

Critical Barriers of Collective Battery Storage

An Evaluation of Policy Interventions



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Critical Barriers of Collective Battery Storage

An Evaluation of Policy Interventions

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Executive summary

Increased renewable generation capacity and growing electrification to reduce greenhouse gas emissions present significant challenges to the Dutch energy system. The intermittent nature of renewable energy sources requires system flexibility to balance energy supply and demand. The importance of system flexibility is highlighted by the current network congestion issues on distribution and transmission grids. Collective in-front-of-the-meter (FTM) battery storage systems can offer the much-needed flexibility. These collective battery systems can be more cost-effective and efficient in increasing local self-consumption, decreasing curtailment, and alleviating local congestion than individual behind-the-meter batteries. While collective batteries are already deployed in residential areas as neighborhood batteries, they are yet to be implemented in business parks in the Netherlands. Given the advantages of collective battery storage, and since business parks are abundant in the Netherlands and often house energy-intensive companies, the systems could be valuable in the Dutch energy transition. Nonetheless, several implementation barriers prevent the widespread adoption of collective FTM batteries.

A preliminary literature review identifies two knowledge gaps in current research: (1) the lack of scientific research on the identification of implementation barriers of collective FTM battery systems in business parks in the Netherlands and (2) the lack of scientific research on policy interventions that can overcome these critical barriers. The study aims to close these research gaps and stimulate the successful integration of these systems to help fuel the Dutch energy transition. This leads to the main research question of the study:

What policy interventions can be implemented to overcome critical barriers of collective in-front of the meter battery energy storage systems in Dutch business parks?

To answer the research question, a mixed research methods approach is taken. In the first part of the study, a simplified model of a business park with a collective battery system is constructed to quantitatively demonstrate the advantages of community battery storage over individual storage. In the modeled scenario with a collective battery, the curtailment of renewables is reduced by 64% compared to the scenario with three individual batteries that amount to the same capacity as the collective battery. The self-consumption of renewables is increased by 38%. The collective battery also has social and economic benefits. The economic analysis of the model shows that only increasing self-consumption and decreasing curtailment with a collective battery do not create a viable business case. For the battery business case to be feasible, benefit stacking or policy interventions are needed. The next stage of the study identifies 23 theoretical barriers to collective FTM battery storage with a literature review. Using a systemic funneling approach that utilizes the multi-layered micro-meso-macro framework and eight expert interviews, the barriers are reduced and grouped into three critical implementation barriers. In the next part of the study, using literature and expert interviews, three viable policy interventions are proposed per critical barrier. The critical barriers and their policy interventions can be found in Table 1.

Critical Barrier (CB)	Policy intervention (PI)	Description
CB1 – The economic costs and benefits of battery systems	Policy intervention 1	Governmental loans
	Policy intervention 2	Revised tariff structures
	Policy intervention 3	Contractual remuneration for energy services
CB2 – Grid connection procedures for battery	Policy intervention 4	Predict and disclose physical congestion
	Policy intervention 5	Revision of grid connection procedures
	Policy intervention 6	Adjustment of private grid regulations
	Policy intervention 7	Toolkit with standardised agreements

CB3 – Lack of local cooperation	Policy intervention 8	Improved process assistance
	Policy intervention 9	Implement pilot projects

Table 1: Critical barriers and corresponding policy interventions

The three policy interventions aimed at overcoming critical barriers are evaluated in three assessment frameworks to identify the most effective intervention for each critical barrier. The choice of assessment framework is based on the nature of the corresponding critical barrier and policy interventions. Since policy interventions 1, 2, and 3 involve significant public funding, an impact assessment framework is used to select the policy instrument with the greatest positive economic, social, and institutional impact. On the other hand, policy interventions 4, 5, and 6 are evaluated using a multi-criteria decision analysis, which is ideal for assessing changes in current institutions. The third assessment framework is a case study of the Schiphol Trade Park collective energy project since the impact of policy interventions on critical barrier 3, lack of local cooperation, is case-specific and challenging to evaluate theoretically.

An impact assessment was conducted to analyse the potential effects of the policy interventions on the energy sector and society, taking into account their economic, social, and institutional impacts. **Policy intervention 2 - Revised tariff structure** was found to be the most effective instrument to overcome critical barrier 1 - the economic costs and benefits of battery systems. The revised tariff scheme includes two revisions: (1) battery operators are eligible for a rebate on their transport tariffs when performing congestion management, and (2) batteries are exempted from additional fees for peak uses of transport capacity.

For the multi-criteria decision analysis (MCDA), seven commonly used policy assessment criteria were selected. The three policy interventions were scored on these criteria based on expert interviews, literature, and the researcher's interpretation. The scores were then standardized, and experts assigned weights to each criterion's importance. Subsequently, overall scores were derived for the policy interventions, and the results were evaluated. **Policy intervention 4 - Predicting and disclosing physical congestion** was found to be the most effective in overcoming critical barrier 2 - grid connection procedures for battery systems and was selected as the preferred instrument. Predicting and disclosing physical congestion enables the DSO and market parties to shape alternative contracts that state that, during local congestion, the market party will deploy its battery in favor of the grid. The market party can then freely deploy its battery on different energy markets during the remaining time, reducing uncertainty for both the DSO and the battery operator.

In the case study assessment framework, the characteristics of the Schiphol Trade Park project are discussed, along with the hindering effects on local cooperation in this project. The assessment indicates that **policy intervention 7 - a Toolkit with Standardized Agreements** would have been most helpful in overcoming critical barrier 3, which is the lack of local cooperation at the Schiphol Trade Park. It is suggested that the results of this study can be generalized to other similar cases. The proposed toolkit should include a standard participation contract, a data-consent document, and a standard contract between the DSO and various parties for sharing transport capacity and energy. Furthermore, this contract should be incorporated as an exception to the private grid regulations in the *Netcode*.

