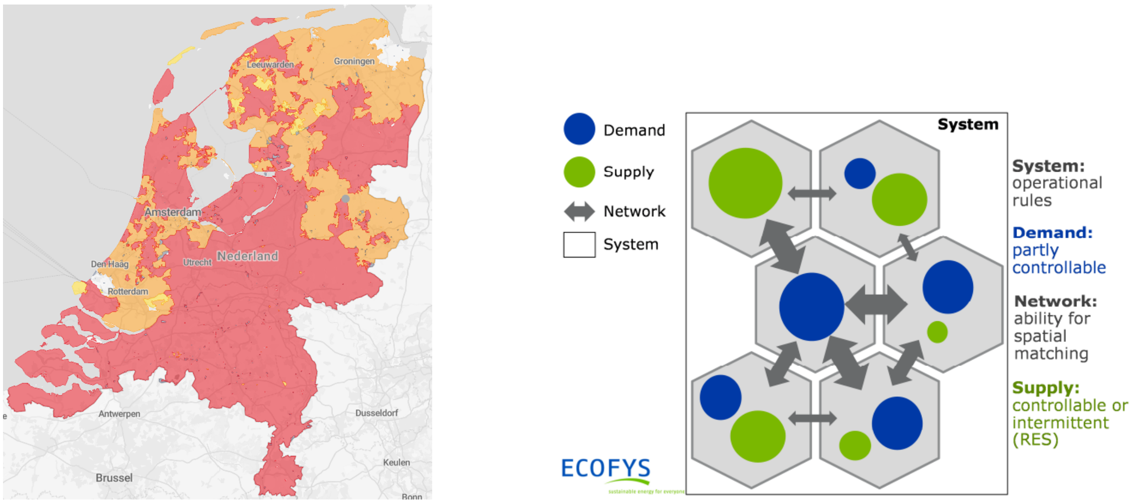
Figure 2.2: Impact flexibility on distribution of electricity (Source: Sperstad, Degefa, and Kjølle [57])

2.2. Spatial flexibility

The need for flexibility in the electricity system varies significantly depending on grid congestion levels and the geographical location of market participants providing flexible services [64]. Flexibility requirements are shaped by the physical characteristics of the grid infrastructure, regional energy generation and demand profiles, and the presence of various market actors who can offer operational flexibility services. This spatial aspect of flexibility means that the grid's ability to respond to changes depends not only on available resources but also on their location and how quickly they can react to system needs.

At present, nearly all regions in the Netherlands face significant grid congestion issues (see Figure 2.3a). This has made it increasingly difficult for grid operators to connect both new residential areas and businesses to the electricity network. By alleviating congestion and, consequently, reducing strain on the electricity grid, its functionality can be improved.

Categorizing stakeholders that can provide flexibility can help address spatial congestion issues. This categorization should focus on the specific geographical areas affected by congestion, the types of flexibility these actors can deliver, and their capacity to respond to system demands.



(a) Congestion map of the Netherlands (2024)

(b) Electricity system (Source: Papaefthymiou, Grave, and Dragoon [48])

Figure 2.3: Congestion map and spatial flexibility

Ultimately, the power system should evolve into a configuration resembling Figure 2.3b. In this configuration, the supply from the grid, combined with variable renewable energy sources (vRES), is balanced with the available grid capacity.

2.3. Different types of flexibility

The following section briefly describes all forms of flexibility, classified as outlined in [64]. While all forms will be mentioned, this study primarily focuses on demand-side flexibility and its implementation among market actors. This focus arises from the fact that an abundance of electricity on the supply side is easier to manage through curtailment than a shortage, which requires behavioural changes from market participants. To facilitate such behavioural changes and effectively influence the demand side of the system, this study provides more extensive background information on demand-side flexibility.

Demand-side flexibility

One of the key benefits of demand-side flexibility is its ability to support the integration of larger volumes of renewable energy into the electricity grid. By adjusting or shifting consumption patterns, flexible demand helps to reduce the curtailment or shortage of renewable electricity during periods of their respective generation pattern. However, a significant challenge remains in ensuring that both residential and industrial consumers are equipped to modify their energy usage quickly and effectively when needed.

Demand-side flexibility can be categorized into two main types: explicit and implicit. Explicit demand response compensates consumers for adjusting their energy usage upon request, often triggered by grid constraints or fluctuating prices. This can be managed independently or through an aggregator, such as a third-party service provider or the consumer's energy supplier. In contrast, implicit demand response relies on consumers independently modifying their consumption in response to variable electricity tariffs or prices, based on their personal cost-benefit analysis.

Dutch studies and recommendations, such as the reports of Berenschot et al. [12] & Kalavasta [32], make a further distinction between process flexibility and utility flexibility. In the case of utility process flexibility, end-users can use their utility processes to provide flexibility. This includes, for example, storing electricity in batteries. Flexibility can also be gained from industrial production processes themselves. Here, processes are temporarily, if possible, reduced or shifted to another time.

In the research of Lund et al. [37], different types of demand side flexibility are given. These are shown in Figure 2.4.

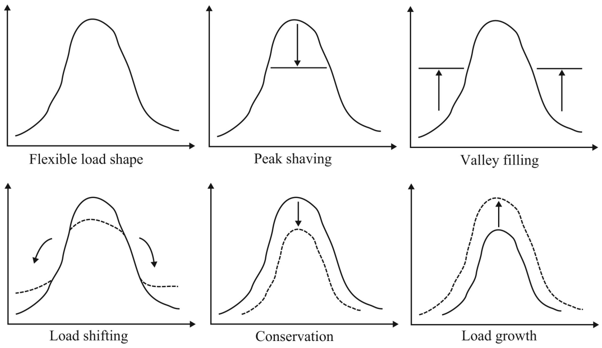


Figure 2.4: Different types of demand-side flexibility

Supply-side flexibility

Supply-side flexibility focuses on adjusting the electricity output of power sources to align with demand fluctuations. This option is critical for balancing the system, particularly during periods of excess electricity generation from variable renewable energy sources (vRES). For instance, curtailing surplus electricity from vRES can provide temporary relief to the grid.

However, supply-side flexibility faces challenges, particularly as conventional power plants are phased out. In the Netherlands, coal-fired power plants are planned to be completely decommissioned by 2030, which reduces the availability of traditional flexible power sources. As these are replaced by renewable energy systems, ensuring sufficient supply-side flexibility becomes increasingly complex due to the intermittent nature of vRES and the lack of stable baseload generation when needed.

Storage flexibility

Storage flexibility provides the ability to store electricity during periods of low demand and release it when demand is high, offering a valuable tool for balancing the electricity system. One of its key benefits is enabling seasonal shifting of electricity, which is essential for integrating higher shares of renewable energy. Technologies such as battery energy storage systems (BESS), pumped hydro storage (PHS) in salt caverns, and compressed air energy storage (CAES) are examples of storage solutions that contribute to system flexibility.

Despite its benefits, energy storage technologies face challenges, particularly in terms of cost. High upfront investment remains a barrier to widespread adoption. In residential settings, technologies like home battery systems and the use of electric vehicles (EVs) as mobile storage units are increasingly gaining traction. However, further cost reductions and advancements in technology are necessary to fully realize the potential of storage flexibility.

Inter-sectoral flexibility

Inter-sectoral flexibility involves converting electricity into other energy carriers or products, enabling its use across various sectors. Examples include the use of hybrid electric boilers in industries and greenhouse horticulture, where electricity is converted into heat, or the production of hydrogen via electrolysis. Additionally, electricity can be transformed into ammonia or methane for use in industrial processes.

While inter-sectoral flexibility can significantly support the integration of renewable energy, large-scale deployment poses challenges like increased grid congestion, particularly during peak electricity production periods. Proper planning and coordination are essential to maximize the benefits of inter-sectoral flexibility while minimizing its impact on the electricity grid.

Cross-border trade

Transmission flexibility involves the ability to transport electricity across regions and borders to address local imbalances between supply and demand. This spatial flexibility option is unique in its capacity to enable inter-regional shifting of electricity, making it indispensable for balancing the system on a larger scale. While transmission flexibility offers significant benefits in some electricity markets, like the

Norwegian electricity market, this type of flexibility is less relevant in the case of the Netherlands.

2.4. Flexibility value chain

The flexibility value chain, as described by USEF [69], plays a key role in understanding how flexibility is utilised and traded within the electricity market. With the increasing penetration of intermittent renewable generation and the electrification of energy demand, the need for demand-side flexibility has grown significantly, presenting both challenges and opportunities for market participants. Flexibility primarily serves three key functions: balancing the grid, alleviating congestion, and improving overall grid management.

Demand-side flexibility can be achieved through two main mechanisms: incentive-based demand response (DR) and price-based DR, also referred to as explicit and implicit DR. Implicit DR functions through financial incentives, where market participants adjust their consumption patterns in response to dynamic tariffs. Explicit DR, on the other hand, is driven by market-based trading, where participants offer their flexibility as a product in structured energy markets. The effectiveness of these mechanisms depends on the presence of barriers that hinder flexibility adoption. These barriers may arise from regulatory constraints, technological limitations, or financial uncertainty, all of which influence the willingness of large consumers to engage in flexibility markets.

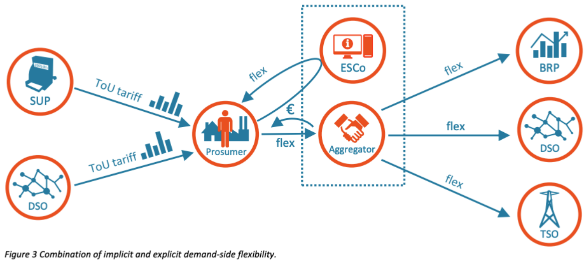


Figure 2.5: Value of flexibility in the system (Based on Topsector Energie [65]

The purpose of flexibility is therefore to balance the grid, reduce congestion and encourage the adoption of VRES. The focus in this research will be on the adoption of VRES and the reduction of congestion. To achieve this, it is necessary to understand how implicit and explicit changes can be induced. The study will therefore focus on tariff structures, implicit DR and the incentives and barriers that shape the behaviour of large industrial consumers. The primary objective is to address grid congestion by improving the utilisation of current grid capacity, which will result in more users accessing the grid. Improved grid utilisation will also allow greater integration of variable renewable energy sources (VRES) to meet agreed climate change reduction targets. However, for this transition to be successful, market conditions need to be adapted to support its implementation, ensuring that financial incentives and regulatory frameworks are aligned with the flexibility needs of the system.

2.5. Conclusion

This research focuses on demand-side flexibility, particularly the drivers behind implicit Demand Response (DR) and the barriers to explicit DR. The theoretical framework is aligned with these steering mechanisms of demand-side flexibility. Optimal utilisation of the electricity system offers several benefits, which will serve as the main focus for the study's recommendations. Additionally, the research assesses the impact of demand-side flexibility on congestion and system reliability. In this study, flexibility is considered a product and is examined as a marketable service that contributes to grid stability and efficiency.

Better utilisation of the network should ensure the following outcomes:

- **Resource adequacy**
  Ensuring a reliable and affordable energy supply during the energy transition. This is particularly relevant given rising system costs, increasing network expansion costs due to electrification, and significant volatility of energy prices.

- **Essential system services**
  Strengthening the power system during the transition away from conventional producer-to-consumer models. Flexibility must be recognised as both a product and an essential service in the new market system, enabling more efficient grid utilisation.
- **Integration of VRES**
  Supporting the incorporation of both realised and projected uptake of Variable Renewable Energy Sources (VRES) into the grid.
- **Transmission network access**
  Facilitating new grid connections for residential areas, business parks, and other energy users, ensuring adequate access to electricity infrastructure.

3
Theoretical background

As discussed in the previous chapter, the behaviour of actors can either be driven by price signals or actively traded. To understand the lack of flexible behaviour in the Dutch electricity system, the underlying factors will be explored through a literature review. This review aims to provide insight into general barriers within the overall system and the adoption and utilisation of flexibility. Following this, a theoretical framework based on Economic Theory and the Economics of Institutions is developed to establish the foundation for the analysis in the following Chapters. These identified barriers, along with the findings from various analyses, will serve as the basis for the interviews.

Section 3.1 presents the literature review and its findings on barriers to flexibility. Section 3.2 outlines the theoretical framework, while Section 3.3 provides an in-depth discussion of the Transaction Cost Theory framework. This framework will form the foundation of the research approach and the remainder of this thesis. Finally, Section 3.4 concludes the chapter.

3.1. Literature review

The primary objective of this literature review is to provide insights into the existing knowledge of market dynamics, focusing on three key aspects: barriers faced by industrial and other market participants, potential distortions of operational flexibility, and the effects of current market design. These insights help to identify knowledge gaps related to why stakeholders may be reluctant to adopt flexibility options or how their behaviour is influenced. The methodology used to select the literature is presented in Appendix A.

The literature review resulted in the selection of 18 articles, selected on the basis of their contribution to understanding the main barriers faced by industrial and large electricity market actors in adopting and using flexibility options. An overview of these articles can be found in the appendix A. The results of the literature review are discussed below.

3.1.1. Discussion of the literature

The successful adoption of flexibility options in the electricity market is hindered by various barriers, which can be categorized as technological, economic, behavioural, and regulatory. These barriers highlight the complexities faced by different market actors and emphasize the need for targeted interventions. Additionally, the literature identifies key drivers that can promote demand-side flexibility, providing a balanced perspective on both the challenges and opportunities within the market.

The potential of flexibility

To understand the factors influencing the potential flexibility that the system can regulate, it is essential to map both achievable flexibility and demand response. Dranka and Ferreira [21] has mapped the distribution of achievable demand response potential, providing valuable insights into its spatial and sectoral characteristics. Refer to Figure 3.1 for an overview.

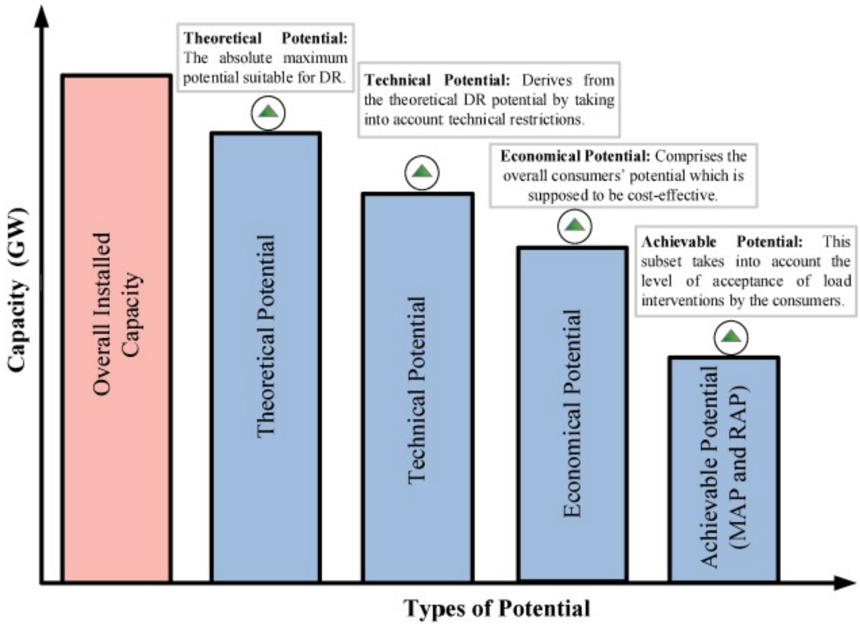


Figure 3.1: The achievable potential of flexibility (Source: Dranka and Ferreira [21])

By examining how the achievable potential of flexibility in the Dutch electricity system can be increased through an analysis of existing barriers, the focus naturally shifts to both the economic potential and the achievable potential. These are influenced not only by various barriers but also by market policies and financial incentives.

The research assesses the different barriers identified in the reviewed literature, as well as the methodologies used to analyse actor behaviour. The central question is whether the lack of adoption stems from the barriers and issues found in the literature or whether institutional and policy-related factors in the market also play a role. The focus will be on large electricity consumers within the system. These barriers will be analysed in relation to the identified knowledge gaps within this theme and will also serve as key discussion topics for the interviews.

Technological barriers

The lack of advanced infrastructure required for flexibility integration remains a key barrier. Essential components such as smart metering systems, energy storage solutions and automation technologies are not yet widely deployed, limiting the effectiveness of demand-side response (DSR) programmes [15, 46]. The integration of variable renewable energy sources (vRES), such as wind and solar, requires sophisticated forecasting and grid management systems to manage fluctuations in supply. Without these technologies, grid operators and market participants face operational risks, making the introduction of flexibility less attractive.

Another challenge is interoperability between existing and new technologies, which is particularly problematic for large industrial plants [16]. Digitalisation and grid modernisation are therefore needed to improve system reliability and ensure scalable, cost-effective flexibility solutions.

Studies on industrial flexibility also show that technical constraints are linked to sector-specific operational requirements. Some industrial processes cannot easily adjust their electricity consumption without disrupting production, which limits their ability to provide flexibility [16].

Economic barriers

Economic barriers stem mainly from high upfront costs and uncertain returns on investments in flexibility technologies such as battery storage and energy management systems [56]. Many industrial stakeholders are reluctant to invest in these capital-intensive solutions because financial incentives and cost savings are often unclear or insufficient [54, 21].

In addition, hidden costs - such as operational adjustments and system maintenance - further discourage companies from participating in flexibility programmes [46]. Without clear, long-term financial benefits, many businesses remain reluctant to engage in flexibility markets.

Network tariffs also influence the economic feasibility of introducing flexibility. Willems and Zhou [71] argue that cost-reflective tariff structures are crucial to incentivise demand-side flexibility. This includes higher capacity-based pricing and alternative systems that encourage load shifting. Similarly, Vallés et al. [70] highlights that dynamic tariffs that adapt to local network congestion and demand patterns could provide more effective price signals.

However, simply introducing new pricing models is not enough. D'Ettorre et al. [20] emphasise that successful uptake of flexibility depends on active user engagement. If companies do not see clear financial benefits, they are unlikely to participate. Furthermore, achieving a fully renewable electricity system requires more than just economic incentives; well-designed governance frameworks and stable market conditions are also essential [17].

Behavioural and organisational barriers

Behavioural factors play an important role in the slow uptake of flexibility. Many industrial end-users lack awareness of the benefits that demand-side response (DSR) programmes can offer [54, 56]. Without clear, accessible information, companies often overestimate the risks and underestimate the potential cost savings of participating in flexibility programmes.

In addition, habitual energy consumption patterns create inertia that prevents companies from adopting new energy management strategies. Many companies are reluctant to change their operations or invest in new energy management systems, even when the long-term financial benefits are clear. Overcoming these barriers requires targeted education programmes and user-friendly digital tools to help businesses navigate the flexibility options and participation requirements [16, 1]. Another limiting factor is the lack of expertise within companies. Many organisations do not have in-house energy specialists or staff trained in energy management. Implementing flexibility often requires adjustments to shift planning, operational processes and load management, which companies find difficult to assess or implement effectively.

A further complication is risk aversion. Stagnaro and Benedettini [58] points out that end users require more compensation to give up an existing right than they would be willing to pay to acquire that right if they did not already have it. This makes it difficult to design effective incentives, as companies are often reluctant to adjust their energy use even with strong external motivation.

Regulatory barriers

The governance of demand-side flexibility is shaped by policies, institutions, rules and incentives that influence energy demand and the decision-making processes of market participants [67]. However, the current market design presents significant barriers to the integration of flexibility options, in particular due to fragmented regulation, high transaction costs and a lack of well-defined market structures.

One of the main barriers is the complexity of coordinating multiple actors, such as aggregators, transmission system operators (TSOs) and end users. This lack of coordination increases transaction costs and delays the implementation of flexibility solutions [19]. The lack of appropriate market mechanisms further exacerbates the problem. Industries face challenges due to poorly defined market structures, technical constraints and inadequate policy support focusing solely on flexibility, making it difficult to integrate flexibility options effectively [53].

Regulatory fragmentation is another important barrier. The lack of a standardised framework for implementing and measuring flexibility creates uncertainty for market participants [15]. In addition, inconsistencies between regulatory bodies complicate the integration of flexibility, particularly for aggregators, who play a crucial role in pooling the resources of smaller consumers but receive insufficient regulatory support [16, 56].

The pricing mechanisms currently used to encourage the uptake of flexibility also contribute to inefficiencies. El Gohary [23] argue that the reliance on price signals places the burden on end users and reduces the role of DSOs, regulators and policy makers to merely providing market signals. While price signals are intended to drive behaviour change, many end users lack the awareness, resources or incentives to respond effectively, as indicated by the barriers above, leading to low participation in flexibility markets.

A well-designed market should align incentives with system needs. According to Vallés et al. [70], cost-reflective tariffs and dynamic pricing models tailored to local grid conditions are essential to promote efficient grid operation and reduce price uncertainty. Without clear policies and better aligned governance frameworks, the current market design will continue to struggle to effectively integrate flexibility solutions [67].

3.1.2. Link to framework

The barriers identified in the literature review can be divided into internal and external barriers. External barriers exist in the institutional context, where regulatory frameworks, market design and policy structures shape the adoption of flexibility. Internal barriers arise from knowledge gaps, structural constraints or ingrained behavioural patterns of market participants. These barriers, as well as the transactions and behaviours associated with them, are closely related to economic theories, in particular Transaction Cost Economics (TCE).

Several studies in the literature review apply transaction cost theory, focusing primarily on household energy use and private transaction costs. Aasen and Christensen [1] examined the impact of new network tariff schemes in Norway, highlighting how uncertainty, low trust in network operators and a complex institutional framework increased the costs of participating in demand-side management (DSM) programmes. Similarly, Skoczkowski et al. [54] studied small electricity consumers in Poland and found that financial incentives was the main driver in participation, while technological barriers and behavioural barriers, such as the lack of awareness hindered engagement. These studies highlight that bounded rationality, opportunistic behaviour and regulatory uncertainties contribute to high transaction costs, making the adoption of flexibility in the system difficult.

Given the importance of transaction costs in explaining stakeholder behaviour, this thesis adopts transaction cost theory as its analytical framework. By applying this approach, the research aims to identify and analyse the main barriers to flexibility adoption in the Dutch electricity market. This framework will provide deeper insights into how institutional and behavioural factors shape decision-making processes, ultimately contributing to strategies for improving market efficiency and flexibility integration.

3.2. Institutional Economics

3.2.1. Economics theory

In order to examine the barriers within the Dutch electricity system, it is essential to analyse the problem through the lens of an econometric theory. Institutional economics explains that markets are not inherently efficient. Factors such as transaction costs, information asymmetries and power imbalances often prevent markets from achieving an optimal allocation of resources. As a result, regulatory interventions and institutional adjustments are needed to improve the functioning of markets and ensure a more effective coordination of economic activities [18]

Transaction cost theory has been discussed in several of the selected studies, including Stagnaro and Benedettini [58], Cardoso, Torriti, and Lorincz [16], Aasen and Christensen [1] and Skoczkowski et al. [54]. These studies use transaction cost theory to assess inefficiencies and barriers faced by market participants in energy markets. This framework is part of economic theory, specifically within Williamson's institutional design approach [75]. The application of a theoretical framework provides insights into whether the identified barriers are consistent with the existing literature, how they differ, and how they can be addressed to facilitate behavioural change. Each theory offers a different perspective, with a different focus on different actors, underlying assumptions and level of abstraction. Before discussing transaction cost theory in detail, Williamson's institutional framework will first be explained to ensure a structured application of transaction cost economics (TCE) in this research.

3.2.2. Institutions

Market structures and economic systems operate within a broader institutional framework that influences decision-making, transaction costs, and governance mechanisms. Williamson [73, 75] conceptualised this framework through a four-layer model that categorises institutional influences from the most abstract societal norms to the most concrete economic mechanisms. These layers highlight the different degrees of formality of institutions and their interrelationship in shaping economic activity. Each layer has its own economic theory, which operates at a different level of abstraction, offering valuable insights but also being constrained by its assumptions. While each layer can be analysed separately, it is important to recognise their interdependencies. Figure 3.2 provides an overview of these layers as given by Williamson and are summarised and explained below.

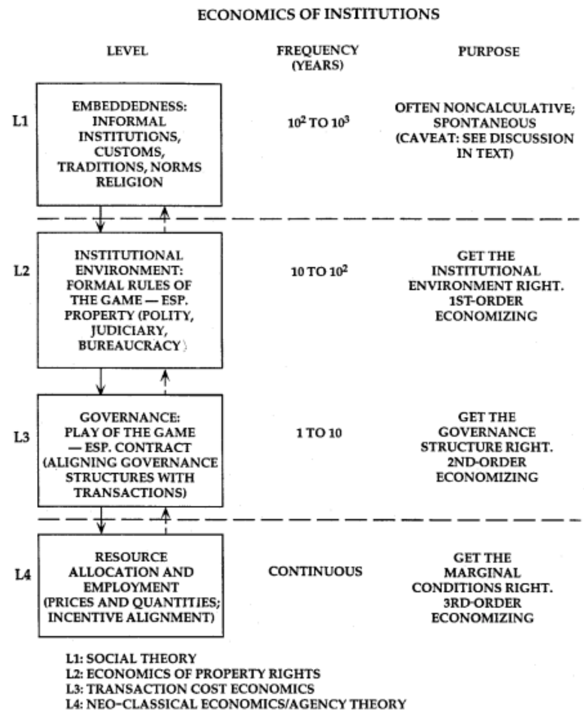


Figure 3.2: Williamson four layer scheme

Layer 1: Social Embeddedness – Informal Institutions
The first layer consists of informal institutions, including cultural norms, traditions, social conventions and religious beliefs. These elements shape collective behaviour and influence how formal institutions evolve over time. Because change at this layer occurs gradually - often over centuries - this layer provides long-term stability to economic and social systems. For example, the increasing societal focus on sustainability and environmental responsibility has influenced regulatory frameworks and business practices, even without direct policy intervention.

These high-level institutions, classified in the first layer, play a crucial role in shaping the broader context of this research. The growing societal emphasis on sustainability and decarbonisation serves as a key driver behind the challenges examined in this study, but while highly relevant, this layer operates at a level of abstraction that falls outside the direct scope of analysis in this research. It does not explain the decision-making process of large electricity users.

Layer 2: Institutional Environment – Formal Rules and Regulations
The second layer of the institutional framework consists of formal institutions such as legal frameworks, regulatory policies and governance structures. These define the rules of the game and shape property rights, contract enforcement and overall market functioning. A well-structured institutional environment can reduce transaction costs and improve market efficiency, but institutional change is often slow and shaped by political and regulatory decisions.

In this research, this layer is particularly relevant to assess whether the lack of uptake and use of flexibility is due to institutional constraints in the Dutch electricity market. A policy analysis is conducted to examine existing policies, recent regulatory changes and the broader vision of flexibility, providing insight into how institutional factors influence market behaviour.

Layer 3: Governance Structures – Organisational and Market Coordination
The third layer focuses on governance structures that facilitate economic transactions through market mechanisms, hierarchical organisations and hybrid models such as long-term contracts and public-private partnerships. The effectiveness of these structures is determined by factors such as transaction costs, asset specificity and trust between market participants. This layer is often referred to as the ”game” layer, as it examines how economic actors interact within the institutional framework.

In this research, a market analysis is conducted to examine the different contractual arrangements that shape the adoption of flexibility. By applying transaction cost theory, this study will assess whether the barriers to flexibility adoption are primarily rooted in the institutional environment or whether they arise from high transaction costs that discourage market participants from engaging in flexibility markets. This approach will provide a deeper understanding of the incentives and constraints that influence the behaviour of actors in the Dutch electricity system.

Layer 4: Resource Allocation and Market Mechanisms
The fourth layer focuses on resource allocation and economic decision-making, where price mechanisms, incentives and market competition determine how resources are distributed. This layer is traditionally analysed by neoclassical economics, which assumes efficient markets, perfect information and rational decision making. In addition, agency theory examines the relationship between principals (e.g. policy makers, regulators) and agents (e.g. market participants, firms), assessing how incentives and contractual relationships influence behaviour.

While this layer is critical to the day-to-day operation of markets, it is not the focus of this research. Before analysing the optimal allocation of resources, it is first necessary to determine whether market failures, adoption barriers and behavioural responses are driven by institutional and policy constraints. If adoption of flexibility were already widespread and behaviour aligned with system needs, an efficiency analysis at this layer would be relevant. However, this study will primarily focus on understanding the institutional barriers and transaction costs that shape decision making in the Dutch electricity market.

Interdependencies
While each layer provides distinct insights, they are deeply interconnected. Informal institutions shape the evolution of formal rules, while governance structures determine how effectively these rules are applied in practice. Ultimately, market mechanisms operate within this broader institutional context, influencing and being influenced by higher-layer structures.

While lower-layer economic activities are constrained by higher-layer institutions, feedback effects also occur. For example, failures in governance structures (Layer 3) may lead to calls for institutional reforms (Layer 2), while changes in resource allocation (Layer 4) may eventually reshape societal norms and expectations (Layer 1). Understanding these interdependencies is critical for designing institutional interventions that foster economic efficiency and long-term stability. For this research, the primary focus will be on Layers 2 and 3, as these layers provide the regulatory and governance context within which transaction costs emerge, influencing the adoption of flexibility solutions.

how are they described by the theory and what are the main sources of transaction costs? what are the transactions of interest

3.3. Transaction Cost Economics

3.3.1. Transaction Costs Theory

Transaction Cost Theory originates from Transaction Cost Economics (TCE), pioneered by Oliver Williamson [74] and further developed through the institutional analysis of Douglass North [44]. The transaction cost theory follows an micro economic approach and focuses on transactions on individual level.

This theory investigates the costs involved in coordinating and facilitating exchanges within economic systems and searches particularly to market failures or inefficiencies within the system. Central to the theory are two behavioural assumptions: (1) actors have bounded rationality, and, (2) they may engage in opportunistic behaviour. The critical characteristics of transactions are:

1. Frequency: with which the transaction recur, e.g. one time specific transaction or reoccurring.
2. Uncertainty: degree of uncertainty surrounding the transaction, e.g. uncertainties in the market or uncertainties about knowledge and intentions of other economic actors.
3. Asset Specificity: can it be redeployed to alternative uses and by alternative users without the sacrifice or loss of productive value.

Transactions are more than simple market exchanges or changes in property rights. Transactions require negotiation, contracting and enforcement, all of which incur costs. These transaction costs - arising from information gathering, negotiation and contract monitoring - can be substantial and can hinder the efficient functioning of the market [39].If these transaction costs are too high, they may explain the unresponsiveness of market participants to developments in the electricity market.

Contracts play a fundamental role in Transaction Cost Economics (TCE) by structuring economic exchange, mitigating opportunism and providing governance mechanisms to reduce uncertainty [72]. However, it remains unclear whether current contract structures provide sufficient flexibility to adapt to changing market conditions.

According to Williamson [74], analysing these factors allows researchers to evaluate whether the current governance and institutional context generate transaction costs that negatively impact the system, thereby preventing it from functioning as an optimal market.

3.3.2. The framework

To apply the framework, the studies by Aasen and Christensen [1] and Lundmark [38] were examined. These studies classify transaction costs into three groups that help explain these costs: transaction characteristics, transactor characteristics, and the institutional context. When applying the framework, it is assumed that while an energy user can technically provide a flexibility service, it is crucial to understand whether the actor would be willing to provide it and at what cost [58].

Transaction characteristics

Transaction characteristics significantly influence transaction costs and include uncertainty, frequency, and asset specificity. Uncertainty arises from technical, market, or behavioural factors, such as complex systems or fluctuating energy prices, increasing the need for information. Frequency refers to how often a transaction occurs, with more frequent interactions reducing costs through standardisation and trust. Asset specificity indicates how easily an asset can be repurposed without losing value; higher specificity, such as specialised grid connections, raises costs due to tailored contracts and monitoring needs.

Transactor characteristics

The characteristics of transactors, including bounded rationality, opportunistic behaviour, and social dimensions, greatly influence transaction costs. Bounded rationality refers to the cognitive limits of transactors in processing information and making efficient decisions, especially in complex contexts like energy efficiency investments. This leads to higher transaction costs due to increased informational and analytical efforts. Opportunistic behaviour, where transactors act in self-interest by withholding information or engaging in deceptive practices, further raises costs by necessitating contracts and monitoring. In contrast, social dimensions such as trust, reputation, and shared norms can lower transaction costs by fostering cooperation and reducing the need for extensive oversight. Together, these factors shape the overall efficiency of transactions.

Institutional context

The institutional context consists of formal rules, such as subsidies and legal requirements, and informal norms, such as societal expectations, that shape the incentives and constraints faced by market participants. Understanding how these institutional elements influence decision-making, like information gathering, administrative efforts, and legislative changes, can reduce transaction costs and encourage the adoption of flexibility options. For instance, governance mechanisms that simplify participation in demand-side management programs or provide financial incentives for flexibility can lower the barriers for the implementation of flexibility.

3.3.3. Application of the framework

The framework is applied by focusing on the behaviour of market participants and investigating the role of transaction costs in their decision-making processes. By mapping the institutional context and the roles and responsibilities of different actors within the system, the research aims to unlock the 'black box' of decision-making. This involves analysing how different characteristics influence decisions and identifying the policies and instruments that can promote flexibility. An overview of this can be seen in figure 3.3.

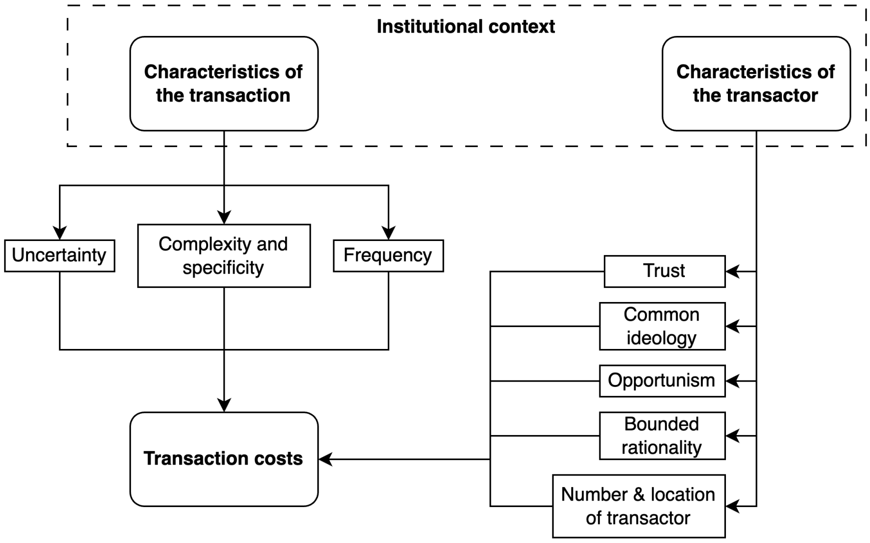


Figure 3.3: Transaction costs

In order to develop targeted policy recommendations, it is essential to first identify where market failures occur. This is examined using the framework outlined above. By analysing the factors that influence an actor's behaviour, such as instruments, external factors and transaction costs interact to shape the adoption of flexibility. The theory explores how high transaction costs - including uncertainty, bounded rationality and asset specificity - can hinder decision making and create barriers to change. This approach bridges the abstract 'black box' with measurable economic and institutional factors, providing insights that support targeted interventions to improve flexibility adoption.

3.4. Conclusion

The introduction established the necessity of adopting and utilising flexibility in the Dutch electricity sector. The literature review identified the key barriers that hinder large electricity consumers from engaging in flexibility, categorising them into four primary types: technical, regulatory, behavioural, and institutional. These barriers can be further classified as internal barriers, which are linked to transaction costs, and external barriers, which stem from the contractual and institutional context governing the electricity market.

To analyse these barriers, this study applies a theoretical framework grounded in Institutional Economics. This framework helps identify the institutional levels at which these barriers emerge and examines how adjustments to the institutional context can foster market conditions that facilitate the adoption and utilisation of flexibility options.

These identified barriers form the core themes of the interviews, creating a direct link between the theoretical framework and the empirical research. The study specifically investigates transaction costs, contract structures, and the institutional environment. While theory provides hypotheses regarding transaction costs, the interviews aim to offer empirical insights into their practical relevance. This chapter has outlined the overarching theoretical framework, which will be further refined and applied in subsequent chapters.

Using Transaction Cost Economics (TCE), this research will investigate whether implicit incentives alone are sufficient to stimulate flexibility among large electricity consumers or whether that follows from transaction costs. The research aims to provide answers to:

- Identifying the specific barriers preventing large users from providing flexibility services.
- Determining whether these barriers stem from market structures or institutional constraints.
- Assessing whether the barriers found in literature also apply to the Dutch electricity system.

By examining Layers 2 and 3 of Williamson's institutional model and applying a transaction cost framework, this research investigates whether market structures, governance inefficiencies, or high transaction costs constitute the primary obstacles to large electricity consumers providing flexibility services.

4 Research design & Methodology

Chapter 4 outlines and discusses the research methodology. Building on the three concluding points from the previous chapter, the chapter introduces the sub-questions that contribute to the formulation of the main research question. It also describes the research approach and the specific methods used throughout the thesis.

Based on the identified knowledge gaps, Williamson's institutional layers and market governance, findings are collected through desk research and semi-structured interviews. These methods provide valuable insights into the perspectives of different stakeholders regarding the integration and use of flexibility in the electricity sector.

4.1. Research questions

The aim is to analyse the behaviour of actors in the electricity sector and how it is influenced by current policies, regulations and financial measures, with a specific focus on the Dutch market. Understanding these institutional and market dynamics is crucial for identifying market failures and barriers to flexibility integration and for formulating actionable policy recommendations.

In order to explore these dynamics, the following main research question has been formulated in the introduction:

What policy, market, and behavioural factors influence the decision-making of actors in the Dutch electricity market to adopt and utilise flexibility options effectively?

Addressing this question requires an exploratory approach with a focus on four core aspects: (1) identifying how the current market is structured; (2) which market uncertainties influence market participants; (3) determining which changes in the market are being considered or should be implemented; and (4) determining which changes are necessary to influence the decision-making processes that encourage actors to provide flexibility.