In addition to closing the two research gaps, the primary scientific contribution of this thesis lies in the innovative approach of combining various research methods and perspectives in assessing policy interventions that can overcome critical barriers for new, viable renewable energy technologies in the Dutch energy sector. This study serves as a foundation and provides a framework for future research that also aims to scrutinize sustainable technologies based on different perspectives.

Regarding the practical contributions of this thesis, it provides policy developers with guidance to make informed decisions when implementing various policy interventions. For market parties, this study identifies implementation barriers that need to be monitored and overcome. For DSOs, this thesis holds value because it pinpoints issues in their organization and provides insights to improve cooperation with market parties in overcoming net congestion problems.

In terms of societal contributions, collective battery storage can balance the local grid and offer flexibility in a cost-effective and energy-efficient manner, making them potentially valuable in the energy transition. This study can help stimulate the integration of these systems and make business parks more sustainable, thus providing social value. Moreover, the implementation of collective FTM storage aligns with the increased use of decentralized renewable energy sources, acting as a steppingstone for the adaptation of other distributed renewable energy sources.

One of the significant limitations of this study is the subjectivity inherent in using expert interviews and expert opinions in the deduction process of the barriers, the selection of policy interventions, the scoring of instruments, and the weighting of criteria in the MCDA. Furthermore, the different assessment frameworks also bear limitations. The model is a simplified representation of reality, whereas the MCDA strongly depends on which criteria and policy interventions are considered. The most significant limitation of the case study could be questionable generalizability.

The limitations of the applied research method have led to two recommendations for future research. Future research should assess the policy interventions differently and more thoroughly, including varying the MCDA method with other criteria and policy interventions. Another recommendation is to assess whether the results of this thesis can also be generalized to collective battery storage in different environments, such as neighbourhood batteries in residential areas. To conclude, more attention should be paid to implementing the proposed policy interventions in future research.

In conclusion, this thesis proposes four policy recommendations. It is recommended to fully design the proposed policy interventions and thoroughly analyse their impact on the energy sector before implementing them. Secondly, DSOs, municipalities, governmental bodies, and the ACM should proactively enable collective, local energy solutions. Furthermore, it is pointed out that non-critical barriers and policy interventions that are not selected still hold value in the policy development process. To conclude, the importance of governance and policy consistency is emphasized.

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List of abbreviations

aFRR	automatic Frequency Restoration Reserve
BRP	Balance Responsible Party
BSP	Balancing Service Provider
BTM	Behind-The Meter
CBC	Capacity-limiting Contract
CB	Critical Barrier
CSP	Congestion Service Provider
DoD	Depth of Discharge
DSO	Distribution System Operator
EMS	Energy Management System
EV	Electric Vehicle
FCR	Frequency Containment Reserve
FTM	in-Front-of-The-Meter
LAN	Landelijk Actieprogramma Netcongestie
MCDA	Multi-Criteria Decision Analysis
mFRR	manual Frequency Restoration Reserve
PI	Policy Intervention
RES	Renewable Energy Source
SoC	State of Charge
TSO	Transmission System Operator

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Chapter 1 Introduction

Chapter I starts with a problem introduction. Secondly, the knowledge gap found using a preliminary literature review and the research objectives will be elaborated, whereafter, the main research question and sub-questions will be enlisted. Hereafter, the thesis's link with the CoSEM programme will be described. To conclude the chapter, an outline of the thesis will be given.

1.1 Problem introduction

The pressing issue of global warming is driving society towards more sustainable energy use (Arent et al., 2011). To reduce greenhouse gas emissions, the Dutch government has adopted the Klimaatwet (Rijksoverheid, 2021), which aims to lower carbon emissions by 95 percent in 2050 compared to 1990 levels (Rijksoverheid, 2021). The energy sector is rapidly transitioning from centralized fossil-based electricity generation to generation based on decentralized renewable energy sources (RES) (IEA, n.d.) to achieve these goals. In the Netherlands, this mainly involves a switch to wind and solar energy (IEA, 2020).

While the large-scale implementation of wind and solar is critical for decarbonizing the energy sector, it also presents significant challenges. Solar and wind generation are variable, and output depends on weather conditions (Lopes, Madureira & Moreira, 2012), which can result in a mismatch between electricity supply and demand (Vargas & Davis, 2016; Goop, Odenberger, and Johnsson, 2017). Additionally, the energy transition is accompanied by increased electrification due to a growing fleet of electric vehicles (EVs) and the electrification of heating and industrial processes (Netbeheer Nederland, 2022). These changes in our energy system place pressure on the electricity grid, leading to net congestion. Net congestion occurs when parts of the grid reach their capacity and cannot carry any more electricity. Net congestion is a major issue in the Netherlands and currently prevents the connection of new neighbourhoods, EV charging infrastructure, and large solar and wind parks to the grid, in addition to impeding the electrification of industries and housing (see Figure 1). Therefore, net congestion poses a significant threat to the progress of the energy transition.