To provide a structured and comprehensive answer, four sub-questions (SQs) were formulated, each of which is addressed in a specific chapter of this thesis.

Table 4.1: Sub questions and their respective Chapter

SQ:	sub question	Chapter
SQ 1	How does the current market and governance structure influence the integration of flexibility in the Dutch electricity sector?	5
SQ 2	What policies, regulations, and financial instruments influence the decision-making of large consumers regarding flexibility adoption?	6
SQ 3	What are the key barriers, risks, and uncertainties perceived by large consumers regarding flexibility adoption, and how do these perceptions align with existing market mechanisms?	7
SQ 4	How do transaction costs affect the behaviour of large consumers, and what interventions can be designed to mitigate their impact?	8

Each of these sub questions is explored through a structured step-wise approach, integrating different research methods that are explained in the following sections.

4.2. Research approach

Sub question 1

To answer the first sub question, which examines how flexibility and its associated impacts shape the electricity sector, Chapter 5 presents a market analysis. As a first step, the Dutch electricity sector is analysed in order to identify the relevant actors and market segments, including existing contracts, the regulatory framework and the role of flexibility within the system.

The analysis aims to define flexibility and provide an overview of the current market dynamics that influence its uptake. These findings form the basis for the following institutional analysis, which clarifies the structure and components of the market.

This approach is aligned with Layer 3 of Williamson's institutional model, which focuses on governance structures and contractual relationships within the market.

Sub question 2

Chapter 6 addresses sub question 2 by examining which policies, regulations and financial mechanisms currently influence the decision-making processes of large consumers in the Dutch electricity market. The policy analysis focuses on how these instruments create both incentives and constraints, and how they have evolved over time to align with broader policy objectives and support the integration of flexibility.

The analysis includes relevant Dutch policies, including taxation, energy subsidies, network tariffs and other measures, as well as implicit incentives that influence the electricity system. The aim is to highlight inconsistencies in current policies and identify areas for improvement. The results will form the basis for stakeholder interviews in the next phase, where market participants' perspectives on these policies will be assessed to assess their alignment with real operational needs.

This analysis also facilitates the identification of potential market failures within layer 2 of Williamson's institutional model. This layer comprises the formal institutional framework, including the laws, regulations and market rules that govern the electricity sector. By examining these structures, it is possible to determine whether existing policies create barriers to the adoption of flexibility or provide misaligned incentives for large electricity consumers.

Sub question 3

The third sub question focuses on validating and refining the findings through expert interviews. These interviews assessed whether market participants confirmed the findings of the desk research or provided alternative explanations. The interviews were designed to provide in-depth responses to the hypotheses and transaction costs faced by the market and to synthesise new perspectives. In order to capture the perspective of the market, the interviews involved a wide range of stakeholders following the market analysis, including end-users, policy makers, system operators and representatives of industry organisations. These insights were compared with the findings from the desk research and literature review. The aim of this phase was to explore individual participation in flexibility markets and the barriers to engagement.

In order to further structure the findings, the interview data is placed within the framework of Transaction Cost Economics (TCE). This approach allows for an explicit link between perceived market barriers and transaction costs, helping to determine whether barriers are driven by formal institutions, informal behaviour or structural inefficiencies. By integrating the results of the interviews into the framework presented in Chapter 3, the study will assess how market participants perceive regulatory constraints, contractual restrictions and financial incentives, and what institutional and policy changes they suggest to facilitate the adoption of flexibility. This structured analysis will provide a clearer understanding of market behaviour and the potential for institutional adjustments to meet stakeholders' needs.

Sub question 4

The fourth sub question will synthesise all relevant findings from the literature review, desk research and interviews, with a focus on identifying specific interventions to promote the uptake of flexibility. By integrating all the findings within the proposed framework, the analysis aims to identify where the barriers originate, i.e. whether they stem from institutional inefficiencies, pricing mechanisms, contractual constraints or high transaction costs.

This methodological approach makes it possible to determine whether the necessary interventions should focus on adjusting pricing incentives, revising contractual arrangements or reducing transaction costs in order to promote flexibility. This provides an opportunity to consider whether the flexibility market should be incentivised through informal changes between stakeholders or through formal government intervention. The results will provide actionable policy recommendations and outline potential market changes, providing a clear pathway for regulatory improvements and further exploration of the role of flexibility in the Dutch electricity system.

5

Market analysis

This chapter sets the market context and is central to the first sub-question: *"How does the current market and governance structure influence the integration of flexibility in the Dutch electricity sector?"*. In order to formulate an answer, the structure of the Dutch electricity grid, how flexibility is currently integrated, the main actors involved and the governance mechanisms that shape their interactions are examined. The market analysis provides an overview of the institutional framework of the electricity sector, identifies the relevant actors and their roles, and links these elements to the broader institutional context as explained in Williamson's third layer.

Section 5.1 outlines the main actors in the Dutch electricity system and the different markets in which they operate. Section 5.3 examines the flexibility value chain, detailing the different forms of flexibility within the system and their relationship to both market dynamics and actors. Finally, section 5.3 examines the contractual and governance structures that govern the interactions between actors, thus concluding the market analysis. Section 5.4 formulates an answer to the sub-question and provides the basis for the next chapter.

5.1. Stakeholders in the Dutch electricity grid

To effectively conduct desk research on the effects of market and policy design, the relevant stakeholders within the Dutch electricity system are introduced here. According to research by Lampropoulos et al. [35] and TenneT [59], various market actors can provide flexibility as a service, helping to alleviate congestion and optimise energy usage. However, the roles, responsibilities, and interactions between these stakeholders directly impact the efficiency and effectiveness of flexibility integration. Table 5.1 provides an overview of the stakeholders in the market.

Table 5.1: Overview stakeholders (based on: Lampropoulos et al. [35] and TenneT [59])

Stakeholders	Description
Aggregator	An aggregator is an entity that pools the flexibility of multiple small consumers and/or producers into a portfolio and offers the combined capacity on the wholesale, balancing, or congestion market.
Balance Responsible Party (BRP)	A BRP manages energy portfolios, balancing supply and demand at the wholesale level, and coordinates with TenneT (TSO in the Netherlands) to ensure daily schedules align with actual consumption. BRPs are responsible for reporting discrepancies and adjusting forecasts to stabilize the grid.

Continued on next page

Stakeholders	Description
Balancing Service Provider (BSP)	A BSP is a market player that provides balancing services to the transmission system operator (TSO) by adjusting supply or demand to maintain grid stability. It operates under agreements to deliver these services efficiently, either to a connected or contracting TSO.
Congestion Service Provider (CSP)	A CSP is an independent market player that acts as an intermediary between TSOs or DSOs and large business customers, providing location-specific congestion management services to alleviate congestion on the electricity grid.
Distribution System Operator (DSO)	DSOs manage, maintain, and develop the distribution networks to ensure safe and secure electricity delivery to consumers. They are also responsible for planning and overseeing network expansions while complying with regulations set by the Dutch regulator, ACM.
National Regulatory Authority (NRA)	The ACM oversees competition and enforces regulations in the energy sector to safeguard fair practices, consumer rights, and supply security. It supervises compliance with the Electricity Act, ensuring market transparency and independence. The ACM has to act in interest of all market participants.
Supplier	Suppliers deliver energy to end-users based on contractual agreements, sourcing from their own generation or the market. They handle metering, billing, and ensure compliance with licenses and regulations set by the ACM.
System User	System users include all entities (producers, consumers and prosumers) that connect to the grid, managing their generation, storage, or consumption units while complying with system regulations.
Transmission System Operator (TSO)	The TSO manages the high-voltage transmission grid, ensuring stable operations, cross-border connectivity, and efficient energy transport to meet demand while maintaining system balance.

The interaction between these stakeholders is shaped by contractual agreements and institutional regulations, with TSOs and DSOs managing system constraints and market participants responding to financial incentives or regulatory obligations. The governance of these relationships influences transaction costs and the ability to integrate demand-side flexibility into the system.

5.1.1. The segmentation of end-users

In the Dutch electricity system, consumers are categorised into small and large users based on their connection capacity, as defined in Article 95a of the Dutch Electricity Act (Elektriciteitswet 1998). Users with a connection greater than 3x80A are classified as large users, while those below this threshold are considered small users.

This classification is mentioned, as different regulatory frameworks and market incentives apply to different end-users. Large users operate under different regulated tariffs, meaning their contract structures, network fees, and available flexibility mechanisms differ significantly from those of smaller consumers. As this research specifically focuses on large users, the relevant institutions governing these types of users will be explored.

5.2. The electricity grid

The electricity grid in the Netherlands is structured into three main layers: the high-voltage grid, operated by TenneT, and the medium- and low-voltage grids, managed by the distribution system operators (DSOs). Each layer serves a distinct role in the transmission and distribution of electricity, ensuring a stable and reliable energy supply across different levels of the market [42]. The three types of grids will be explained in the following sub sections.

High-Voltage Grid
The high-voltage grid is designed to transport electricity over long distances, ensuring regional, national, and cross-border energy distribution. Electricity flow within this grid fluctuates throughout the day, dictated by the balance between generation and consumption. To accommodate these variations, redundancy is built into the network, allowing for stability and resilience in the event of failures or outages. Unlike the lower-voltage grids, high-voltage infrastructure is typically meshed, meaning that multiple routes exist between inflow and outflow points, enhancing system reliability.

Large-scale electricity generation facilities, such as power plants, (offshore) wind farms, and high-intensity electricity users, are generally connected to this grid level. Because of its role in maintaining national grid stability, the high-voltage grid is critical for balancing supply and demand and preventing system-wide disruptions.

Medium-Voltage Grid
The medium-voltage grid acts as the link between the high-voltage transmission system and the low-voltage distribution networks. Electricity from the high-voltage grid is transformed at transformer stations to medium-voltage levels before being further distributed. This grid level supplies electricity to a mix of consumers, including industrial facilities, commercial buildings, and larger business complexes, alongside distribution to the low-voltage grid. Many of these industrial consumers have direct medium-voltage connections, allowing them to manage energy consumption with more flexibility compared to small users.

Low-Voltage Grid
The low-voltage grid distributes electricity to households and small businesses. Electricity is transformed from medium voltage to low voltage at local transformer substations before final delivery. Due to the rapid expansion of distributed generation, such as rooftop solar PV, low-voltage grids must increasingly handle bidirectional electricity flows. This shift presents new challenges in grid operation, requiring updated infrastructure and management strategies to maintain system reliability.

5.3. Elektricity market
The Dutch electricity market consists of multiple sub-markets, each operating on different time frames. These markets ensure security of supply while responding to demand forecasts, weather conditions, and system dynamics [60]. Since this research focuses on flexibility in relation to congestion management and behavioural adjustments, it is important to clarify where flexibility is traded and utilised within these markets.

5.3.1. Wholesale Market
Electricity trading in the wholesale market takes place across different timeframes, from long-term contracts to last-minute adjustments. While long-term markets provide price stability, they offer little room for real-time flexibility, as contracts are fixed well in advance. Shorter-term markets allow for more adjustments, making them more relevant for flexibility integration.

Long-term Market
The long-term market covers trading between four years and one month before delivery and is primarily used by large producers, industrial consumers, suppliers, Balance Responsible Parties (BRPs), and traders to hedge electricity prices over a fixed period [60]. This market does not support short-term flexibility, as contracts are settled in advance and do not respond to real-time system conditions.

Day-ahead Market
The day-ahead market is the main reference point for electricity pricing in the Dutch market. Trading takes place daily on EPEX and Nordpool, where participants submit hourly bids for the next 24-hour period. The market price is determined through a blind auction based on supply and demand [60]. While the day-ahead market allows for some degree of flexibility, it is limited by the fact that all transactions are locked in the day before delivery, meaning that unexpected system changes must be handled in other markets.

Intraday market
The intraday market allows for adjustments after the day-ahead market closes, up to five minutes before delivery. This market is crucial for short-term flexibility, as participants can modify their trading positions in response to updated forecasts, renewable fluctuations, or unexpected congestion. Large industrial consumers, aggregators, and traders use this market to fine-tune their positions and adapt to changing conditions. Compared to the day-ahead market, the intraday market is more dynamic and directly relevant for congestion mitigation.

5.3.2. Other markets

Beyond wholesale trading, flexibility plays a key role in balancing the grid and resolving local congestion issues. These markets allow system operators to procure flexibility from market participants when required.

Balancing market
The balancing market, operated by TenneT, is responsible for real-time grid stability. When an imbalance occurs, Balancing Service Providers (BSPs) supply Frequency Containment Reserves (FCR) and Frequency Restoration Reserves (FRR) to restore balance [60]. Unlike the intraday market, balancing is not a voluntary trading platform, as flexibility is activated directly by the TSO when needed.

Congestion management
Where balancing services focus on overall system stability, congestion management addresses location-specific grid constraints. Flexibility providers offering congestion services help prevent local bottlenecks in the electricity grid by adjusting their consumption or generation. This is particularly relevant for DSOs, as distribution grid congestion is increasing due to decentralised generation and rising electricity demand. Unlike balancing markets, congestion management solutions must be tailored to specific locations, making flexibility a crucial tool to avoid unnecessary grid expansions.

5.4. Contracts

5.4.1. Focus on Energy-Intensive Stakeholders

This research focuses on energy-intensive stakeholders, which are typically connected either directly to the high-voltage grid operated by TenneT or to the medium-voltage networks managed by DSOs. These large industrial consumers have different flexibility needs and operate under distinct contractual agreements that depend on their grid connection.

For industrial consumers at the high-voltage level, contracts and agreements are arranged directly with TenneT, often including customised solutions for capacity allocation and congestion management. On the other hand, industries connected to the medium-voltage grid deal primarily with DSOs, where contract structures vary depending on regional grid conditions and available capacity. These differences are important, as the type of grid connection determines access to flexibility mechanisms, tariff structures, and participation in demand-side management programs.

The basis of the institutional context within the Dutch electricity market is largely determined by the type of connection and the agreement actors have with the TSO or DSOs. These contract forms set the initial agreements defining or, on the contrary, limiting the possibilities for flexibility. These agreements not only define the technical and financial conditions, but also form the basis for further flexibility options that actors can exploit.

5.4.2. Contract forms

In order to get a clear understanding of the current situation in the market, it is important to look at the possibilities for actors to offer flexibility based on contract forms. In this context, it is necessary to look at the possible room for flexibility within connections agreements, as well as the impact of new contract forms. The current contract forms for the Dutch market are described below. These are taken from the ACM [5, 4, 6, 7], the DSO websites and Article 7 & 9 of the Net Code Electricity.

(firm) ATO

End-users are connected to the network under an Access and Transmission Agreement (ATO).This defines the contracted transmission capacity for that specific actor. This is divided into contracted feed-in capacity (GTV-T) and contracted withdrawal capacity (GTV-E). If more is electricity is used than contracted, the end user pays a penalty and has to change its ATO to the increased amount of GTV-E. This contractual form ensures stability in grid planning but limits flexibility for dynamic grid usage.

Non-firm ATO (NFA)

The Non-Firm ATO (NFA) is a flexible contract type that allows grid operators in congested areas to offer discounted contracts without guaranteed transmission capacity. This means that users may not always have access to the contracted capacity. By opting for a non-firm ATO, network users in congested areas can still gain grid access under certain conditions, thereby improving overall grid utilisation. This was recently formalised in the netcode electricity ([2]).

This contract type is particularly beneficial for flexible network users, such as battery storage operators and large industrial consumers, who can adjust their consumption based on grid availability. The incentive of lower grid tariffs ensures more efficient network use, ultimately creating additional space for renewable energy integration.

Alternative transmission rights

Since the new congestion measures announced by ACM in 2024, two alternative transmission rights have been introduced:

- **Time-based transmission right:**
  This guarantees at least 85% of the annualised transmission time for full capacity use on TenneT's high-voltage grid. It primarily targets flexible consumers such as battery storage facilities and large industrial users. Time-based transmission rights will enter into operation on 1 April 2025.
- **Time-block based transmission:**
  This transmission right entitles pre-agreed time-block transmission on regional grids and is operated by DSOs. These alternatives, offered with lower grid tariffs, encourage efficient grid use and help reduce congestion, supporting the energy transition. Time-block-based transmission rights will be mandatory from 1 October 2025.

5.5. Types of congestion

Congestion in the electricity network occurs when power flows exceed the available transmission capacity, leading to constraints in the system. Based on regulatory definitions and technical constraints outlined in the European Union Agency for the Cooperation of Energy Regulators (ACER) study ([13]) and the study of on congestion definitions, congestion can be categorized into three primary types: physical congestion, market congestion, and structural congestion.

Structural Congestion
Structural congestion is a persistent and geographically stable form of congestion that frequently recurs under normal electricity system conditions. Unlike non-recurring congestion caused by temporary factors, structural congestion is a fundamental limitation of the grid that cannot be resolved through short-term measures alone.

Structural congestion is typically caused by fundamental grid bottlenecks, where transmission infrastructure does not match the long-term demand and generation patterns. The Electricity Regulation (EU) 2019/943 defines structural congestion as congestion that is:

- Predictable
- Geographically stable over time
- Frequently reoccurring under normal power system conditions

Addressing structural congestion requires long-term solutions, such as network reinforcements, capacity expansions, or significant market restructuring. In contrast, temporary congestion issues can often be managed through short-term flexibility mechanisms, such as redispatching or demand-side response.

Non-structural congestion

Non-structural congestion occurs when forecasted or actual power flows exceed the operational security limits of the electricity network. This includes exceeding the thermal capacity of transmission lines or the voltage stability limits. Physical congestion is a direct constraint on grid operations, requiring interventions such as redispatch, curtailment of generation, or demand-side flexibility. This type of congestion is identified through real-time monitoring and system security assessments, ensuring that power flows remain within safe operating thresholds.

5.5.1. Focus

This thesis investigates structural congestion in the Dutch electricity grid. The primary focus is on how contractual arrangements, policy instruments, and market-based flexibility mechanisms can be leveraged to reduce this type of congestion. Exploring governance changes in contract types, aiming to incentivise market participants to adopt contracts that enhance grid efficiency. Given the persistent nature of structural congestion, the analysis will assess whether alternative contractual structures, such as NFAs and CBCs, can contribute to long-term congestion mitigation. Transaction costs are hypothesised to be a determinant in whether market participants are willing and able to provide flexibility. The thesis examines how these transaction costs influence participation in redispatch, demand response, and other congestion management schemes.

5.6. Congestion management

Effective congestion management is essential to maintain grid stability and ensure the efficiency of the electricity system. Recently, new market mechanisms and regulatory measures have been introduced to address both physical and structural congestion. These initiatives aim to optimise the use of the network, improve flexibility and provide economic incentives to reduce congestion. The following sections describe these mechanisms, distinguishing between short-term (physical) congestion solutions and long-term (structural) congestion mitigation strategies.

Redispatch

A redispatch bid means that a connected party, through its CSP, offers to adjust the power at a specific location up or down from the original forecast data for an agreed fee. When network operators activate redispatch bidding within a congested area, an equal amount of power is adjusted outside of that area. This moves power from a congested location to one where there is still sufficient capacity. The redispatch product allows network operators to resolve physical congestion on the electricity network.

Capaciteitsbeperkingscontract (CBC)

The capaciteitsbeperkingscontract (CBC) is an additional customised contract on top of the (firm) ATO. The connected party retains a normal connection with transport capacity, but gives up part of it under pre-agreed conditions. When their capacity is limited, the connected party gets paid the agreed price. The CBC helps to resolve physical congestion and offers benefits to both connected parties and the network operator. Parties queuing for transmission capacity may also offer this flexibility. The CBC may include agreements on, for example, the number of requests per year or specific terms and other conditions of use. Because of this flexibility, the contract is not standard but is tailored to the specific situation of the connected party.

Obligation for flexibility

DSOs often experience a shortage of congestion management products in congested areas. The obligation to participate requires connected users to make an offer for a congestion management service. However, connected users are allowed to set the price for their flexibility and flexible capacity. When introducing the obligation, the network operator specifies whether it applies to feed-in or offtake of electricity and which product (redispatch or CBC) is to be offered. Article 9 of the electricity grid code, which has been in force since 13 November 2023, states that connected parties with a larger capacity of >1 MW are obliged to offer flexibility in the form of demand response. In the province of Utrecht, there is a mandatory participation of ≥ 3 MW due to the high level of congestion.

GOTORK

GOTORK (Use-It-Or-Lost-It) allows grid operators to limit unnecessarily contracted transmission capacity (GTV) and make it available to other users. This encourages connected parties to critically examine their GTV. The scheme only applies to medium, high and extra-high voltage grids, in congestion areas and in case of significant amounts of unnecessary GTV.

5.7. Conclusion

It is clear that the governance structure in the market is shifting from traditional ATO contracts to adapted and newly introduced contract forms. It remains unclear whether market participants are willing to change their standard ATO contracts to these alternative contract forms. While discounts on network tariffs are often highlighted as an incentive to change their contract, these discounts need to be significant enough for market participants to consider changing their existing contracts.

By limiting capacity through flexibility obligations and the GOTORK principle, stakeholders are required to actively map their flexibility capacity. This raises the question of whether they have the necessary information and expertise to do this effectively, which was identified as a behavioural barrier in the literature review. However, it is clear that market design is evolving by reallocating existing capacity where possible, reflecting a shift in the way congestion is managed.

The contractual structures and congestion management mechanisms in the Dutch electricity market can be analysed within Williamson's Transaction Cost Economics (TCE) framework. Contracts such as ATO, CBC, and redispatch agreements belong to the Governance Layer (Layer 3), defining market structures and contractual obligations between TSOs, DSOs, and large industrial consumers.

As these contractual structures continue to evolve and require implementation, the policy analysis and impact of network tarrifs need to be identified. The next chapter will explore policy measures and regulatory frameworks, providing a deeper analysis of how the Institutional Environment (Layer 2) shapes market behaviour and flexibility adoption.

6 Institutional Analysis

This chapter examines the institutional environment of the Dutch electricity sector, focusing on its impact on the operational flexibility of large consumers. It is central to answering the second sub-question: *"What policies, regulations, and financial instruments influence the decision-making of large consumers regarding flexibility adoption?"*

To answer this question, the chapter examines the legal, regulatory and financial mechanisms that shape flexibility adoption. A wide range of sources - including laws, government policies, regulatory guidelines, industry reports and market incentives - have been analysed to map the institutional landscape and its role in influencing large consumers' decision-making processes. The analysis identifies both explicit regulatory requirements and implicit market signals that shape flexibility uptake, such as subsidy schemes, tax policies and network tariffs.

The Chapter is structured as follows: Section 6.1 outlines the institutional environment. Section 6.2 examines energy policy, while section 6.3 looks at implicit steering mechanisms such as network tariffs, taxes and price incentives. Section 6.4 looks at external factors such as market uncertainties and infrastructure developments. Future outlook and changes in the institutional environment are assessed in section 6.5. An answer to the second sub-question and the link to theory is formulated in Section 6.6.

6.1. Institutional environment of the electricity sector

The energy sector in the Netherlands is highly regulated to ensure stability and reliability. The Dutch Authority for Consumers and Markets (ACM) provides a comprehensive overview of all relevant regulations and laws governing the energy market [10]. This overview includes all European regulations, Dutch laws specific to electricity, General Administrative Orders, and Ministerial regulations for energy. Additionally, there are specific rules, known as energy codes, which apply to all entities utilizing the energy grid infrastructure, which include grid operators, energy suppliers, metering companies, and end-users of electricity and gas. These codes play a crucial role in defining the operational framework of the electricity infrastructure and clarifying the responsibilities of operators and market participants. This analysis focuses on the technical codes for electricity, which expand on and are organized under the articles of the Electricity Act of 1998. Table 6.1 provides an overview of all technical codes and their respective legal basis.

Table 6.1: Overview of regulations

Policy, regulation, or code	Policy scope
Electriciteitswet 1998 (Electricity Act 1998)	Creates a balanced, competitive, and secure energy market. The Act governs the generation, distribution, and transmission of electricity within the Netherlands.
Samenwerkingscode elektriciteit (Electricity Cooperation code)	Aims to achieve optimal coordination between grid operators to ensure each operator can fulfill their legal duties and obligations.
Gebiedsindelingscode elektriciteit (Area classification code electricity)	Contains the area classification of grid operators, as outlined in Article 31 of the Electricity Act 1998.
Netcode elektriciteit (Netcode Electricity)	Specifies regulations for grid operators and users regarding the operation of grids, customer connections, and electricity transportation over grids, as outlined in Article 31 of the Electricity Act 1998.
Meetcode elektriciteit (Measuring code Electricity)	Regulations for grid operators and users regarding the measurement of electricity transported and consumed, as outlined in Article 31 of the Electricity Act 1998.
Tarievencode elektriciteit (Tariff code electricity)	Describes how grid operators must calculate tariffs for connection services, transport services, and system services.

The Electricity Act of 1998 will be central to this analysis, with a particular focus on the Netcode Electricity, which outlines the obligations related to congestion management and the mandatory participation of stakeholders. Additionally, to assess implicit flexibility, the Tariff Code Electricity will be examined, enabling an evaluation of changes in network costs, grid expansion, and other provisions affecting network tariffs.

6.1.1. Energy Policy

The primary focus of Dutch energy policy is the transition to a low-carbon energy system. As stated in an report of OECD [45] energy policy in the Netherlands has largely become climate policy, with carbon reduction targets driving regulatory and market interventions. Initially, flexibility was introduced to support the energy transition and stabilise the grid. However, with grid congestion becoming an increasingly pressing issue, the role of flexibility has shifted from a long-term stabilisation measure to an operational necessity.

Institutional responses to flexibility needs have often lagged behind market developments. Policies that were originally designed to support long-term sustainability goals and a stable grid with a predictable baseload profile are now being restructured to address short-term congestion challenges [26]. This shift is particularly evident in contractual adjustments and new market-based flexibility mechanisms aimed at better utilising existing grid capacity.

6.2. The elctricity price

This section highlights implicit Demand Response (DR). As stated in the background information, one way for stakeholders to provide flexibility is by adjusting consumption based on electricity prices. In the Netherlands, electricity costs consist of three main components: (1) energy costs, (2) network costs, and (3) taxes, which include levies and fees. This section explores the drivers and recent changes affecting these three components. By mapping these elements, the impact of new policies can be incorporated into the hypothesis formulation.

A particular focus is placed on network costs, which are regulated by the ACM under the Tariff Code Electricity. Additionally, an analysis of various electricity taxes is provided, examining their impact on price developments over time. Understanding how these implicit cost factors influence market behaviour is essential for assessing their role in incentivising flexibility utilisation through implicit DR mechanisms.

6.2.1. Energy prices

Energy prices are largely determined by the merit order of power plants and their respective fuel costs play a crucial role in setting electricity prices. As shown in Figure X, energy prices were highly volatile from 2022 until the spring of 2023. This trend with spikes in natural gas prices surged following the geopolitical instability caused by the Russian invasion of Ukraine.

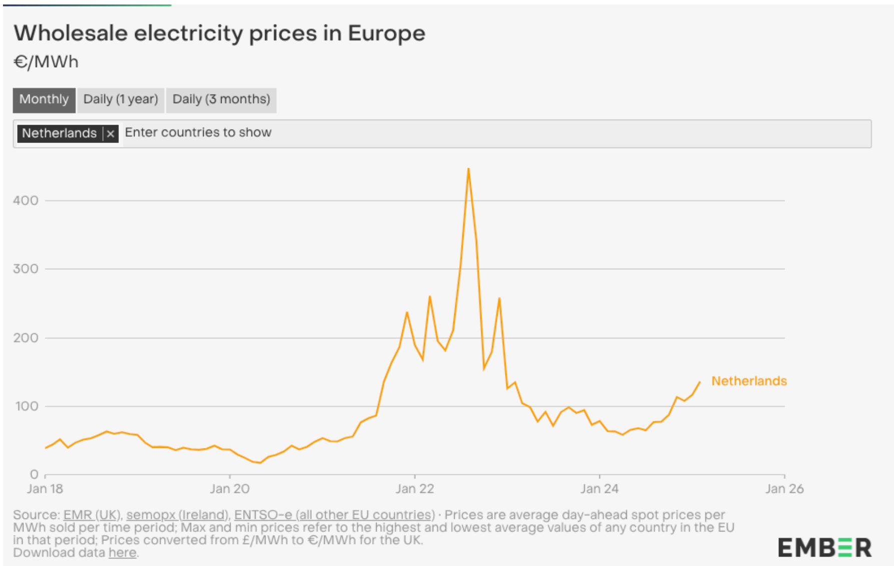


Figure 6.1: Energy prices (Source: Ember [24]

As renewable energy capacity continues to expand and intermittent sources such as wind and solar become more dominant, the occurrence of negative electricity prices is expected to increase. This trend is primarily driven by the low marginal costs of renewable generation, which can lead to price declines during periods of oversupply, especially when demand is low.

While accurate forecasting remains difficult due to the influence of many factors, including commodity price fluctuations and broader market dynamics, this volatility presents both challenges and opportunities. It underlines the growing importance of flexibility measures and demand response strategies, which can help mitigate risks while increasing the efficient use of renewable energy sources.

6.2.2. Network Tariffs

The focus on reducing network costs has been greater coverage of these costs in the context of contractual governance, as discussed in Chapter 5. Network tariffs are regulated by the ACM under the Electricity Tariff Code.

Network tariffs in the Netherlands are regulated by the Authority for Consumers and Markets (Autoriteit Consument & Markt, ACM) and cover the costs of grid operation, maintenance, and expansion. The regulatory framework for network tariffs is primarily based on the Electricity Act (Elektriciteitswet) and the Tariff Code Electricity (TarievenCode Elektriciteit). The determination of network tariffs are in accordance with European regulations. The four guiding principles used by ACM to set these tariffs are:

- **Cost reflectivity** – Tariffs should reflect the actual cost of grid operation and expansion.
- **System efficiency** – Pricing should incentivize the optimal use of grid capacity.
- **Transparency** – Market participants should have clear insight into tariff structures.
- **Non-discrimination** – All consumers and producers should be treated fairly under the tariff system.

TNO [63] study shows that there is a lack of information and awareness about the possibilities and benefits of demand response. This applies to both small and large consumers and hinders its wide acceptance. Current grid tariffs are seen as an obstacle, as they do not provide sufficient scope for cost-reflective and efficient use of the electricity grid. Flexible applications, such as devices that can use more or less energy at specific times, can make a positive contribution to grid stability. However, high grid tariffs are currently a barrier.

Recent changes

There have been some recent changes to the network tariff structure for electricity intensive industrial users. The Volume Correction Scheme (VCR) was introduced in 2014 under Article 29, Section 7 of the Dutch Electricity Act (1998) to provide large electricity consumers with up to a 90% discount on electricity transmission costs. The objective was to incentivize stable electricity consumption among industrial users, thereby reducing volatility and supporting grid stability.

However, in 2023, ACM decided to phase out the VCR, following research conducted by Royal HaskoningDHV [52], arguing that the scheme no longer aligned with the need for greater flexibility in industrial demand [30]. As can be seen in Figure 6.2, network tariffs have risen sharply. An unintended consequence of the abolition of the VCR is that industries that move towards flexible energy consumption are faced with higher effective network tariffs. As Dutch grid tariffs are largely capacity based, industrial users implementing demand response strategies have seen their costs increase rather than decrease, potentially discouraging investment in flexibility enabling technologies such as battery storage or other flexible types.

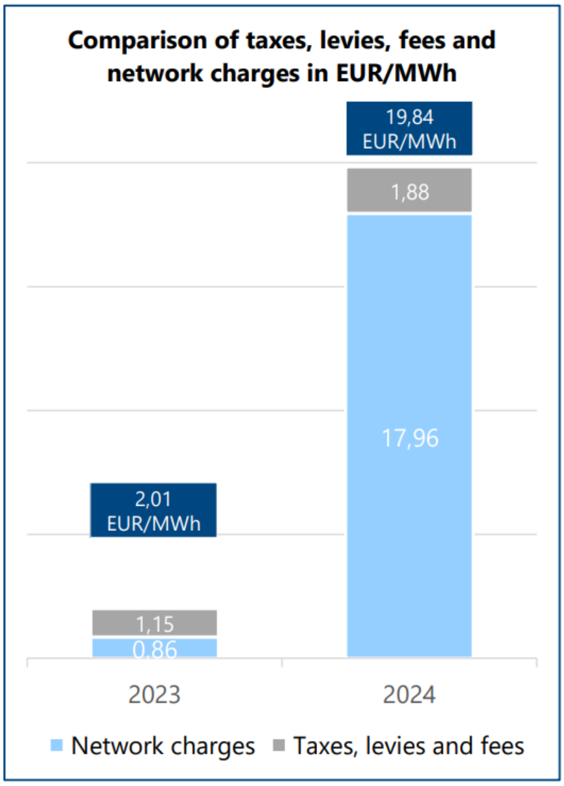


Figure 6.2: Abolition of VCR (Source: E-Bridge [22])

Outlook on Future Tariffs

According to network operators, electricity network tariffs are projected to increase annually by 4.8% to 6.7% until 2040, excluding inflation [43]. This increase will significantly impact the electricity costs paid by industries, potentially influencing electrification efforts and the decarbonisation of the energy system. The rising network tariffs could undermine the intended effect of subsidies designed to promote sustainable investments.

To mitigate these rising costs and improve grid efficiency, a shift away from a flat tariff structure is taking place. A critical design principle of network tariffs is to encourage end-users to optimise their consumption profiles, ensuring the efficient allocation of scarce grid capacity. This is being addressed through tariff differentiation, such as off-peak discounts, peak-load tariffs, and dynamic pricing models. These mechanisms aim to reduce peak demand and enhance system flexibility, helping to align cost structures with the needs of an evolving electricity system.

Time-of-Use Transmission Tariffs

To further encourage demand-side flexibility, ACM introduced time-of-use transmission tariffs on the high-voltage grid [4]. This approach, referred to as "peak-peak charging", would make grid usage more expensive during peak hours and cheaper during off-peak hours. The aim is to shift consumption away from peak periods, improving grid stability and reducing the need for costly grid reinforcement. As can be seen in Figure 6.3, prices vary according to seasonal and daily patterns.

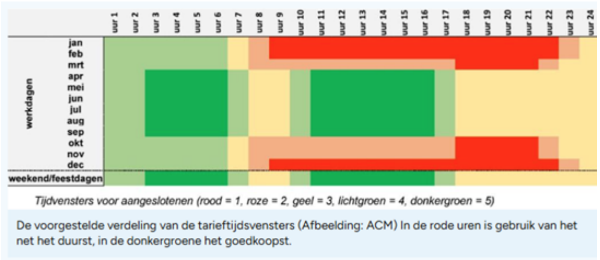


Figure 6.3: "Spitsheffing"-structure

The introduction of time-of-use pricing aligns with broader European trends, where dynamic pricing models are being increasingly used to balance electricity supply and demand in real-time. However, the effectiveness of this measure depends on how well industrial consumers can adjust their load without negatively impacting their operations.

Introduction of a Feed-in Tariff for Large-Scale Generators

The ACM has proposed the introduction of a feed-in tariff, requiring large-scale electricity producers—including power plants, solar farms, battery storage facilities, and wind farms—to contribute to the rising costs of grid expansion and reinforcement [3]. The key motivation behind this tariff is cost distribution fairness, ensuring that grid users, both consumers and generators, share the financial burden of network improvements.

Additionally, this measure is expected to impact international electricity trading. By charging producers for feeding electricity into the grid, the Netherlands aims to ensure that foreign consumers benefiting from Dutch electricity exports also contribute to the associated grid costs. This policy shift reflects an increasing focus on interconnection flexibility within the European market.

The Role of Network Tariffs in procuring flexibility

The ongoing evolution of network tariff structures in the Netherlands reflects a shift towards dynamic pricing mechanisms that incentivize demand-side flexibility. Measures such as time-of-use tariffs, feed-in tariffs, and the removal of VCR discounts indicate a move away from rigid pricing models towards market-based incentives for grid stability.

However, the effectiveness of these tariffs in reducing congestion depends on how industrial consumers respond to pricing signals. While some companies may adjust consumption patterns, others may face financial barriers that prevent them from fully participating in flexibility programs. Additionally, network tariffs alone may not be sufficient, requiring complementary policies such as market-based congestion management tools (CBC, redispatch, GOTORK) and regulatory flexibility obligations.

Impact of network tariffs

As electricity prices become more volatile and network tariffs continue to rise, it is expected that over time end users will be encouraged to adopt flexibility measures as a cost-saving strategy. As network tariffs become a larger proportion of the total cost of electricity, the economic incentive to optimise consumption patterns and reduce peak demand will increase.

Looking at the average electricity price per MWh in 2024, which was €134/MWh, network tariffs accounted for €18/MWh, almost 12.5% of the total price. If this trend continues, network tariffs could eventually exceed the cost of electricity itself, fundamentally changing the cost dynamics for large consumers. This shift could provide a stronger financial push towards demand-side flexibility, self-generation and storage solutions as companies seek to mitigate rising grid-related costs.

6.2.3. Taxes

Energy Tax

Energy taxes in the Netherlands serve multiple purposes: they generate revenue, promote energy efficiency, and encourage renewable energy adoption. The key policy instrument is the Energy Tax (Energiebelasting), which applies to electricity and natural gas consumption.

Energy tax is a levy on the consumption of natural gas and electricity, designed to encourage energy efficiency and reduce greenhouse gas emissions. For large consumers, such as industrial companies, the rates per unit consumed are lower than for small consumers. The tax is calculated on a sliding scale basis, with the rate decreasing as consumption increases.

Over the past decade, energy tax rates have increased, particularly for fossil fuel-based energy. A key reform in 2023 introduced a more progressive tax structure, reducing the burden on small consumers while increasing rates for large industrial users [40]. Additionally, tax exemptions for renewable energy production have been expanded. As can be seen from 6.2, large consumers have been subject to an increase in energy tax rates in recent years in comparison to other categories.