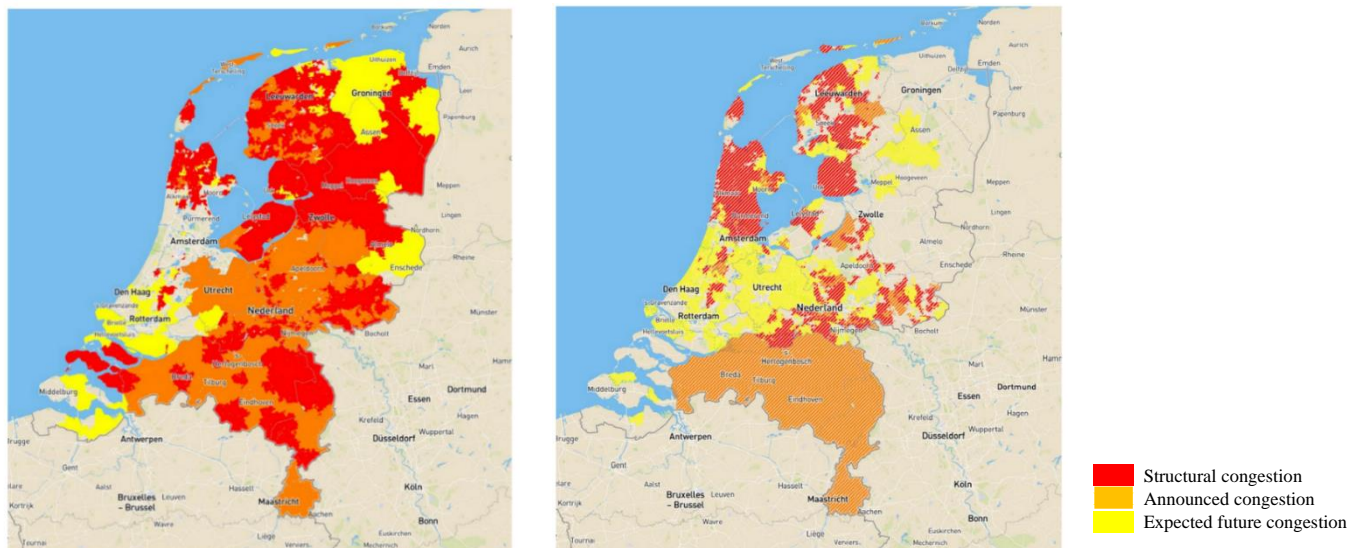


Figure 1: Net congestion in the Netherlands due to feeding in electricity (left) and extracting electricity (right) (Netbeheer Nederland, 2022)

Currently, coal and gas plants provide a significant amount of flexibility to the power system. Power system flexibility refers to the ability to respond quickly to changes in electricity supply and demand (IEA, 2019). However, with the decommissioning of these plants in the Netherlands, new forms of flexibility and balancing will be required to support electrification and stabilize the fluctuations in renewable energy sources (Koirala, van Oost & van der Windt, 2018; IEA, 2019). This necessitates extensive modifications to the existing energy system.

Battery energy storage systems are expected to be an essential component of the future fossil-free energy system in the Netherlands, providing the flexibility needed (European Commission, 2020). Battery storage systems can store energy during times of high renewable energy generation and discharge it during times of high energy demand, ensuring efficient integration of renewable energy sources (Koirala, Hakvoort, van Oost & van der Windt, 2019). This way, batteries can alleviate net congestion and prevent curtailment, which is the deliberate reduction of renewable energy output due to transmission and distribution constraints (Chang et al., 2017). Battery storage systems can also maximize self-consumption of renewable energy and energy security.

Battery storage systems have a wide range of applications and can create value for multiple stakeholders in different locations in the grid (Fitzgerald, Mandel, Morris & Touati, 2015). Based on their applications and grid location, batteries can be categorized as either in-front-of-the-meter (FTM) or behind-the-meter (BTM). BTM batteries are on the customer's side, while FTM systems are directly connected to the grid (Chang, Zhang, Xu & Spence, 2017). Although BTM battery systems are typically used individually by their users, FTM storage systems can be used collectively.

Collective FTM storage can be connected directly to the low-voltage (LV) and medium-voltage (MV) distribution networks (Tickler, 2020). Collective FTM battery storage may offer more advantages than individual BTM battery storage. Collective FTM batteries can reduce peak electricity demand locally, reduce curtailment, and increase self-consumption by balancing multiple loads and renewable generation units (LAN, 2022). Since collective batteries can balance the grid locally, net congestion is reduced in the surrounding grid, and costly grid reinforcements can be deferred (Castillo & Gayme, 2014). This also enhances the stability and resilience of the local grid. Because collective batteries can balance multiple loads and generation units, they can be more energetically and cost-efficient than their individual counterparts. The capacity required for collective batteries is generally lower than that needed when deploying multiple individual ones (Mair, Suomalainen, Evers & Jack, 2021). Thus, collective batteries offer advantages over multiple individual batteries. Collective FTM battery storage could play a significant role in the energy transition due to their positive impact on the local grid.

1.2 Knowledge gap and research objective

Despite the advantages of collective batteries for local energy systems, implementing these systems in the Dutch energy network seems to need to catch up (Zwang, 2022). Current socio-technical configurations, including governmental, financial, and regulatory systems, fail to anticipate the proper integration of collective FTM storage in the energy system (Koirala et al., 2018). In other words, the institutional climate in the Netherlands fails to stimulate the adoption of collective FTM battery storage. Collective batteries have already been implemented as pilot projects in residential areas as neighbourhood batteries but are yet to be implemented in business parks (DNV GL, 2018). Since business parks are abundant in the Netherlands and often house energy-intensive companies, collective battery storage systems to make business parks more sustainable are worth researching. According to TNO (n.d.), making the approximately 3500 business parks in the Netherlands more sustainable will reduce just as much greenhouse gas emissions as making all Dutch residential areas natural gas free.