Table 6.2: Energy tax per kWh electricity

Year	0 tot 2.900 kWh	2.901 t/m 10.000 kWh	10.001 t/m 50.000 kWh	50.001 kWh t/m 10 million kWh	>million kWh
2018	€ 0,10458	€ 0,10458	€ 0,05274	€ 0,01404	€ 0,00057
2019	€ 0,09863	€ 0,09863	€ 0,05337	€ 0,01421	€ 0,00058
2020	€ 0,09770	€ 0,09770	€ 0,05083	€ 0,01353	€ 0,00055
2021	€ 0,09428	€ 0,09428	€ 0,05164	€ 0,01375	€ 0,00056
2022	€ 0,03679	€ 0,03679	€ 0,04361	€ 0,01189	€ 0,00057
2023	€ 0,12599	€ 0,12599	€ 0,10046	€ 0,03942	€ 0,00115
2024	€ 0,10880	€ 0,10880	€ 0,09037	€ 0,03943	€ 0,00188
2025	€ 0,10154	€ 0,10154	€ 0,06937	€ 0,03868	€ 0,00321

The current Energy Tax (EB) is a flat tariff, applied to every kilowatt-hour (kWh) delivered. In practice, this means that even when electricity prices are low or negative, taxes must still be paid on delivered energy. This system could discourage market participants from engaging in flexible consumption, as the tax burden remains unchanged regardless of market conditions, limiting the effectiveness of demand-side flexibility measures.

Exception Hydrogen
The energy tax exemption for the supply of electricity used for hydrogen production by electrolysis is introduced as of 1 January 2025. This exemption is limited to electricity used directly in the process of converting water into hydrogen [36].

Carbon-tax

As of 1 January 2024, the Dutch minimum carbon tax for the industrial and electricity generation sectors will increase, with a fixed annual increment scheduled until 2030. This pricing mechanism is designed to incentivise carbon reduction efforts and drive industries toward more sustainable energy consumption.

The new minimum carbon tax prices are outlined in Table 6.3, showing the progressive increase over time.

Table 6.3: Carbon price table

	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Tariff (€/ton)	30,48	41,75	55,94	74,17	87,90	100,74	113,58	126,42	139,26	152,10

The impact of the carbon tax will vary from sector to sector. For companies with low carbon emissions or no direct reliance on gas-fired power generation, the financial impact is expected to be minimal. However, for carbon-intensive industries, rising costs may accelerate investment in decarbonisation technologies, energy efficiency improvements or a transition to alternative low-carbon energy sources.

6.2.4. Horticulture sector

Currently, the Dutch greenhouse horticulture sector benefits from a reduced energy tax rate on natural gas. However, recent policy changes aim to phase out these exemptions to align the sector with national and EU decarbonisation goals. The Dutch government has announced a gradual reduction of tax benefits starting in 2025, with the objective of fully integrating the sector into standard taxation schemes by 2030.

This transition includes the removal of the CHP gas input exemption, meaning that natural gas used for combined heat and power (CHP) systems will no longer be tax-free. Additionally, the reduced gas tax rates for greenhouses will be incrementally increased, ensuring alignment with standard taxation rates by 2030.

For a detailed assessment of the impact of these policy changes on the horticulture sector, reference is made to another thesis within the DEMOSES project, specifically Princen [49], which investigates the implications of these regulatory adjustments.

6.3. Subsidies

Subsidies have been examined through various studies, policy documents, and incentive programs. However, most subsidy schemes are primarily focused on supporting the adoption of energy-saving technologies rather than directly incentivizing flexibility. This aligns with the broader observation that current market instruments are largely designed around carbon reduction rather than promoting system flexibility.

Table 6.4: Overview of subsidies and their working mechanism

Subsidy	Working Mechanism
Stimulering Duurzame Energieproductie en Klimaattransitie (SDE++)	This scheme offers subsidies to companies and non-profit organisations that generate renewable energy or reduce carbon emissions on a large scale. The subsidy offsets the difference between the cost price of renewable energy (or carbon reduction) and the market value of the product produced.
EIA (Energie-investeringsaftrek)	This scheme offers tax benefits to entrepreneurs investing in energy-efficient technologies and renewable energy. Entrepreneurs can deduct 40% of the investment cost from taxable profit, giving an average benefit of 10%.
ISDE (Investeringssubsidie duurzame energie en energiebesparing)	This subsidy supports business users to invest in renewable energy and energy-saving measures, such as heat pumps, solar boilers and small-scale wind turbines.
VEKI (Versnelde klimaatinvesteringen in de industrie)	This scheme is aimed at industrial enterprises investing in proven carbon-reducing measures with a payback period of more than five years. Subsidy can be applied for investments in energy efficiency, circular economy, infrastructure facilities and other carbon-reducing measures.

6.3.1. Future outlook

A parliamentary letter [51] addressed to the House of Representatives discussed important changes around flexibility. From 2025, new subsidy schemes will become available for business, including subsidies for flexibility scans. These scans should identify users who can potentially offer flexible control capabilities. Although still in the design phase, these programmes are a step towards wider adoption of flexibility.

6.4. External factors

External factors also play a significant role in influencing the behaviour of actors. These factors can be divided into market uncertainties, such as fluctuating prices, evolving carbon reduction targets, and other developments in the market. Additionally, the implementation of new innovations and technologies, as well as the increasing influx of variable renewable energy sources (vRES), further shape decision-making processes and operational strategies of actors.

6.4.1. Innovations, information and new technologies

Netbeheer Nederland's II3050 report emphasises that the organisation of flexibility is crucial for the success of the energy transition. The amount of flexibility needed, its location and its proper deployment determine whether the transition will be a success. Moreover, the report highlights the importance of technological means that are currently not yet available.

In addition, a central knowledge and communication point will be set up by the Rijksdienst voor Ondernemend Nederland (RVO). This point will support companies and local authorities in optimising flexibility instruments and strategies. Furthermore, the possibility of 'Sector Deals' is being explored, which would allow sectors to identify specific techniques and options for more efficient electricity use.

6.5. Future perspective: Energiewet

A significant development in the regulatory landscape of the Energy sector is the planned integration of the Electricity Act of 1998 and the Gas Act into the new Energy Act. This new Act is currently under review by the Dutch Senate and is expected to reshape the regulatory framework for the energy market.

The new *Energy Act* merges both the existing *Gaswet* and the *Electriciteits wet 1998* into a technology-neutral regulatory framework. This revised regulatory structure provides an updated market framework for electricity and gas, facilitating the continued energy transition and integrating requirements from the EU Clean Energy Package (Directive 2019/944 on common rules for the internal electricity market). The Act emphasizes the role of grid operators, increased digitalization, and data management, as well as the adoption of EU regulations and packages. The *Energy Act* has been approved by the House of Representatives and is currently under consideration in the Senate, where further questions have been raised about its market impact.

6.6. Conclusion

The regulatory framework for network tariffs, energy taxes, and carbon pricing in the Netherlands is evolving to support grid flexibility and decarbonisation. While recent developments have introduced more dynamic and differentiated pricing mechanisms, further refinements are needed to fully align incentives with grid needs. The horticultural sector, which has historically benefited from exemptions, is now facing increasing taxation, necessitating a strategic transition to sustainable energy solutions. Proposed changes, such as real-time dynamic tariffs, progressive energy taxes, and broader carbon pricing, will play a crucial role in shaping the future of the Dutch electricity market.

The findings in this chapter show that tariffs, subsidies and other financial incentives are the main instruments used to influence stakeholder behaviour. However, the key question remains whether these measures alone are sufficient to encourage the uptake of flexibility or whether additional interventions are required.

7 Interview design

This chapter details the design of the interviews conducted for this research. The interviews serve as a qualitative method to validate findings from the market analysis, policy review, and literature framework, while capturing stakeholder perspectives on barriers, risks, and potential regulatory improvements related to flexibility adoption. By carefully structuring the interview methodology, participant selection, and data management, this chapter ensures a rigorous and consistent approach to gathering insights from relevant market actors.

Section 7.1 outlines the interview methodology, explaining the rationale behind choosing a semi-structured format and the approach to designing the questions. Section 7.2 describes the structure of the interviews, detailing how they were conducted and the themes explored. Section 7.3 discusses the selection criteria for interviewees, ensuring a representative and diverse set of perspectives.

7.1. Interview methodology

A deductive interview design was used, using Deductive Qualitative Analysis (DQA) to structure the findings. DQA is a method that applies qualitative data to pre-existing theories, frameworks or concepts [28]. In this case, the Transaction Cost Economics (TCE) framework serves as the foundation, assuming that certain barriers act as explanatory factors preventing the adoption and use of flexibility. The analysis starts from the premise that transaction costs - such as uncertainty, bounded rationality and asset specificity - create barriers for market participants to engage with flexibility measures.

A key advantage of DQA over other deductive approaches is that it allows theoretical assumptions to be tested and refined by assessing whether empirical evidence supports, contradicts or extends the framework. The hypothesis is that high transaction costs limit the adoption of flexibility and influence market behaviour. By structuring the interviews around this framework, it is possible to determine whether TCE is sufficient to explain market inefficiencies or whether additional institutional or behavioural factors are present.

7.2. Structure of the interviews

To ensure comparability and consistency of data, semi-structured interviews were chosen as the interview technique. Semi-structured interviews allow for a structured conversation, with standard questions asked of each actor, facilitating comparisons, while open-ended questions and follow-up themes allow for deeper exploration of insights from the actor's perspective that may have been missed in the analysis [77].

The first section of the interviews explores the barriers perceived by market actors that limit flexibility adoption, building on insights from the analysis in Chapter 5 and Chapter 6. In addition, within these barriers, participants were asked about the implications of relevant findings on the influence of market design and policies on flexibility adoption. The effectiveness of existing policies and instruments - including subsidies, carbon taxes, network tariffs and financial incentives - will be assessed to determine their actual impact on decision making. For an overview of the instruments, refer to D.

As Transaction Cost Ecnomics may not be widely known among market participants, it was not explicitly addressed in the interviews. However, the structure of the questions was designed to guide participants towards statements that implicitly reveal transaction costs within the system. The emphasis of the questions was on identifying transaction costs in forms such as lack of knowledge, staff training, and other indirect costs that are needed for the transaction. The responses were categorised and grouped according to the aspects identified in the framework, highlighting economic, technical, and regulatory inefficiencies that increase the complexity of participating in flexibility markets.

7.2.1. Data management

Data collection follows the ethical guidelines of TU Delft's Human Research Ethics and Consent (HREC). For details on data handling procedures, consent form, and transcription methodology, refer to Appendix B.

7.3. Interviewee selection

The strategy used to select the interviewees was a non-random approach. This strategy was chosen to ensure that the information provided by the interviewees would provide insights into the institutional environment, the stance of different actors and the current market design in order to analyse the willingness to adopt flexibility. This approach allows the exploration of perceptions that may be influenced by stakeholders' and experts' specific roles, backgrounds,and knowledge of the electricity system.

The selection of stakeholders is based on the stakeholder analysis in Chapter 5 and includes various system operators, energy companies, (semi) governmental organisations and interest groups representing the industrial sector and other companies.

The interviewees were grouped and addressed according to type. Table 7.1 shows these types and the number of stakeholders and experts interviewed.

Table 7.1: Overview of interviewed stakeholders and experts

Stakeholder type	Company	Number of interviews
DSO	DSO 1; DSO 2: DSO 3	3
Energy company	Agro Energy; EBN	2
NRA	ACM	1
(Semi-)governmental organization	RVO	1
Interest organizations	Netbeheer Nederland; Energie Nederland; VEMW	3
TSO	TenneT	1

8 Results

This chapter presents the findings from the interviews, providing insights into the barriers, risks, and uncertainties that influence the adoption of flexibility by large electricity consumers. By analysing stakeholder perspectives, the results highlight how various technical, economic, behavioural, regulatory, and institutional factors shape decision-making processes related to flexibility adoption. The findings offer a comprehensive view of the challenges faced by market participants and how they perceive existing market mechanisms in facilitating or hindering flexibility.

The chapter aims to answer sub-question 3: *What are the key barriers, risks, and uncertainties perceived by large consumers regarding flexibility adoption, and how do these perceptions align with existing market mechanisms?*

The structure of this chapter is as follows. Section 8.1 provides an overview of the key findings from the interviews, summarising recurring themes and shared perspectives across different stakeholders. Section 8.2 explores the specific barriers and considerations affecting flexibility adoption, structured along technical, economic, behavioural, regulatory, and institutional dimensions. These insights establish a foundation for the next chapter, which further examines how transaction costs shape market behaviour and explores potential interventions to enhance flexibility adoption.

8.1. Overall results of the interview

This section provides an overview of the aspects discussed during the interviews. As outlined earlier, the main components—barriers, drivers, and perceptions—were predefined based on the literature review and Transaction Cost Economics (TCE) framework. However, while some measures and barriers were directly derived from the theoretical analysis, others emerged through the discussions with the interviewees.

Table 8.1: Overview of all barriers

Type	Sub-barrier	DSO1	DSO2	DSO3	Agro	ACM	NN	TT	RVO	EN	VEMW	EBN
Technical	Dependence on stability		■	■		■	■			■		
	Unavailability of grid capacity										■	■
Economic	Costs to enter								■		■	
	Financial Instruments				■	■			■	■		■
	Tariff Structures	■			■	■					■	
Behavioural	Business type	■		■		■		■			■	
	Short-term focus					■						■
	Lack of knowledge	■	■		■			■	■			
Regulatory	Lack of clear perspective	■	■	■				■		■		
	Policy spillover				■							
	Lack of sector-specific guidance					■	■		■			
	Waiting list					■	■	■		■	■	
Institutional	Contracts complexity and uncertainty					■	■	■		■		
	Diverging priorities					■				■		
	Formal interventions to flexibility integration	■	■	■				■		■		
	Informal barriers to flexibility integration	■	■	■		■					■	
	Lack of transparency								■			

8.2. Barriers and considerations

This section provides an overview of the key findings from the interviews. As outlined earlier, the main components - barriers, drivers and perceptions - were predefined based on the literature review and the Transaction Cost Economics (TCE) framework. While some barriers and drivers closely matched theoretical expectations, others emerged from stakeholder discussions and revealed additional complexities in the practical adoption of flexibility.

8.2.1. Technical barriers

Technical barriers pose a significant challenge to the introduction of flexibility in the energy system. While flexibility solutions exist, their implementation is often hampered by the need for operational stability and the limited availability of grid capacity. Many companies, particularly those with energy-intensive processes, are reluctant to adopt flexibility due to concerns about reliability and security of supply. Furthermore, even where companies are willing to contribute to grid stability through flexible demand, grid congestion and infrastructure constraints limit their ability to do so. The following subsections explore how reliance on stability and lack of available grid capacity act as key technical barriers to the adoption of flexibility.

Dependence on stability

The stability and continuity of operations were identified as critical concerns for companies when considering the adoption of flexibility measures. Many industrial consumers are highly dependent on uninterrupted power supply, and any potential disruption to their grid connection is perceived as a risk to core business operations. DSO 3 highlighted that operational security remains a top priority, and businesses are hesitant to engage in flexibility if it jeopardizes their stability.

This aversion is particularly strong among companies that rely on fixed and predictable energy consumption for industrial processes. DSO 2, Netbeheer Nederland, ACM and Energie Nederland all emphasised that these companies are unwilling to change their existing grid connections, even when offered favourable incentives for flexibility.

Unavailability of grid capacity

Another technical barrier, which can also be attributed as the current problem situation, that was identified is that actors who do however want to adopt and provide flexibility, are limited by the available grid capacity (EBN, VEMW). Companies that are willing to adopt flexibility initiatives, or need to do this as a result of decarbonization targets, often face infrastructure constraints, preventing them from participating. This highlights an loop that without proper government intervention, better utilisation of the grid faces this problem. It was mentioned that for current companies, an increasing capacity through additional cables seems like the most logical solution. Temporary measures to optimise existing grid capacity have been suggested, but their implementation requires significant collaboration, which is with the current institutions difficult to achieve.

8.2.2. Economic barriers

Economic barriers significantly influence companies' willingness to adopt flexibility measures. While financial incentives such as subsidies and tariff structures aim to encourage participation, high investment costs, unclear pricing mechanisms, and limited economic incentives for flexibility hinder widespread adoption. Businesses, especially those where electricity costs are not a dominant factor, see little financial motivation to adjust their energy consumption. Moreover, existing tariff structures and financial instruments do not always align with companies' operational needs, limiting their effectiveness. The following subsections explore how high entry costs, financial policies, and tariff structures shape the economic challenges to flexibility adoption.

Costs to enter

The adoption of flexibility measures requires substantial investments, which can deter companies from participation (RVO). According to VEMW, businesses for whom electricity costs are not a dominant factor have little incentive to offer flexibility. This also applies to energy-intensive companies, as the required investment in new equipment capable of handling flexibility is perceived as a significant financial burden.

Without targeted financial support or clear economic benefits, many companies remain reluctant to engage in flexibility, limiting its widespread adoption.

Financial Instruments

Financial instruments serve as a double-edged tool for influencing market behaviour. They can incentivise flexibility adoption through subsidies for batteries or machinery while also shaping decisions through taxation.

Subsidies such as SDE++ and ISDE provide financial support, but their effectiveness is constrained by the lack of adequate grid expansion, which remains a major bottleneck (ACM, RVO). EBN pointed out that financial policies often focus on incentives without addressing deeper barriers, such as sunk costs or the operational risks of process changes. These limitations reduce the impact of financial tools in driving sustainable adoption, making it essential to tackle underlying structural challenges.

Energie Nederland and EBN highlighted the CO2 tax, which raises costs for companies unable to integrate alternatives but serves as a strong incentive for businesses that can adapt their operations. AgroEnergy pointed to additional financial measures, such as the removal of gas discounts, potential introduction of a feed-in tariff, and rising grid costs, all prompting companies to reassess their strategies. However, the feed-in tariff has faced widespread criticism from stakeholders, including EBN, AgroEnergy, and Energie Nederland, who view it as ineffective and undesirable in its current form.

DSO 3 suggested that with well-designed financial mechanisms, more companies could be encouraged to contribute flexibility to support the grid. These mechanisms should align with companies' operational realities to ensure effective participation.

Tariff Structures

Tariff structures have not been as effective as initially expected in driving behavioural change. According to VEMW, the costs associated with adjusting production processes often outweigh the savings provided by time-of-use tariffs.

Looking specifically to the time-based alternative transimission rights, the interviewees think that this will rather shift costs rather than load profiles. While some companies can adapt to these tariffs, most are either unable or unwilling to adjust their processes to take advantage of them.

DSO 1 noted that current network tariffs play a relatively minor role in influencing behaviour, as the primary driver of the electricity price lies in the energy costs. ACM stated that while tariffs can guide behavioural changes, they should not be viewed as stand-alone solutions for shifting large-scale energy consumption as stated as implicited behaviour.

The horticultural sector, however, demonstrates that tariffs can have a significant impact when combined with other measures. Financial pressures, such as the potential introduction of a feed-in tariff, increased energy taxes, and higher grid charges, are forcing businesses in the sector to reassess their energy strategies. Depending on their size, some horticultural businesses may shift from being flexibility providers to net consumers (AgroEnergy).