Collective battery storage systems are not yet implemented in business parks because of critical implementation barriers. Collective batteries in business parks are often more complex to implement than multiple individual BTM batteries at different companies. One reason is that these systems face more complex energy management, because they are connected to more generation assets and loads than individual batteries. Next to this, collective battery storage has to deal with complex stakeholder relationships (because more stakeholders are involved), more stringent legislation (e.g., legislation on private grids), and complex allocation problems (e.g. the allocation of liabilities, risks, ownership, and of costs/benefits between stakeholders) (Klimaatakkoord, 2022; DNV GL, 2018). Companies thus usually go for an integrated energy system BTM.

The implementation barriers of collective FTM battery storage in business parks are too strong to implement these systems successfully. The preliminary literature study revealed that more scientific research needs to be done on the implementation barriers of collective FTM battery storage in business parks in the Netherlands. This is the first identified knowledge gap.

More than identifying critical implementation barriers of collective FTM battery storage in business parks is needed to stimulate their integration into the Dutch energy system. It should also be researched how these critical barriers can be overcome. While there is scientific literature available, like Koraila et al. (2019), and Dutch reports, like Actieagenda Batterijopslag (2022), on how policy interventions can stimulate the implementation of battery systems in the energy systems, these studies focus on generic policies for numerous forms of battery storage. Little research has been done on how and which policy interventions could overcome critical implementation barriers of collective FTM battery storage in business parks in the Netherlands. This can be seen as the second knowledge gap.

The literature review also showed that studies mainly focus on specific elements of the more generic problems that collective FTM battery systems face. Yang, Hu & Spanos (2021), Muzumdar, Modi, Mahdu, Vyjayanthi (2021), and Houwing, Dukovska & Paterakis (2022), for instance, all focus on fair utilisation of collective FTM storage systems. Furthermore, studies primarily look at technical and economic factors influencing collective FTM battery storage and often turn a blind eye to organisational factors, social behaviour, market mechanisms, regulations, and stakeholder complexity.

This study aims to fill the two knowledge gaps by researching what policy interventions can overcome critical implementation barriers of different natures (technical, institutional, social, and economic) of collective FTM battery storage in business parks in the Netherlands. In other words, the studies' research objective is first to identify critical implementation barriers of collective battery storage (knowledge gap 1), whereafter it will lay down how policy interventions of different natures can overcome these barriers and unlock the true potential of collective FTM battery systems in stimulating the energy transition in the Netherlands (knowledge gap 2).

1.3 Research questions

The research objective is translated into the following main research question:

What policy interventions can be implemented to overcome critical barriers of collective in-front of the meter battery energy storage systems in Dutch business parks?

The main research approach is dissected into four sub-questions:

- I. What are the benefits of implementing collective FTM battery storage in business parks in the Netherlands?*
- II. What are the critical barriers to the implementation of collective FTM battery storage?*
- III. What policy interventions can overcome the critical barriers of collective FTM battery storage?*
- IV. How can these policy interventions be assessed?*

The chosen research approach will be elaborated thoroughly in section 2.1.

1.4 Relevance for MSc program

Collective battery energy storage systems and their local environment are typical examples of complex socio-technical systems (Koirala et al., 2018; Koirala et al., 2019). Technical infrastructure is at the core of the system, while many different actors, institutional arrangements, social conditions, and market factors play significant roles in the system's proper functioning. These elements are closely linked to the principles of Complex Systems Engineering and Management Master (CoSEM). Given the complex socio-technical environment that collective FTM battery storage encounters and the sheer interconnectedness of the system, developing policies to enhance the successful integration of these systems is a challenging and unique task, making it an exemplary topic for a CoSEM thesis. This study aims to reflect the knowledge acquired throughout the master's programme by performing a system analysis and employing various approaches that consider different perspectives to identify the most suitable policy intervention to overcome critical implementation barriers of collective battery storage. The study's implications on the system level are discussed, highlighting the need for a holistic approach, which is typical for a CoSEM thesis.

1.5 Outline of the thesis

This thesis comprises eight chapters, of which this introduction is the first. The next chapter lays down the research methods used during the graduation project. This methodology description is included to improve repeatability and make evaluating the used MCDA method possible. Chapter 3 sets the scope for the study and describes the model used to show the benefits of collective battery storage. Chapter 4 identifies critical barriers to the successful implementation of collective FTM batteries. In the next chapter, chapter 5, the different policies are described. Chapter 6 will display the evaluation process of the different policy interventions. To conclude chapter 7 will entail an extensive discussion and conclusion. Chapter 7 will also give several policy recommendations.

Chapter 2 Methodology

In this chapter, the applied research methodology will be described. The chapter explains which research approach was taken and which research methods were used, why these methods were chosen, and how these methods were executed. The chapter starts by explaining the overall research process. A research flow diagram (RFD) summarises the full research process. Hereafter the different research methods that were deployed in the different stages of this research approach are described.

2.1 Mixed methods research approach

This section will discuss the overall research process of this thesis. The study has a mixed methods research approach. The discussion describes the approach's limitations and specific research methods and how these were overcome. The full study is summarized in the RFD of Figure 4. The RFD shows the different research steps, accompanied by their respective research methods, chapters, research output, and the research questions they answer.