8.2.3. Behavioural barriers

Beyond the technical and financial challenges, behavioural factors play a crucial role in determining the extent to which companies embrace flexibility. Companies are often reluctant to deviate from established operational processes, especially when flexibility is not aligned with their core business. In addition, short-term thinking discourages long-term investment in flexibility solutions, while a general lack of knowledge about flexibility options and their benefits further limits adoption. These behavioural barriers create resistance to change and reduce participation in flexibility programmes. The following subsections examine how business type, short-termism and knowledge gaps hinder the adoption of flexibility.

Business type

The nature of a business determines its ability to adopt and integrate flexibility. Companies already engaged in energy management or related activities find flexibility more complementary to their core business, making adoption easier. In contrast, businesses with other operational priorities may see flexibility as less relevant or even risky (DSO 3; VEMW; TenneT; ACM; EBN).

DSO 1 noted that network operators encourage customers to provide flexibility and congestion services to alleviate grid congestion. While companies specialising in these services have already invested in the necessary infrastructure, others face significant barriers due to resistance or a lack of expertise, making implementation challenging.

Short-term focus

The adoption of flexibility introduces risks and uncertainties, as companies fear losing capacity when offering flexibility, potentially compromising their operations. Even businesses willing to participate hesitate to jeopardise their existing network connections. To mitigate these concerns, flexibility solutions must ensure that companies retain the capacity needed for core operations, reducing perceived risks.

Additionally, flexibility and congestion management are often seen as temporary solutions until sufficient grid capacity becomes available (ACM & EBN). This short-term perspective may discourage companies from making long-term investments in flexibility, affecting their willingness to integrate these measures into their operations.

Lack of knowledge

A significant knowledge gap exists between system operators (SOs) and end-users, particularly regarding the broader benefits of flexibility integration beyond simply modifying existing systems.

AgroEnergy and RVO emphasised that while demand response concepts—such as adjusting consumption patterns—seem straightforward, their implementation requires substantial operational and infrastructural adjustments. This complexity is especially challenging for smaller market players, who often lack the necessary expertise and resources. Additionally, many companies struggle to integrate flexibility into their processes due to limited knowledge of energy systems (DSO 1; DSO 2; AgroEnergy).

A key issue is the lack of in-house specialists, such as electricians or energy traders, who can assess energy processes and identify flexibility opportunities. Even when technical knowledge is available, finding practical and cost-effective solutions remains difficult. Larger companies typically have dedicated energy management teams, whereas smaller companies lack the capacity to explore or adopt flexibility options, leading to unequal participation in flexibility markets (AgroEnergy).

Beyond expertise, adapting operations to flexibility requirements demands additional investments and administrative adjustments, such as hiring energy specialists, implementing advanced data systems, and training staff. These barriers discourage many companies from engaging in flexibility programmes (TenneT; ACM; EBN).

8.2.4. Regulatory barriers

Regulatory uncertainty and policy misalignment create structural barriers that make it difficult to integrate flexibility into the energy system. A lack of clear government direction and inconsistent policy incentives leave companies uncertain about the viability of flexibility investments. In addition, existing regulatory frameworks often fail to adequately reward companies for contributing to grid stability, while non-discriminatory waiting list policies discourage flexibility deployment. Without well-defined rules and structured incentives, companies are less likely to engage in flexibility initiatives. The following subsections explore how unclear government policies, policy spillovers, lack of sector-specific guidance and rigid waiting list policies are barriers to flexibility adoption.

Lack of clear perspective

The government fails to take a proactive role in shaping the business climate and infrastructure planning, particularly for grid operators. Strategic decisions on the location of new industries and flexibility solutions, such as batteries and electrolysers, are crucial to establishing a stable and predictable environment for building viable business cases (DSO 1, DSO 2, DSO 3, Energie Nederland, TenneT).

Additionally, the government must set clear and realistic standards for feasible and efficient flexibility solutions. While hydrogen is frequently cited as a key element of future flexibility, TenneT noted that many hydrogen projects have stagnated. A more targeted strategy could redirect resources toward immediate and high-impact flexibility solutions, ensuring efforts are focused where they are most effective and preventing delays and resource misallocation.

According to Netbeheer Nederland, key decarbonisation decisions—such as whether to prioritise hydrogen or electrification—are often delayed due to unclear market conditions. This uncertainty hinders long-term decision-making and slows down the adoption of flexibility measures, leaving the market unable to move forward with confidence.

Currently, significant uncertainty remains about when and whether companies can transition to more sustainable operations. Government intervention is crucial to providing the stability needed for stakeholders to make long-term investments in sustainability.

Policy spillover

Policy decisions have contributed to the current impasse. AgroEnergy highlighted that the horticulture sector is being pushed toward electrification, with solutions such as heat pumps and electric boilers. However, inadequate grid connections make these transitions unfeasible for some businesses, forcing end-users to incur higher costs while limiting their ability to contribute to flexibility.

Although subsidies exist for alternative energy solutions, such as geothermal and district heating networks, they are not universally accessible or practical, further widening the participation gap. As a result, some businesses remain locked out of flexibility markets despite policy-driven incentives for sustainability.

Lack of sector-specific guidance

A key barrier to flexibility adoption is the lack of sector-specific guidance and support, making it difficult for businesses to identify and implement flexibility opportunities. Many medium-sized businesses struggle to assess how flexibility fits into their operations, as they lack the expertise and resources to explore these options effectively (Netbeheer Nederland, RVO, ACM).

To address this challenge, Flex Scans were introduced to help businesses identify flexibility potential by providing targeted subsidies and tailored assessments. Similarly, Sector Deals emerged as a tool to create industry-specific frameworks, clarifying expectations and offering actionable strategies for flexibility integration. Successful examples include agreements in the data centre and water management sectors, where standardised templates and guidelines have facilitated adoption.

While these initiatives help overcome knowledge and implementation barriers, their effectiveness depends on broader adoption and accessibility. Ensuring that more industries can benefit from structured support remains a critical step in scaling flexibility across different sectors.

Waiting list

One of the strongest incentives for companies to adopt flexibility is the scarcity of grid connections in congested areas. Businesses waiting for grid access often view flexibility as a means to accelerate their connection. Interviews with ACM, TenneT, VEMW, Energie Nederland, and Netbeheer Nederland revealed that many companies on the waiting list are willing to offer flexibility.

However, the current waiting list structure operates on a non-discrimination principle, meaning that all parties are treated equally, regardless of their size or flexibility potential. This rigid system fails to reward companies willing to contribute to grid stability, limiting the incentive for flexibility adoption.

Energie Nederland highlighted an additional barrier: companies that modify their ATO (Allocation Transmission Agreement) to accommodate flexibility are moved to the back of the queue. This discourages willing end-users from participating, as offering flexibility provides no advantage in securing a grid connection.

8.2.5. Institutional barriers

Institutional barriers arise from misaligned priorities, contractual complexity and ineffective communication between key stakeholders in the energy system. While flexibility markets require active cooperation between network operators, regulators and companies, diverging interests and bureaucratic hurdles often delay progress. In addition, contractual uncertainties and a lack of structured interventions prevent companies from engaging in flexibility programmes with confidence. Furthermore, limited transparency and weak informal coordination mechanisms make it difficult for companies to navigate flexibility opportunities. The following subsections examine how contractual complexity, diverging priorities, lack of formal interventions and transparency issues hinder the adoption of flexibility.

Contracts complexity and uncertainty

Contracts play a crucial role in promoting flexibility in the energy market by providing economic incentives and mechanisms for grid stability. However, complexity and uncertainty in contractual agreements hinder their effectiveness (ACM, TenneT, Energie Nederland, VEMW).

A key challenge lies in Capacity-Based Contracts (CBCs), which require companies to offer flexible capacity while allowing them to set their own prices. This pricing autonomy often leads to high flexibility costs, as companies prioritise economic interests over grid stability, making it difficult for network operators to manage flexibility efficiently.

Additionally, group contracts and time-based contracts have been introduced to simplify flexibility adoption (Netbeheer Nederland). While these contracts target specific business groups or offer incentives tied to time periods, they remain poorly understood and underutilised, significantly limiting their impact.

ACM emphasised that while a robust set of flexibility measures exists, they are not effectively leveraged by stakeholders. Businesses are often reluctant to adjust contractual agreements due to fears of introducing uncertainties that could disrupt long-term operational planning. Simplifying contracts and tariffs is essential to reduce decision-making barriers and enhance participation in flexibility initiatives.

Diverging priorities

A fundamental barrier to flexibility adoption is the misalignment of goals between key energy sector actors, particularly between market players and grid operators. While market participants prioritise profitability and operational efficiency, grid operators focus on ensuring grid stability and reliability (Energie Nederland). These contrasting priorities create conflicting interests, making cooperation and decision-making challenging.

A key point of tension, highlighted by ACM, is that grid operators favour scalable and standardised solutions to facilitate efficient, large-scale implementation. In contrast, market players seek tailored agreements that accommodate their specific operational needs and constraints. This discrepancy leads to delays and unresolved issues, as both sides attempt to negotiate a win-win scenario, which is often difficult to achieve.

Addressing these diverging priorities requires a more structured and collaborative approach, ensuring that flexibility solutions align with both market dynamics and grid stability requirements.

Formal interventions to flexibility integration

Several stakeholders, including DSO 1, DSO 2, DSO 3, Energie Nederland, and TenneT, emphasised the lack of effective government intervention in integrating flexibility into the energy system. Formal interventions, such as strategic energy planning, are necessary to better align industrial development with grid capacity, yet these remain largely absent.

Additionally, both DSO 2 and DSO 3 stressed the need for a stronger sense of societal responsibility among businesses. Companies should be incentivised or obligated to participate in flexibility measures, provided these align with their operational processes. However, without clear policies and coordinated efforts, many businesses remain passive, lacking awareness of the urgency of the energy transition and their role in contributing to grid stability.

Informal barriers to flexibility integration
DSOs play a critical role in addressing congestion management and active network planning, yet inefficiencies in communication and coordination limit their effectiveness (VEMW). Improved collaboration between regional and national DSOs, as well as with industrial stakeholders, is essential to enhance grid efficiency and flexibility adoption.

A key issue is the passive role of DSOs, who currently tend to follow customer behaviour rather than actively steering flexibility integration (DSO 1). However, expectations are shifting, with increasing pressure for DSOs to engage proactively with customers, identify flexibility needs, and facilitate solutions (ACM, Energie Nederland). Clearer communication about available capacity and when flexibility is required could improve integration and reduce uncertainty for end-users.

Data-driven flexibility planning is another critical challenge. While advanced data analysis tools could help DSOs pinpoint where and when flexibility is needed, barriers such as data sensitivity and internal process adaptation limit these efforts (DSO 3). Investments in advanced metering systems and data-driven planning are necessary to effectively manage network constraints (ACM).

However, a lack of resources restricts DSOs from scaling up proactive engagement, preventing them from effectively responding to the growing demand for flexibility. Additionally, differences in communication styles and strategic priorities between grid operators and companies create misalignment, reducing the effectiveness of flexibility services (RVO, Energie Nederland). Structured communication between DSOs, TSO, and companies is needed to bridge this gap and ensure that flexibility solutions are fully utilised.

Lack of transparency
A lack of centralised and accessible information poses a major barrier to flexibility adoption (RVO). Businesses often lack visibility into key factors such as the length of the grid connection queue, making it difficult for them to assess whether flexibility could accelerate their access to the grid.

This lack of transparency discourages companies from exploring flexibility options, as they are unable to fully understand the potential benefits or the timeline for implementation. Without clear and reliable information, businesses remain hesitant to invest in flexibility measures, slowing down their adoption and limiting their contribution to grid stability.

8.3. Conclusion

The barriers described in this study are broadly in line with those highlighted by the stakeholders interviewed. While many expected challenges were confirmed, new barriers also emerged, providing additional insights into the complexity of flexibility adoption. The use of Directed Qualitative Analysis (DQA) as a methodology proved valuable in uncovering market-specific dynamics in the Netherlands, offering new perspectives that will be further explored in the next chapter.

A key distinction that emerged from the findings is that stakeholders can be grouped into two categories:

1. Willing but unable – These stakeholders recognize the potential of flexibility and are motivated to adopt it but face external barriers that prevent them from participating. Grid congestion, regulatory uncertainty, and economic constraints—such as a lack of sufficient incentives or infrastructure—are among the main obstacles.
2. Able but unwilling – These stakeholders have the technical and operational capacity to implement flexibility measures but choose not to, often due to economic disincentives, perceived risks, or misaligned business strategies. In some cases, flexibility is simply not a priority within their sector, while in others, unclear market signals fail to provide sufficient incentives for adoption.

Among the most pressing barriers, technical constraints, particularly grid congestion and stability concerns, significantly impact stakeholders willing to participate. In addition, economic factors, such as high entry costs, tariff structures, and the complexity of financial incentives, create further hurdles, especially for those who do not see an immediate business case for flexibility.

Beyond financial and operational concerns, behavioural barriers, including short-term decision-making and a lack of knowledge, suggest that many companies do not fully grasp the benefits of flexibility or lack the expertise to integrate it into their operations. Regulatory uncertainty further complicates the situation, as companies struggle with inconsistent policies, unclear government direction, and misaligned incentives. Finally, institutional barriers, such as contractual complexity, diverging priorities, and a lack of transparency, create additional layers of complexity that discourage engagement in flexibility markets.

The distinction between willing but unable vs. able but unwilling stakeholders suggests that a one-size-fits-all approach to flexibility adoption is ineffective. For the first group, addressing grid constraints, regulatory barriers, and infrastructure limitations is essential to enable participation. For the second group, targeted financial instruments, stronger incentives, and clearer market signals could help encourage flexibility adoption where it is technically feasible.

These findings set the foundation for the next chapter, which links the results to Transaction Cost Economics (TCE). In particular, the role of transaction costs in influencing the decision-making of able but unwilling actors will be further explored, mapping their challenges within the behavioural, economic, regulatory, and institutional barriers identified in this study. Understanding which TCE-related factors have the most significant impact will allow for the development of targeted interventions to address key barriers and enhance flexibility adoption in the Dutch electricity market.

9

Reflection on Results

Chapter 8 identified the key barriers, risks, and uncertainties that influence the adoption of flexibility. This chapter builds on those findings by applying Transaction Cost Economics (TCE) to explain why some actors, despite having the technical and operational capacity, remain unwilling to engage in flexibility markets.

While some market participants face external constraints that prevent them from offering flexibility (willing but unable), others (able but unwilling) deliberately choose not to participate due to the presence of high transaction costs. These costs arise from information asymmetry, contractual uncertainty, regulatory complexity, and strategic market behaviour. By examining these factors, this chapter provides insights into how transaction costs shape decision-making and how they can be reduced through targeted interventions.

This chapter aims to answer SQ4: *How do transaction costs affect the behaviour of large consumers, and what interventions can be designed to mitigate their impact?*

The chapter is structured as follows. Section 9.1 reflects on the interview findings, highlighting why transaction costs are a critical determinant of flexibility adoption. Section 9.2 identifies the key transaction costs derived from the interviews, structured according to the TCE framework: characteristics of the transaction, characteristics of the transactor, and the institutional context. Section 9.3 explores formal and informal interventions aimed at reducing transaction costs and increasing participation in flexibility markets. Section 9.4 concludes the chapter, summarising the findings and their implications.

9.1. Reflection on Findings

The findings from the interviews highlight that stakeholders fall into two categories:

1. Willing but unable – These actors would like to provide flexibility but are constrained by grid congestion, infrastructure limitations, and regulatory barriers. Their lack of options means that financial or contractual incentives alone cannot resolve their situation.
2. Able but unwilling – This group has the technical and operational capacity to engage in flexibility but chooses not to due to economic, contractual, and behavioural uncertainties.

While the willing but unable group faces external constraints that require systemic solutions such as grid expansion and regulatory changes, the focus of this chapter lies on the able but unwilling actors. Their reluctance to engage in flexibility markets cannot be fully explained by technical or economic barriers alone—transaction costs play a crucial role in their decision-making process.

From a Transaction Cost Economics (TCE) perspective, the key reasons why actors who are able to provide flexibility choose not to include:

- Search and information costs – Identifying flexibility potential, understanding market structures, and evaluating contractual conditions require significant effort and expertise. Many companies lack the internal capacity to assess these factors effectively.

- Bargaining and enforcement costs – Contractual complexity and uncertainty about the frequency and financial implications of curtailment make flexibility contracts risky. Companies prioritize stability over engaging in complex negotiations.
- Opportunistic behaviour – Some companies strategically retain excess capacity, anticipating future benefits, or withhold flexibility to secure better financial compensation. This behaviour is reinforced by unclear market incentives.

These findings suggest that for many companies, the perceived risks and costs of participation outweigh the expected benefits, leading to inaction. As a result, transaction costs act as hidden barriers that are not addressed by current financial incentives or regulatory measures.

The following section examines transaction costs in detail, categorizing them according to the characteristics of the transaction, the behaviour of the transactor, and the institutional context.

9.2. Transaction Costs

To understand why some stakeholders remain unwilling to engage in flexibility markets, it is necessary to examine the role of transaction costs. In TCE, transaction costs include:

- Search and information costs – Time and resources needed to gather relevant data and assess market participation.
- Negotiation and bargaining costs – Effort required to reach agreements and secure contracts.
- Enforcement and adaptation costs – Costs of complying with regulations, monitoring agreements, and adjusting operations to meet changing flexibility requirements.

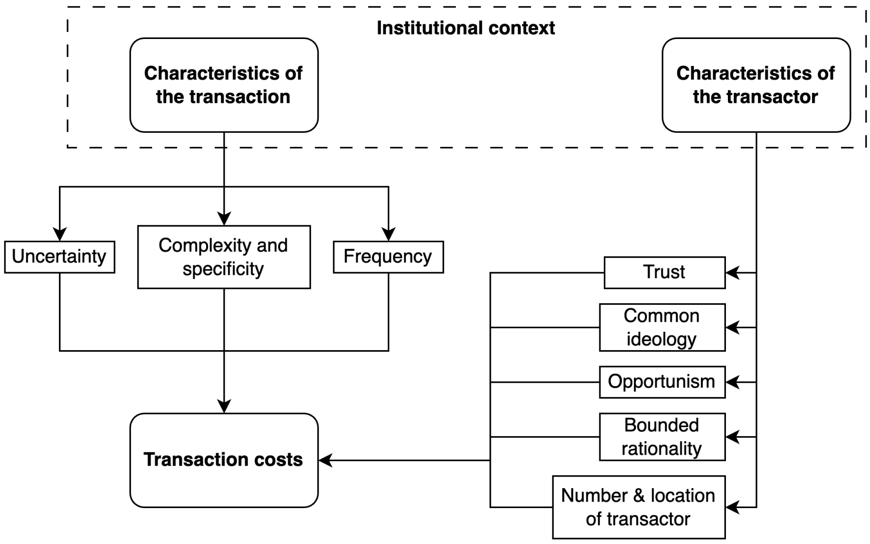


Figure 9.1: Transaction costs

9.2.1. Characteristics of the Transaction

For companies with the ability to provide flexibility within their Allocated Transport Capacity (ATO), the first hurdle is the cost of acquiring and processing information. Identifying flexibility potential, mapping processes, and understanding regulatory and contractual implications requires significant effort. If these initial transaction costs are perceived as excessive, companies may decide that the effort is not worthwhile, leading to inaction.