Scope and model

After the introduction and methodology, chapter 3 describes the scope of the system. An elaboration on the scope was deemed necessary to define the system boundaries and guide the thesis. The second part of the chapter was used first to describe the model. Hereafter, the energetic and societal benefits of collective systems over individual ones that the model shows were described. Furthermore, an economic analysis of the model was performed. The economic analysis showed the economic benefits of collective battery storage over individual batteries. It also quantitatively analysed whether collective batteries on business parks in the Netherlands can create a viable business case by only increasing self-consumption and reducing curtailment of renewables or whether other applications are also needed to create additional value with the battery system. It was deemed necessary to perform the energetic and economic analyses since collective battery storage systems are not yet implemented in business parks in the Netherlands. Before the full analysis was carried out on how the implementation of these systems can be stimulated by taking away barriers with policy interventions, first the advantages of these systems needed to be shown. Furthermore, the business case analysis gave a first economic insight in why these systems are yet to be implemented, despite their energetic advantages. This can be seen as a proof of concept for collective battery storage systems on business parks in the Netherlands.

A business park with three different companies was modelled in Microsoft Excel. The three companies all have different hourly generation and electricity usage profiles. Three scenarios were modelled: the companies without battery storage systems, the three companies all with separate battery systems, and a system with a collective battery. Based on this model, the benefits of collective battery storage in business parks were shown. Chapter 3 answers the first research question.

Barriers

To adequately determine which policy interventions can be implemented to improve the successful integration of collective FTM battery storage systems, it was necessary to identify the current barriers to their integration in the Netherlands. Chapter 4 of this study first identifies theoretical implementation barriers in the Netherlands, based on an extensive literature review that forms the basis for the identification of these barriers. The literature review methodology is described in section 2.2, and a schematic representation of the process is shown in Appendix A. A total of 32 scientific articles and 30 reports, websites, and news articles (grey literature) were reviewed, with 22 scientific articles and 21 grey literature pieces included in the analysis. This approach ensured that as many theoretical barriers as possible that

currently exist in the Netherlands are captured in this chapter. Although it is difficult to assess whether all theoretical barriers are described in this chapter, the scrutiny of the literature review does ensure a comprehensive overview of theoretical barriers.

The identified barriers were of technical, economic, institutional, and social origin and were placed in the multi-layered micro-meso-macro framework to provide a theoretical perspective on the level of the system in which the barriers occur and how they might be overcome. After the micro-meso-macro framework provided more insight into the system orientation of the barriers, it was necessary to reduce the theoretical barriers to a few critical barriers. This was done to keep the analysis comprehensible as it would be impossible to select policy interventions that can overcome all 23 theoretical barriers accurately. By focusing on a few critical barriers, the analysis was kept concise. The reduction from theoretical barriers to a few critical barriers was done using a funnelling approach consisting of three steps.

The first step assessed whether the barriers and their possible policy interventions are inside or outside of the scope of this study. To reach the research goal (overcoming critical barriers of collective battery storage so that collective battery storage can be implemented in the Dutch energy system), effective policies were evaluated that specifically target collective battery storage systems in the energy system. General barriers that might have a hindering effect, but are also common in other sectors in the Netherlands, were excluded since they cannot be targeted with energy-sector-specific policies. They require a more holistic, general governance approach that is out of the scope of this thesis. Besides, for some barriers, it was argued that they are out of scope because the barriers are sector-specific but are unlikely to be overcome with policy interventions.

The second step assessed the criticality of the barriers. The expert interviews with IV1 – IV6 were used to select the barriers that have the largest negative effect on the integration of collective battery storage since some barriers have a more negative influence than others. This triangulation of the barriers ensured that only the barriers that are perceived as highly impeding by different stakeholder groups with differing perspectives remain. The assessment of the criticality of the barriers was also supported by some literature. The methodology of the expert interviews can be found in section 2.4.

The third and final step compared the critical barriers named by the interviewees with the theoretical barriers that are left. Barriers that showed similarities were grouped to form the critical barriers. By systematically carrying out the funnelling process, it was ensured that the right critical barriers are captured. The funnelling process resulted in the identification of three critical barriers: the economic costs and benefits of battery systems (critical barrier 1), grid connection procedures for battery systems (critical barrier 2), and a lack of local cooperation in collective battery storage systems (critical barrier 3). The critical barriers were once more validated using the interviews with IV7 and IV8. The funnelling process can be found in Figure 2.

Shifting the focal point of analysis to a few critical barriers made sure that impactful, implementable policy interventions were proposed and thus that viable results were obtained. By combining the theoretical knowledge from the literature review with the practical insights from the interviews, it was assured that the right critical barriers are identified. The full analysis can be found in chapter 4. Sub-question 2 is answered via this analysis.