Beyond the initial phase, other transaction costs play a crucial role. Companies need to monitor, comply with and adapt their operations to evolving regulations, contractual obligations and market conditions. Frequent operational changes increase the overall cost and might discourage participation in flexibility services. On the other hand, if flexibility requirements are infrequent and predictable, companies may be more inclined to participate as the associated transaction costs remain manageable. However, due to the nature and volatility of VRES, this may be difficult to achieve.

Another important issue is contractual uncertainty and the negotiation costs that come with it. Many firms are reluctant to adjust their existing contracts because it remains unclear how often, for how long and under what financial conditions capacity reductions might occur. Without clear guarantees, companies choose stability over flexibility for fear of disruption to their core business. In addition, regulatory complexity, with a wide range of contracts, tariffs and subsidies, creates uncertainty rather than clarity, particularly for smaller companies.

9.2.2. Characteristics of the Transactor

The ability of companies to engage in flexibility is shaped by their cognitive and strategic behaviour. Two factors are particularly relevant:

Bounded Rationality – Many companies lack the expertise or data to assess whether flexibility is viable for them. This leads to higher search and negotiation costs, discouraging participation.

Opportunism – Companies with excess capacity may refuse to offer flexibility, anticipating better future opportunities. Some companies withhold information or flexibility potential to secure higher financial returns and reduce risks. This results in higher transaction costs both system operators (DSOs, TSOs).

9.2.3. Institutional Context

Financial and operational instruments play a crucial role in promoting flexibility, yet their effectiveness varies depending on the willingness and ability of actors to engage in flexibility markets. The interviews revealed that while these instruments function well for companies that are both willing and able to provide flexibility, their impact on those who are either unwilling or unable remains uncertain. Many firms that fall into these latter categories struggle to respond effectively to financial incentives, as they are primarily focused on capital investments in new equipment or technological upgrades. The issue lies in the misalignment between the design of subsidies and the actual barriers companies face. Current subsidy schemes predominantly support investment in new machinery or generation technologies but do not address the ongoing operational and administrative costs associated with participating in flexibility markets. As a result, transaction costs remain a significant barrier, discouraging companies from considering flexibility as a viable option.

Beyond direct financial incentives, broader policy measures such as carbon and energy taxes also shape the institutional context. These policies are primarily designed to drive decarbonisation by increasing operating costs and encouraging more sustainable practices. However, they do not explicitly target flexibility adoption, leading to uneven impacts across different types of companies. While some firms can integrate flexibility into their operations to offset rising costs, others lack the structural ability to do so. This disparity means that for some businesses, increased regulatory pressure does not result in greater flexibility participation but instead reinforces their reliance on conventional operational models.

For firms that are unwilling to engage in flexibility, energy costs are often not the primary driver of their consumption behaviour. These companies may not perceive financial incentives or tax policies as sufficiently compelling reasons to alter their operations. In cases where high compliance costs make continued operations unsustainable, some firms may even opt to relocate outside the Netherlands, reducing their role in the domestic energy system altogether.

Network tariffs further complicate the flexibility landscape, with their impact varying significantly depending on the type of end-user. In particular, sectors such as horticulture face structural shifts that could force them to modify their behaviour, transitioning from flexible prosumers to net consumers. Without adequate policy adaptation, the combined effect of increasing network tariffs and inflexible regulatory structures may inadvertently discourage flexibility rather than promote it. Addressing these challenges requires a more nuanced policy approach that considers the operational realities of different sectors. Providing targeted incentives and refining the design of subsidies to account for both investment and operational transaction costs could help reduce these barriers, ensuring that companies remain active participants in the energy system while contributing to long-term sustainability goals.

9.3. Intervention

Interventions for Reducing Transaction Costs Addressing the barriers to flexibility adoption requires targeted interventions that reduce transaction costs, improve market transparency, and align incentives among stakeholders. Following Williamson's second and third layers, these interventions can be divided into formal measures, shaped by government policies and regulations, and informal approaches, driven by industry collaboration and proactive market facilitation. The success of these interventions depends on their ability to lower administrative burdens, improve accessibility, and encourage participation in flexibility markets.

9.3.1. Formal Interventions

Focus on energy policy

A major institutional barrier identified in this study is the lack of a coherent national strategy for flexibility within the energy transition. In the absence of clear policy direction, companies struggle to develop viable business cases, investments remain uncertain, and coordination between market actors is weak. This lack of regulatory certainty increases transaction costs, as businesses must navigate an unpredictable landscape without clear infrastructure commitments or market incentives.

To resolve this, the government should establish a national flexibility target, similar to carbon reduction commitments, to provide a structured approach that ensures clarity and coordination across stakeholders. This would prevent fragmented initiatives and guide investment, innovation, and policy development toward integrating flexibility into the energy system. Without such a mandate, flexibility adoption risks remaining an ad hoc development rather than an integral part of the transition strategy.

In the short term, improving stakeholder dialogue and regulatory communication is essential. Many market participants lack a clear understanding of their role within flexibility markets, leading to information asymmetry that reinforces uncertainty and bounded rationality. Engaging stakeholders in structured discussions, regulatory sandbox initiatives, and public-private partnerships would help close this knowledge gap and ensure that market players receive the necessary guidance to navigate flexibility frameworks effectively.

Addressing lock-in effects

Another significant barrier to flexibility adoption is the presence of lock-in effects, which prevent market actors from adjusting their operations despite potential benefits. The interviews revealed that these structural constraints cannot be resolved without targeted government intervention.

Many companies are bound by long-term energy contracts that do not incorporate flexibility provisions, making it difficult to integrate demand-side response mechanisms. The rigidity of these agreements increases sunk costs, discouraging firms from renegotiating their contracts or considering alternative energy strategies. As a result, even companies that recognize the value of flexibility may find themselves structurally constrained by past commitments.

In addition, grid congestion has created long waiting lists for new connections, further exacerbating the lock-in effect. Companies willing to provide flexibility often face delays in obtaining necessary grid capacity, preventing them from acting on their willingness to participate in demand-side response initiatives. This structural limitation discourages investment in flexibility solutions and reinforces reliance on conventional, inflexible energy consumption patterns.

To reduce these lock-in effects, regulatory interventions should introduce contractual flexibility mechanisms, allowing businesses to periodically renegotiate their energy agreements and integrate flexibility provisions. Prioritizing grid access for flexible consumers could further alleviate congestion issues by ensuring that companies contributing to demand-side management receive preferential treatment in connection queues. Additionally, reforms in capacity allocation policies must create stronger incentives for flexibility participation, addressing the current non-discriminatory approach in waiting lists. At present, companies that are willing to offer flexibility receive no advantage over those that do not, reducing the motivation for businesses to adapt their energy strategies.

9.3.2. Informal Interventions

Expanding knowledge and awareness initiatives

One of the key findings from the interviews is that many companies lack the expertise, data, and resources necessary to evaluate whether flexibility is a viable option for them. This lack of knowledge acts as a significant transaction cost, discouraging firms from even considering flexibility adoption.

To bridge this gap, existing initiatives such as Flex Scans should be expanded and further developed. These programs provide structured assessments, expert guidance, and targeted financial support, helping companies to map out their flexibility potential and understand the costs and benefits of participation. By offering customized sector-specific recommendations, these assessments could significantly reduce the effort required for businesses to explore flexibility solutions.

In addition to individualized assessments, the creation of a central knowledge platform would enhance accessibility to information. A digital platform featuring case studies, standardized flexibility models, and best practices could streamline the search process for businesses, reducing the time and effort required to evaluate flexibility options. Making regulatory updates, market incentives, and success stories readily available would further encourage wider participation by lowering information barriers.

Encouraging a more proactive role for system operators

System operators play a crucial role in shaping the energy market, yet their current approach remains largely reactive. While they are responsible for servicing market needs, a more proactive stance could significantly enhance flexibility adoption by identifying opportunities and facilitating participation.

Rather than simply responding to market demand, system operators should take an active role in investigating where flexibility would provide the most benefit and proactively engaging with businesses to explore potential solutions. This could involve the use of data-driven forecasting tools to pinpoint regions where congestion relief is most needed and designing tailored incentive structures accordingly.

Additionally, stronger collaborations between DSOs, TSOs, and industry groups could ensure that businesses receive the necessary support in adapting to flexibility markets. Structured engagement initiatives, such as sectoral discussions and working groups, would enable system operators to better align flexibility opportunities with the needs and capabilities of different market players.

9.4. Conclusion

This chapter has examined how transaction costs shape the behaviour of large electricity consumers in relation to flexibility adoption. While some actors are willing to participate but face external constraints (willing but unable), others deliberately refrain from engaging in flexibility markets despite having the technical and operational capacity (able but unwilling). The latter group is primarily influenced by high transaction costs, which arise from information asymmetry, contractual uncertainty, regulatory complexity, and strategic market behaviour.

By applying Transaction Cost Economics (TCE), this chapter has shown that search and information costs, bargaining and enforcement costs, and opportunistic behaviour significantly impact the decision-making process of market participants. High transaction costs create uncertainty and risk, leading many businesses to prioritise stability over flexibility, even when financial incentives are available. Additionally, bounded rationality limits companies' ability to assess the feasibility of flexibility, while opportunistic strategies—such as withholding flexibility to secure higher financial returns—further contribute to market inefficiencies.

To reduce these transaction costs and enhance flexibility adoption, targeted interventions are needed. Formal measures, such as establishing a national flexibility policy, integrating contractual flexibility mechanisms, and prioritising grid access for flexible consumers, can provide regulatory clarity and economic incentives. Meanwhile, informal interventions, including expanding Flex Scans, creating a central knowledge platform, and encouraging a more proactive role for system operators, can reduce information barriers and improve market accessibility.

10
Discussion

This chapter discusses the results, places them in a broader academic context, and reflects on their implications for understanding operational flexibility in the Dutch electricity market.

The discussion in this chapter is structured as follows: Section 10.1 explains the variance in expectation. Section 10.2 highlights the scientific and societal contribution. Section 10.3 considers the limitations of the study, reflecting on data gaps, validation and constraints. Finally, section 10.4 concludes with recommendations for future research, identifying areas for further investigation that follow on from the findings in order to improve the understanding of operational flexibility in the Dutch electricity market.

10.1. Difference in expectation

The main objective of this research was to identify the impact and relevance of (financial) instruments in influencing stakeholders' decision-making processes and their role in incentivising the uptake and use of flexibility. To address this, an exploratory analysis was carried out to identify the impact of instruments, categorise them by drivers and barriers, and identify bottlenecks in their implementation. However, this analysis revealed significant mismatches between the intended incentives and the practical challenges faced by stakeholders. As the research progressed and the perceptions of market actors were explored, it became clear that financial instruments were less influential in decision making than initially thought. This finding challenges the assumption that financial measures will increase the willingness of end users, who are in a position to adopt flexibility options, to integrate them.

A significant factor is that flexibility has only recently gained attention among end-users, and even now, it is not perceived as an personal necessity. This lack of prioritisation, combined with mistrust and limited awareness, further reduces the effectiveness of current tools. For many actors - especially those with a fixed ATO who do not need additional transport capacity - bounded rationality and structural factors reduce the perceived value of flexibility. These actors want to preserve their individual benefits rather than solve the societal problem.

Active participation from the electricity sector is essential to integrate non-connected actors currently on the waiting list and increase the adoption of VRES, yet system operators, governments, and organisations struggle to motivate end-users. This is explained by transaction costs in Chapter 9, however, this challenge stems from the reality that energy management is not in line with the core operations for these actors. On top of that, these actors are accustomed to operating in a stable, secure, and predictable environment. For such end-users, whether due to bounded rationality or other structural factors, flexibility offers little individual benefit.

Establishing effective policies and regulatory frameworks that allow for industrial flexibility is a difficult task, as this sector is also governed by the spillover effects on other policies within the energy and climate change framework. The push toward large-scale electrification and decarbonisation has exposed the technical and systemic inefficiencies that further complicate policy alignment and realisation of set decarbonisation goals. As a result, some stakeholders are now exposed to increased operating costs while having to meet those targets without sufficient capacity or ability to redesign their processes to accommodate both the goal of the targets as well as to provide flexibility to alleviate the congestion problem.

As with other energy transition challenges, such as the establishment of a hydrogen economy, a chicken-and-egg problem persists: stakeholders have different views on who should take the first steps to enable flexibility. This results in an impasse, where each actor points out the responsibility to another stakeholder while holding on to roles established in conventional systems. Without clear efforts to redefine roles and improve collaboration, the current instruments fail to meet the broader need for adaptability in the system. This leaves the electricity system stuck in inefficiency instead of moving toward workable solutions.

Furthermore, it is crucial that stakeholders recognise flexibility as a societal issue. However, this aspect is often overlooked, both in the existing literature and in the behaviour of stakeholders. This oversight is reflected in the informal rules that govern the electricity market. To address this gap, societal awareness needs to be actively created to ensure that stakeholders understand their role and responsibility in contributing to a more sustainable and flexible electricity system.

10.2. Scientific and societal contribution

Scientific

This thesis contributes to the scientific understanding of flexibility adoption by examining the role of transaction costs and institutional frameworks in the decision-making process of end users. While theoretical models often highlight the potential of flexibility and calculate its integration effects, this research explores why implementation of theoretical flexibility is scarce. The findings bridge the gap between theory and practice by identifying explanatory factors that limit adoption. The results of this research are based on the Dutch institutional context but can be used in other studies or countries to examine institutional constraints. By combining theoretical approaches with qualitative data, this thesis adds a nuanced perspective to the existing literature.

Societal

This research addresses the challenge of achieving a stable, better utilised, and decarbonised electricity system through the integration of flexibility options. The findings provide actionable insights to reduce barriers and encourage active participation by identifying barriers faced by end-users, such as transaction costs and behavioural factors. Increased uptake of flexibility will benefit society by opening up the system to users waiting to be connected, reducing congestion and increase the amount of VRES in the system. Key stakeholders, including system operators, policymakers, and end-users, can use these recommendations to further improve cooperation and develop strategies for a more sustainable energy transition.

DEMOSES

The thesis contribution to the DEMOSES-project would be on the policy and instrument implementation. While it may be difficult to directly simulate the exact impact of the instruments on behaviour, the findings provide valuable insights for modelling scenarios based on different levels of end-user acceptance. By including variations in the adoption and market integration of flexibility options, the project can explore the gap between the theoretical flexibility potential and the more realistic or achievable potential. The ability to simulate different levels of acceptance adds depth to the project's scenario analyses and provides additional perspectives for redesigning the Dutch energy system.

10.3. Validation and limitations

Validation

The findings presented in this thesis are derived from insights of various stakeholders in the electricity sector. The data collected through the semi-structured interviews may reflect subjective biases or incomplete perspectives on the subject. Furthermore, the data collected may not fully reflect or represent the position or view of the company on the subject of flexibility. In addition, the selection of interviewees on the end-user side was primarily based on interest groups or associations. This means that a different selection of actors could potentially lead to a shift in the results. Furthermore, since the interviews were not conducted with individual end-users, it is not possible to generalise the impact of the instruments.

The challenge of flexibility and congestion itself is multifaceted and does not have a single solution, as several interviewees pointed out. The different needs of stakeholders, organisational structures and capacities of system operators illustrate the complexity of the issue and show that there is no one-size-fits-all approach.

Limitations

Difference in perceptions
End-users in the electricity market vary greatly in terms of their load profiles, tax structures, connection nodes, tariff frameworks, processes and capacity for flexibility. For example, companies with no immediate need for flexibility, or those located outside congested areas, are likely to have a different perspective on subsidies and related policies than those subject to these constraints. In addition, the strategic behaviour of stakeholders adds further complexity. The diversity of circumstances and incentives makes it difficult to generalise research findings or to create a market design that is applicable to all situations. In addition, the perception and implementation of policies and measures will be influenced by real-world factors that have not been considered or have been overlooked in this research.

Deductive Qualitative Analysis
One of the main limitations of Deductive Qualitative Analysis (DQA) is the risk of confirmation bias. As this research is structured around a pre-defined theoretical framework (TCE), there is a possibility that interview questions and analysis may have been biased towards confirming expected barriers rather than allowing for fully open-ended findings.

10.4. Future research

In order to deepen the findings of this research, further future research is recommended. The following aspects have been identified as potential starting points.

- In the literature, the desk research and the interviews, there was a lot of additional debate about the role of households in providing flexibility. On a large scale, households can alleviate the electricity grid. Transaction cost theory can also be applied to this group. As they are exposed to different instruments, but may also be more affected by the instruments, this group should be researched.
- This thesis has focused on demand-side flexibility. However, as noted in Chapter 2, there are many more types of flexibility. Instruments and policies could shape their behaviour differently. It is interesting to see how transaction cost theory can be applied to the other types of flexibility.
- Examine the effects of the implementation and enforcement of the new Energy Act. Important innovations such as (1) the transition from customer to active customer or group of final customers and the creation of energy communities; (2) new rules for real-time energy data; (3) more rules for DSOs and TSOs on transparency, expected availability of transmission capacity and new schemes for purchasing congestion management or system operation services. These changes may have an impact on characteristics that were now identified.
- Investigating whether compound effects occur when applying multiple measures is important. As seen in the findings of the horticultural sector, where significant institutional changes have occurred and both long- and short-term goals in the sector lead to spillover effects. While policies are not necessarily problematic when applied in isolation, they may create unforeseen challenges and barriers that hinder operational flexibility.
- Future research could explore new insights by facilitating discussions within specific industry clusters or among stakeholders from the same sector. While this study included a broad range of stakeholders, a more focused approach could reveal sector-specific challenges and opportunities for flexibility adoption, i.e. the horticulture sector.

11

Conclusion and recommendations

This research highlights the influence of regulatory frameworks, market dynamics and institutional contexts on the decision-making of stakeholders in the electricity sector. While previous studies have mainly focused on technological barriers and financial incentives, this study provides a deeper understanding of why flexibility uptake remains limited, despite its critical role in building a sustainable and resilient energy system.

The importance of increasing flexibility uptake is driven by the need to integrate more renewable energy sources and alleviate widespread grid congestion. A more flexible electricity system can help optimise grid use, reduce the need for short-term infrastructure expansion and enable new users to connect. However, significant institutional, economic and behavioural barriers limit full participation in flexibility services. These challenges led to the formulation of the main research question: ***What policy, market, and behavioural factors influence the decision-making of actors in the Dutch electricity market to adopt and utilise flexibility options effectively?***

The research identified two main groups of end users who face different barriers to flexibility adoption. On the one hand, there are those who are willing but unable to participate. These stakeholders recognise the benefits of flexibility but face external constraints such as grid congestion, infrastructure limitations and regulatory uncertainty. In their case, financial or contractual incentives alone are insufficient to address the challenges they face without broader systemic reforms. On the other hand, there are those who are able but unwilling to engage in flexibility markets. These actors have the technical capacity to introduce flexibility but choose not to because of economic barriers, perceived risks or strategic market behaviour. Their reluctance is often not due to technological limitations, but can be explained by the presence of high transaction costs that discourage participation.