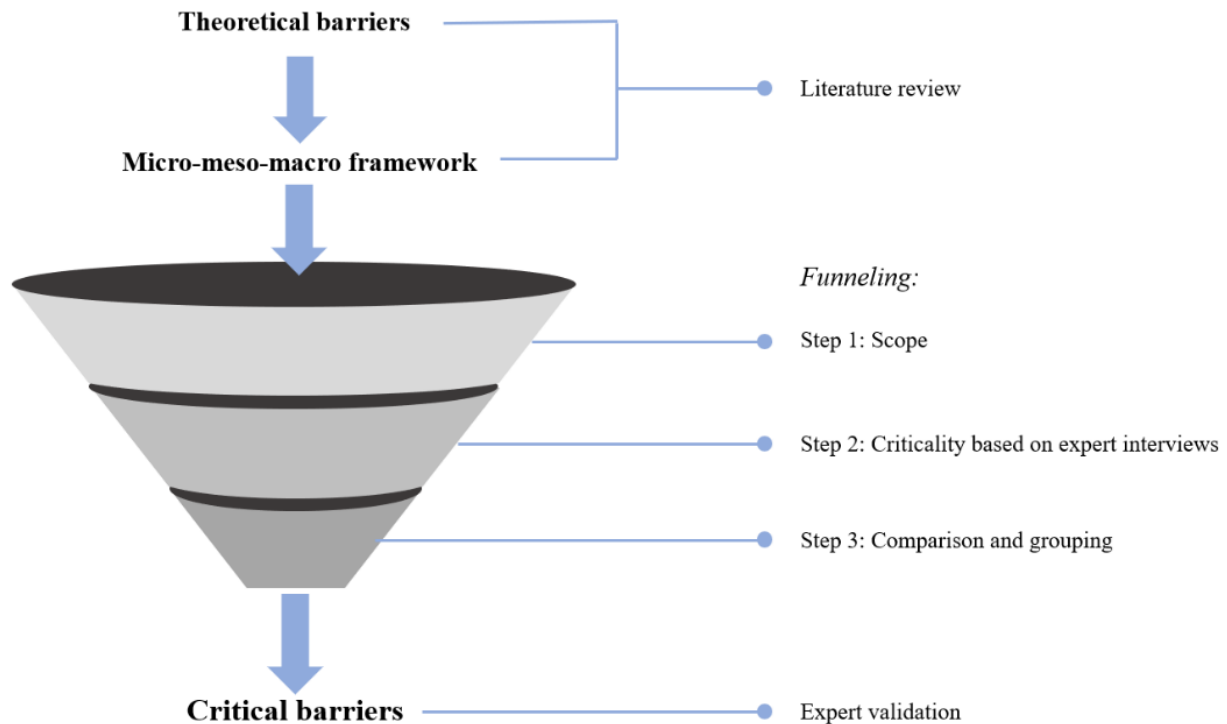


Figure 2: Funnelling process

Policy interventions (PI)

In chapter 5, three policy interventions are proposed per critical barrier. Per critical barrier, and in particular for critical barrier 1 – economic costs and benefits of batter systems, numerous policy interventions were available. Three policy instruments was seen as an adequate amount to on the one hand keep the analysis comprehensible and within the time-scope of the thesis, but on the other hand still explore different options and make a thorough consideration between different interventions. The choice for the three specific policy interventions per barrier was explained. The policy options were considered based on literature and the conducted interviews. Chapter 5 gives the answer to the third research question. The proposed policy interventions can also be found in the research flow diagram of Figure 4.

Assessment frameworks

After the policy interventions had been identified, they were assessed in three different frameworks. The assessment methods were chosen based on the nature of the corresponding critical barriers and policy interventions. This analysis is displayed in chapter 6 and gives the answer to the fourth research question. *Critical barrier 1: the economic costs and benefits of battery systems* was assessed using an impact assessment of the policy interventions. While the first three policy interventions are financial support measures and involve large amounts of public money, an impact assessment was chosen as method to make sure the money is spend well and that the policy interventions with the biggest positive impact on the energy sector is chosen. The impact assessment methodology can be found in section 2.5. *Critical barrier 2: grid connection procedures for battery systems* was an institutional barrier and its corresponding policy interventions resemble policy changes. A multi-criteria decision analysis (MCDA) is particularly suited for assessing institutional changes based on different criteria (Belton & Stewart, 2002). This is why this method was chosen. The MCDA process is further elaborated in section 2.6.

Critical barrier 3: Lack of local cooperation evolved around local cooperation in collective battery projects. The policy interventions that can overcome this barrier are best evaluated in real-life projects. Therefore, these policy interventions were evaluated using a case study of the collective energy project at Schiphol Trade Park. The case study methodology is further described in section 2.7. The motivation for the proposed assessment frameworks is described in more detail in chapter 6.

2.2 Literature methodology

In Chapters 3, 4, and 5, literature was utilized to support various aspects of the study. The identification of theoretical barriers in chapter 4 involved an extensive literature review, whereas in other parts of the study, literature was used to complement other research methods. To identify all theoretical barriers that exist in the Netherlands, a semi-structured literature search methodology was employed. The Google Scholar and Scopus databases were used to identify relevant academic literature, using different Boolean searches. These Boolean searches were also used to obtain relevant grey literature, such as reports, news articles, and websites, given the practical nature of the barriers. The relevance of the literature for the research project was then assessed, and less relevant articles were excluded. Eligibility of the articles was also tested, and articles older than fifteen years were removed. This time scope was applied since the research field of collective FTM batteries is rapidly developing, and articles older than fifteen years may have outdated methods and results. Appendix A provides a schematic representation of the literature review process in chapter 4.

2.3 Stakeholder analysis methodology

A stakeholder analysis was conducted to clarify which groups should be involved in various stages of the policy development process, as it provides decision-makers with valuable strategic information about the groups that may affect the successful integration of collective FTM battery storage. Additionally, key stakeholders were primarily focused on in the remaining study, such as in the expert interviews and in the weighing of criteria in the MCDA. The stakeholder analysis thus guided other parts of the research. A power-interest grid was used in the stakeholder analysis to identify key stakeholders, who are groups with high power and high interest in collective FTM battery storage. The key stakeholders identified were the battery project developer, the battery operator, and the DSO. Given the government's sheer institutional influence and the policy viewpoint of the analyses, the government and the ACM were also taken into account. The complete stakeholder analysis is included in Appendix B, which can be used as a reference for the roles and responsibilities of the various parties mentioned in this thesis.

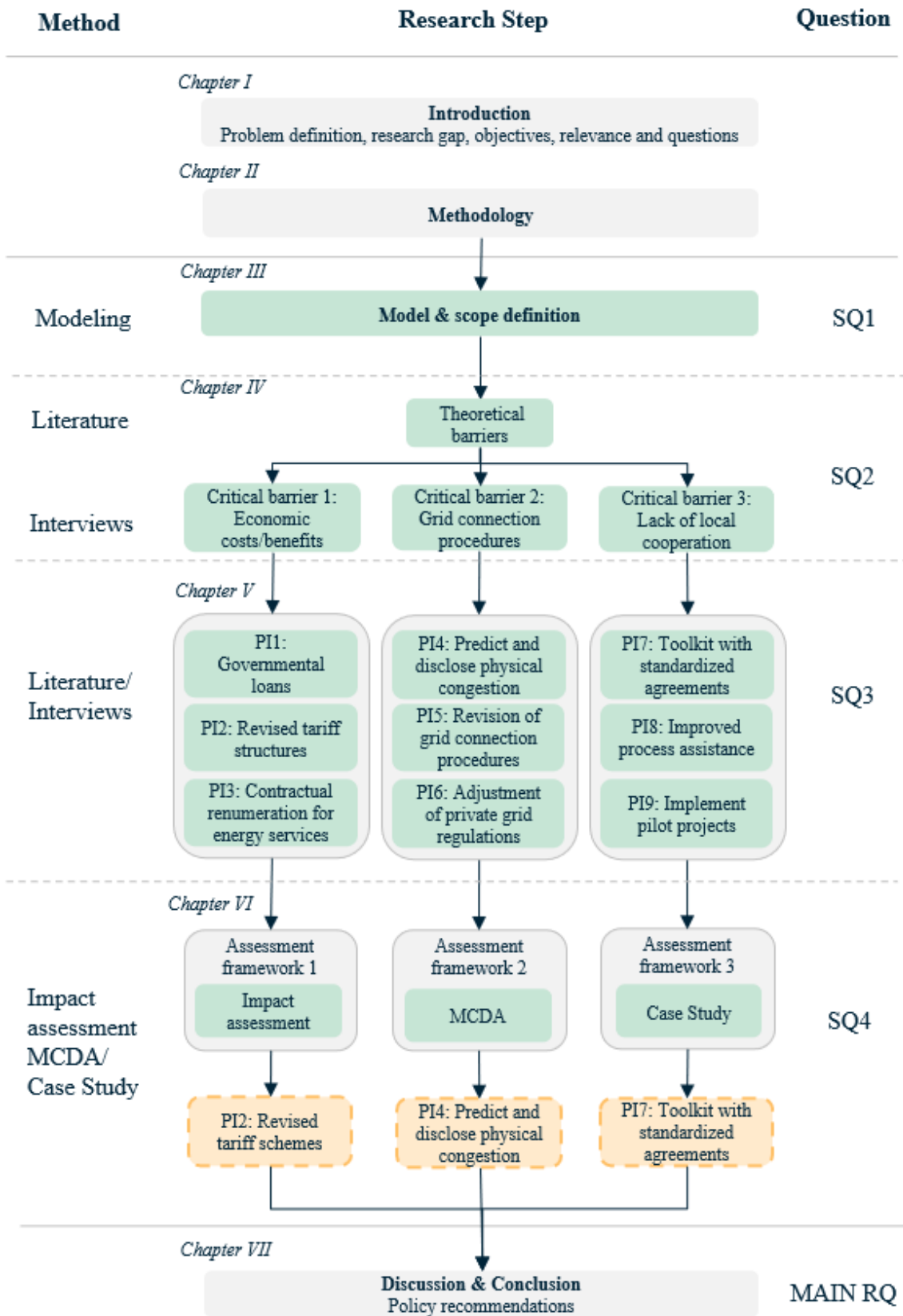


Figure 3: Research flow diagram

2.4 Interview methodology

As mentioned above, step 2 of the funnelling process from theoretical to critical barriers was done using expert interviews. The interviewees were asked to name critical implementation barriers. They were also asked to define non-critical barriers out of a barrier list. The critical barriers identified in the interviews were then compared with the theoretical barriers, in order to find similarities. After grouping of the theoretical barriers, this resulted in the identification of the three critical barriers. Besides, for the identification of viable policy interventions in chapter 5, and the scoring of the policy alternatives in the MCDA, interviews were conducted. Interviews were also used to retrieve information for the case study in chapter 6. This section lays down the methods behind the interview process. The report on every interview can be found in Appendix E, as well as the pre-defined questions that formed the basis for the interviews. These questions were slightly adjusted before every interview based on the interviewee's background and the purpose of the interview but remained similar for every interview. Besides this, a slide deck was used to explain the goal of the interview to the participants. This slide deck acted as a guideline during the interview. The slide deck can also be found in Appendix E.

The interviews were of a semi-structured nature, using open-ended questions so that detailed and descriptive information can be gathered without influencing the respondent's answers. Semi-structured interviews are an ideal research method in situations where there is a certain amount of objective information already obtained by the researcher, but personal, empirical data and experiences are lacking (McIntosh & Morse, 2015). Semi-structured interviews provide the structure needed to steer the interview in the direction of the questions that need to be asked but also allow enough room for the interviewee to digress to other subjects that could be of importance in answering the research questions. The full interview process is divided into three main steps: preparation, execution, and analysis. These are subdivided into smaller steps. Figure 5 shows the interview process.