Among the most relevant transaction costs affecting the decision making of the able but unwilling group, three main factors stand out. First, search and information costs create significant barriers, as identifying flexibility potential, understanding market structures and evaluating contract terms require considerable effort and expertise. Many firms do not have the resources to deal with this complexity, which discourages them from exploring flexibility as an option. Second, negotiation and enforcement costs add to the reluctance. Contractual uncertainty, unclear financial rewards and regulatory complexity make flexibility contracts risky and unattractive, leading firms to prioritise stability over engaging in complex negotiations. Finally, opportunistic market behaviour plays a role. Some companies strategically retain excess capacity for future benefits or withhold flexibility to negotiate higher financial returns. This behaviour distorts market incentives, further discourages participation and reduces the overall effectiveness of flexibility measures.

The findings suggest that existing financial incentives and regulatory mechanisms do not sufficiently reduce these transaction costs. Instead, they often focus on financial compensation, while failing to address the structural and behavioural barriers that determine whether firms actually engage with flexibility options. Addressing these barriers is critical to increasing flexibility uptake and ensuring that the electricity system can accommodate growing renewable energy sources and emerging grid constraints.

Policy recommendations

To address the barriers identified in this study, targeted interventions are needed to lower transaction costs, increase market transparency, and align incentives across stakeholders. A combination of formal and informal interventions is required, ranging from regulatory and policy measures to market-driven initiatives aimed at improving awareness, reducing uncertainty, and facilitating collaboration.

1. **Expanding knowledge and awareness initiatives:** Many companies lack the expertise to assess flexibility options, leading to inaction. Flex Scans should be expanded, especially in congested areas, to identify flexibility potential and provide tailored recommendations. A central knowledge platform should offer real-time regulatory updates, case studies, and sector-specific training to lower search and information costs.
2. **Improving regulatory and market structures:** A national flexibility target should provide long-term clarity and ensure flexibility is integrated into the energy transition. Contractual flexibility mechanisms should allow periodic renegotiations to reduce lock-in effects, and grid access policies should prioritise flexibility providers to incentivise participation and lower transaction costs.
3. **Strengthening the role of DSOs and TSOs:** System operators should take a proactive role in identifying congestion areas and directly engaging businesses. Improved real-time data sharing and new incentive structures should encourage DSOs and TSOs to facilitate demand-side flexibility rather than solely relying on infrastructure expansion.
4. **Reforming financial incentives and subsidies:** Current subsidies focus on capital investment but fail to address operational transaction costs. Subsidy design should include operational support, covering administrative costs, training, and post-implementation assistance. Pilot programs should test time-based tariff reforms to determine their effectiveness in influencing behaviour.
5. **Reviewing the grid connection waiting list system:** The current system does not incentivise flexibility providers. Companies offering flexibility should receive priority grid access, with pilot programs exploring conditional access agreements. Transparency in queue management should be improved to provide businesses with clear timelines and conditions for connection.

12 Reflection

Writing this reflection gives me the opportunity to look back at my thesis process and reflect on how I experienced it. During this process, I was able to apply the knowledge gained during my studies while also learning many new things. The energy sector has always fascinated me, and through writing, research, and conducting interviews, my interest in this field has only grown stronger. The sector is complex, interconnected, essential, and full of potential.

Focusing on this thesis has given me broader insights into the energy sector, especially regarding its interactions between policies, stakeholders, and systemic challenges. When I started writing, I believed I had a clear vision for how the thesis would unfold. However, as I reached the conclusion and revisited my original goals, I realised that many aspects turned out differently than I had anticipated. For example, my initial understanding of congestion and flexibility, influenced by media narratives, turned out to be more distant from reality than I had thought.

One of the key lessons I learned during this process was the importance of narrowing my focus earlier. Initially, I aimed to study the behavioural impact of policy parametrisation broadly, hoping to identify changes across a wide range of actors. However, I realised too late that concentrating on a specific group, such as industrial actors, would have made my research more actionable. Choosing Transaction Cost Theory provided a useful framework, but it came too late in the process to fully guide my work. As a result, my initial scope was too broad, leaving me overwhelmed by the diverse interests of the stakeholders I interviewed. Many of these stakeholders had conflicting priorities or viewed one another as obstacles to further investment, which added layers of complexity to my research.

Policy parametrisation was a focus early on, but I discovered through the interviews that it is far more complex than anticipated. Many companies are hesitant to adjust their operations due to either a lack of capacity or an unwillingness to embrace uncertainty and risk, which is understandable. As one interviewee put it, the energy sector often feels like a ”chicken-and-egg problem,” where stakeholders point fingers at each other instead of taking steps toward change. This resistance to altering practices, while aiming to maintain stability and reliability in the network and system operations, reflects one of the core challenges in the energy transition.

Conducting interviews was one of the most valuable parts of this experience. Speaking with passionate professionals gave me critical insights and a deeper understanding of the sector. Their openness, challenging questions, and shared experiences not only broadened my knowledge but also motivated me during this complex project.

There were moments of frustration—times when I felt stuck or overwhelmed. However, this mirrored the nature of the energy sector itself. One interviewee described progress in the sector as often feeling stalled until a breakthrough occurs, only for the system to stagnate again. This perspective helped me understand my own process better. Reflecting on this while writing showed me the value of both setbacks and progress. Just like the energy system, change takes time, understanding, and, occasionally, breakthroughs to evolve into something better.

On a personal note, I was advised early on to avoid getting lost in the literature and policies and to focus on narrowing my scope. This turned out to be harder than I expected. I wanted to read everything about the market and the ongoing changes being proposed. I became so focused on understanding every detail of the system and future legislation that I lost sight of what I needed to accomplish. Initially, I also wanted to include households in this research, as they are an important group to study. However, after conducting the first interviews, I realised this would have made the scope too large and unfocused. After my midterm, I realised that trying to grasp the ”big picture” of the system without a clear objective left me feeling directionless. Refocusing my work and interviews helped me regain clarity and shape the thesis into what it is now.

Applying Transaction Cost Theory to this research gave me insights that complemented what I learned during my studies. While much of the literature focuses on households, I found that the theory could also be effectively applied to the industrial sector. It provided clear links explaining why actors behave the way they do. Even though much of this behaviour stems from the institutional environment surrounding the transaction, Williamson’s theory, almost 50 years later, still holds strong.

In conclusion, this thesis has been a journey of learning and growth, with its share of ups and downs. It has deepened my understanding of the electricity system, its barriers, and the research process itself. The interviews provided new perspectives, insights, and passion, which keeps a technical system also very small.

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A
Literature review methodology

The primary aim of this literature review is to provide insights into the existing body of knowledge concerning market dynamics, focusing on three main aspects: barriers faced by industrial and other market participants, potential distortions in operational flexibility, and the effects of the current market design. This allows the first sub-question to be answered. These insights help identify knowledge gaps related to why stakeholders may be hesitant to adopt flexibility options or how their behaviour is influenced. The analysis focuses on perceived uncertainties and potential drivers of flexibility.

In addition, the literature review also examined the specific focus area for narrowing down the scope of this research. This was essential to ensure the study remains manageable and relevant. Furthermore, attention was given to identifying a suitable methodology that aligns with the research objectives, allowing for an effective and structured approach to analysing flexibility in the Dutch electricity market.

A systematic, multi-step approach was used to conduct the literature review. Based on reports from TNO [64, 62, 61], the Boston Consulting Group [14], and inquiries from the Dutch government, it became clear that understanding the behaviour of different actors and the uncertainties in the market is essential. To address this, multiple search strings were constructed using keywords outlined in Table A.1. After formulating the main research question, various keyword and search strings were utlized and used to find the different studies and papers. The keywords used are shown in Table A.1.

Table A.1: Used keywords

Flexibility options	Market barriers	System	Theory
Flexibility	Tariffs	Electricity grid	Transaction costs
Demand Response	Policy	Power system	Behaviour
Demand side management	Regulations	Renewable energy source	TCE
Congestion management	Subsidies	Energy system	IE
	Grants		
	Cost		

An example of a search string used is:
((Transaction AND Costs) OR (Transaction AND theory)) AND (Electricity) AND (Congestion OR Demand OR Flexibility OR Barrier)

The search strings were applied to the Google Scholar and Scopus databases, focusing on literature published from 2015 onwards. This timeframe was chosen using the Paris Agreement as a reference point to ensure relevance. The papers were then screened by title and abstract to assess their suitability.

Additionally, the snowballing technique was employed to identify further relevant articles. This resulted in the selection of 18 papers. These are provided here.

A.1. Overview of the literature

Following the literature review methodology outlined in Chapter A, the selected papers are presented in Table A.2. These papers form the foundation for the analysis and provide key insights into the barriers, drivers, and dynamics of operational flexibility in the electricity market.

Table A.2: Overview of selected papers

Author	Title	Year	[Ref]
Aasen and Christensen	Lost in transaction?: An institutional analysis of households' transaction costs from demand-side grid management	2024	[1]
Cabot and Villavicencio	The demand-side flexibility in liberalised power market: A review of current market design and objectives	2024	[15]
Cardoso, Torriti, and Lorincz	Making demand side response happen: A review of barriers in commercial and public organisations	2020	[16]
Child et al.	Flexible electricity generation, grid exchange and storage for the transition to a 100% renewable energy system in Europe	2019	[17]
Coggan, Whitten, and Bennett	Influences of transaction costs in environmental policy	2010	[19]
Dranka and Ferreira	Review and assessment of the different categories of demand response potentials	2019	[21]
El Gohary	The price signal paradigm – On the evolution and limitations of demand-side flexibility in the EU	2024	[23]
D'Ettorre et al.	Exploiting demand-side flexibility: State-of-the-art, open issues and social perspective	2022	[20]
Lampropoulos et al.	A system perspective to the deployment of flexibility through aggregator companies in the Netherlands	2018	[35]
Olsthoorn, Schleich, and Klobasa	Barriers to electricity load shift in companies: A survey-based exploration of the end-user perspective	2015	[46]
Panda et al.	A comprehensive review on demand side management and market design for renewable energy support and integration	2023	[47]
Siddiquee et al.	Progress in Demand Response and Its Industrial Applications	2021	[53]
Skoczkowski et al.	Participation in demand side response. Are individual energy users interested in this?	2024	[54]
Sousa and Soares	Benefits and barriers concerning demand response stakeholder value chain: A systematic literature review	2023	[56]
Stagnaro and Benedettini	Who are the customers with flexible demand, and how to find them?	2021	[58]
Torriti	Governance perspectives on achieving demand side flexibility for net zero	2024	[67]
Vallés et al.	Regulatory and market barriers to the realization of demand response in electricity distribution networks: A European perspective	2016	[70]
Willems and Zhou	The Clean Energy Package and Demand Response: Setting Correct Incentives	2020	[71]

B

Interview protocol and questions

B.1. Informed consent form

You are being invited to participate in a research study titled 'Understanding Operational Flexibility in the Dutch Electricity Sector'. This study is being done by Wessel Donkervoort, MSc. student Complex System Engineering and Management from the TU Delft.

The goal of this research is to determine how the installed flexibility options and capacity in the electricity sector can be optimally utilised. Participation in this study will take place through a semi-structured interview, lasting approximately 60 minutes. The data collected will be used solely for this research, which will be completed in January 2025, provided there are no unforeseen delays, and published in the TU Delft Education Repository.

Only your name, email, and company will be shared with the author and the direct TU Delft supervisors to facilitate the scheduling of the interview. Your responses will remain confidential within the TU Delft research team. With your explicit consent, the interview will be audio-recorded for transcription purposes. After the interview, the data will be summarized and sent to you for review before publication. Answers, ideas or other contributions given can be quoted anonymously in the resulting product. The results will be anonymized and aggregated to ensure that no company-specific data can be inferred. The final findings of the interview will be included as supplementary material to the thesis, which will be made publicly available.

As with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by storing the information at an institutional storage solution at TU Delft accessible only by the TU Delft research team. All personal data, including the transcript and audio recording, will be deleted no later than 12 months after the DEMOSES project is completed (December 2026).

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. If you are concerned about the handling of the data, please contact Laurens de Vries, for further questions.

Signatures

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

____________________________	__________________________	________
Name of participant	Signature	Date

Study contact details for further information:

Researcher: Wessel Donkervoort, W.Donkervoort@student.tudelft.nl

Supervisor: Laurens de Vries, L.J.deVries@tudelft.nl

B.2. Interview guide

In preparation for the interviews, the questions were shared with the various stakeholders ahead of time. These questions consist of both general and stakeholder-specific questions, based on different themes that followed from the literature review and desk research. Depending on the type of stakeholder, as outlined in Chapter 7, tailored questions were developed to suit their position and involvement in the electricity sector. Below is an example of the questions sent to Energie Nederland.

General overview of the questions

Background and role

1. Can you briefly explain the role of Energie-Nederland as a trade association in the energy transition?
2. How does Energie-Nederland support its members in promoting (innovative) solutions for flexibility?

Market design

3. According to Energie-Nederland, what are the biggest challenges in the current market design for integrating flexibility?
4. How does Energie-Nederland see the role of cooperation between market players, grid operators and the government in removing barriers in the energy market?
5. To what extent does Energie-Nederland see the need for a level playing field at European level to encourage sustainable initiatives and flexibility?
6. How does Energie-Nederland expect initiatives such as the Flex Scan or Sector Deals to influence market structure and flexibility?

Barriers and drivers

7. What legal, policy or financial barriers do members experience when investing in flexibility and renewable energy?
8. How can existing regulations and policy instruments be improved to stimulate investments in sustainability and flexibility?
9. Are there upcoming regulatory changes or policy shifts (e.g., taxes, rules) that could affect the strategy on flexibility?
10. In your opinion, what policy instruments are needed to address current barriers and enhance flexibility utilization?
11. What is Energie-Nederland doing to strengthen incentives for (energy) companies to invest in innovative solutions?

Institutional instruments

12. What is Energie-Nederland's view on adjusting tariff structures to encourage flexibility for both wholesale and retail consumers? For large consumers: including time-based tariffs; feed-in tariff.
13. What role do incentives play in increasing consumers' willingness to offer flexibility?
14. What are Energie-Nederland's expectations on the development and implementation of contract forms, e.g. CPC and ATO?

Future perspectives

15. How does Energie-Nederland, together with its various members, see the potential for smarter use of scarce grid capacity?
16. How does readiness for flexibility differ between companies with existing connections and those in the queue?
17. There are schemes such as Use on Time or Get rid of it (GOTORK). What other developments does Energie-Nederland see as promising to reduce congestion and encourage flexibility?

B.3. Introduction of the interviews

Nederlandse introductie

Mijn onderzoek richt zich op de uitdaging om operationele flexibiliteit in het elektriciteitssysteem te realiseren en te achterhalen welke barrières, zoals incentives, regelgeving en andere obstakels, dit voor actoren verhinderen. Hierbij heb ik een institutionele analyse uitgevoerd voor verschillende flexibiliteitsopties die in Nederland worden onderzocht. Dit omvatte een beoordeling van relevante wetten en regels per specifieke actor. In deze analyse is gekeken naar beleidsparametrisatie, waarbij onder andere de elektriciteitsbelasting, diverse tarieven en beloningen zijn onderzocht. Deze factoren zijn gebaseerd op de marktvoorwaarden van specifieke actoren en de verwachte ontwikkelingen die in de markt worden doorgevoerd.

Met de komst van het Clean Energy Package (CEP) en de nieuwe Energiewet is het van groot belang te begrijpen hoe de markt deze veranderingen ervaart en of hun bereidheid om flexibiliteitsopties te adopteren wordt beïnvloed door deze nieuwe wetgeving. Mijn onderzoek richt zich op het verkrijgen van inzicht in de drijfveren achter het aanbieden van flexibiliteitsdiensten en het begrijpen van hoe actoren beslissingen nemen over het gebruik van flexibiliteit. Daarnaast streef ik ernaar barrières te identificeren en weg te nemen die de werking van flexibiliteitsopties belemmeren. Dit onderzoek biedt ook aanbevelingen voor het ontwerpen van effectieve nieuwe regelgeving en stelt bedrijven in staat hun volledige flexibiliteitspotentieel te benutten. Door onzekerheden die gepaard gaan met de energietransitie te verminderen, hoop ik operationele flexibiliteit verder te stimuleren en de markttransitie te ondersteunen.

English introduction

My research focuses on the challenge of achieving operational flexibility within the electricity system and identifying the barriers—such as incentives, regulations, and other obstacles—that prevent actors from fully utilizing flexibility options. As part of this research, I conducted an institutional analysis of various flexibility options being explored in the Netherlands, focusing on relevant laws and regulations for each specific actor. This analysis included policy parameterization, examining factors such as electricity taxes, various tariffs, and incentives, all of which are based on the specific market conditions of each actor and anticipated market developments.

With the introduction of the Clean Energy Package (CEP) and the new Energy Act, it is crucial to understand how the market perceives these changes and whether their willingness to adopt flexibility options will be influenced by this new legislation. My research aims to gain insights into the motivations behind providing flexibility services and to understand how actors make decisions regarding flexibility utilization. Additionally, I seek to identify and address barriers that hinder the effective operation of flexibility resources. This study will provide recommendations for the design of effective new regulations, enabling companies to unlock their full flexibility potential. By reducing uncertainties associated with the energy transition, I aim to promote operational flexibility and support the ongoing market transformation.

C Interview transcripts

The contents of this appendix are not included in the public publication due to considerations of anonymity and the advice of the Human Research Ethics Committee of the Technical University of Delft.

D Overview instruments

All the identified instruments that influence the behaviour of actors are listed below. These instruments encompass financial mechanisms, policy measures, and operational frameworks that directly or indirectly impact how flexibility is adopted and integrated.

Table D.1: Overview of instruments

Category	Subcategory	Description
Tariff	Time-of-Use	Encourages large consumers to shift consumption to off-peak times through peak and off-peak tariffs.
	Feed-in Tariff	Requires large generators to contribute to grid reinforcement costs, ensuring fair cost distribution.
Management	Capaciteitsbeperkingscontract (CBC)	Customised contracts limiting transport capacity during congestion, with compensation for connected parties.
	Redispatch	Adjusting power generation or consumption to resolve congestion, shifting load to non-congested areas.
	Obligation for Flexibility	Mandates connected users to offer flexibility services in highly congested regions.
	GOTORK	Limits unnecessarily contracted capacity in congestion areas to optimise grid usage.
Taxes	Energy Tax	Levied on gas and electricity consumption; rates decrease with higher usage; phased-out benefits for horticulture.
	CO2 Tax	Minimum carbon prices for industrial and electricity sectors; aligned with EU ETS.
	Exception Hydrogen	Energy tax exemption for electricity used in hydrogen production starting 2025.
Subsidies	SDE++	Subsidises renewable energy generation and CO2 reduction to offset cost and market price differences.
	EIA	Offers tax benefits for investments in energy-efficient technologies and renewable energy.

Continued on next page

Category	Subcategory	Description
	ISDE	Supports investments in renewable energy technologies like heat pumps and solar boilers.
	VEKI	Targets industrial CO2-reducing investments with long payback periods.
External Factors	Market Uncertainties	Includes fluctuating electricity prices, evolving CO2 targets, and renewable energy growth.
	Innovations and Technologies	Influences decision-making and adoption of flexibility solutions in response to system dynamics.