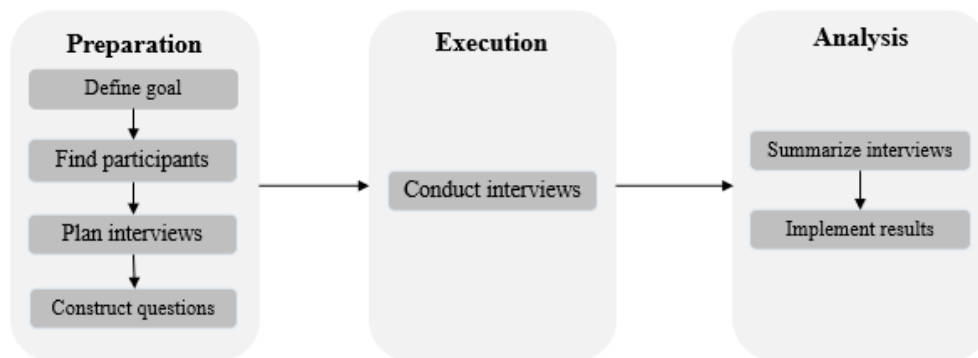


Figure 5: Interview process

First of all, the goal of the interviews was defined. The interview goal for the interviews with interviewee 1 to 6 was to pinpoint critical barriers for chapter 4 and to attain information on the selection of different policy interventions for chapter 5. Furthermore, these interviews were used for the MCDA in chapter 6. The interview with interviewee 7 was used to gain information for the case study of chapter 6. The interview with participant 8 was used for validating the critical barriers and policy interventions. Subsequently, interviewees were asked to partake in the study. Participants were selected out of the stakeholder groups that are labelled 'important' based on the stakeholder analysis of Appendix B. From all these groups, interviewees were invited in order to cover all the different perspectives of the important stakeholder groups. Only interviewees with ample experience in the energy sector and vast knowledge of battery storage

systems and system flexibility were invited from every stakeholder group. Table 2 gives an overview of the anonymized interviewees.

Reference	Stakeholder Group	Role	Experience in energy sector (years)
IV1	DSO	Consultant Energy Transition	7
IV2	Battery project developer	Executive	10+
IV3	Technical service provider/industry association	Energy flexibility manager/Board member	10+
IV4	Policy advisor	Public and regulatory affairs advisor	10+
IV5	Battery project developer/consultancy	Battery project developer/consultant	5
IV6	Battery operator (BSP/BRP)/industry association	Founder/Board member	10+
IV7	System integrator (EMS)	Energy consultancy team lead	5+
IV8	Battery project developer/consultancy	Battery project advisor	5+

Table 2: Overview of interviewees

After planning the interviews, the lists of questions and slide deck were constructed. If the interviewee consented, the interview was recorded for further reference. After the interviews were conducted, the interviews were summarized in the reports that can be found in Appendix E. The summarized interview reports were used to support the reasoning in the aforementioned chapters.

2.5 Assessment framework 1: Impact assessment methodology

An impact assessment was performed in assessment framework 1. The method was chosen since impact assessments provide a good fit with the purpose of assessment framework 1: they are designed to structurally consider the implications of policy proposals, for people and their environment, in stages of the design process that there is still an opportunity to modify the proposals or choose between different proposals (IAIA, n.d.). By assessing the potential impacts of policy interventions in various dimensions, impact assessments can provide a structured framework for decision-making and help ensure that policy decisions are informed by evidence (World Bank, 2018). Furthermore, impact assessments enhance accountability and transparency of the policy developing process (United Nations Environment Programme, 2002). As mentioned before, to assure that public money is well spend and the chosen policy intervention will have considerable positive impact on the energy sector, the impact assessment was designed.

Impact assessments normally analyse the environmental, social, economic and institutional consequences of proposed policy interventions (IAIA, n.d.) Since the policy interventions all promoted the same technology, the environmental impact of the three policy interventions was similar. Hence, the three policy interventions were systematically assessed only on their social, economic and institutional impact.

2.6 Assessment framework 2: Multi-criteria decision analysis (MCDA) methodology

MCDA was first coined by Keeney & Raiffa (1976) to make sound decisions when faced with problems with a lot of external influential factors. The MCDA is a formal model that deals with decision problems with a high degree of complexity by applying an analytical and systematic approach (Belton & Stewart,

2002; Thaler & Sunstein, 2008). MCDA can increase the transparency and objectivity of the decision-making process and generate results that can be replicated (Bonte et al., 1997). MCDA is particularly useful for decisions that have a long-term impact and thus need careful consideration (Belton & Stewart, 2002). Given the complexity of the policy decisions surrounding collective battery storage in the Netherlands and the long-lasting impact these decisions will have on the energy transition, MCDA fits well as the second assessment framework.

MCDA has also gained traction in the field of research on climate change mitigation and sustainable energy policy decision-making. Examples of these studies are Cohen et al. (2018), Janssen (2001), and Wang et al. (2009). Conventional economic modelling tools like cost/benefit analyses that depend upon one criterion to select among possible policy interventions have shown limitations. These limitations predominantly lie in the fact that the formulation of policies involves a large number of stakeholders with differing views and preferences and high complexity (Greening & Bernow, 2004). Using MCDA offers a better alternative because these methods take multiple criteria into account and can make trade-offs between different climate policy interventions understandable (Bell, Hobbs, Elliott, Ellis & Robinson, 2002).

Since Keeney and Raiffa laid the foundation for MCDA, a large amount of different multi-criteria decision methods has been developed over the years. MCDA can be used both with quantitative and qualitative criteria. The MCDA in this study will solely consist of qualitative criteria. The goal of the MCDA was to determine which of the three policy interventions can overcome critical barrier 2 – grid connection procedures for battery systems. To achieve this, different steps were used to rank the different instruments based on predefined selection criteria. Some disadvantages of MCDA are that it could be prone to manipulation and can provide a false sense of accuracy (Janssen, 2001). Guitouni and Martel (1998) advocate accordingly that ‘the formulation of the multi-criteria decision problem usually is the most critical part of the process’. This is why it was important to establish and execute the different steps of the MCDA with scrutiny to minimize subjectivity and biases. The MCDA method used was the weighted summation method (WSM).

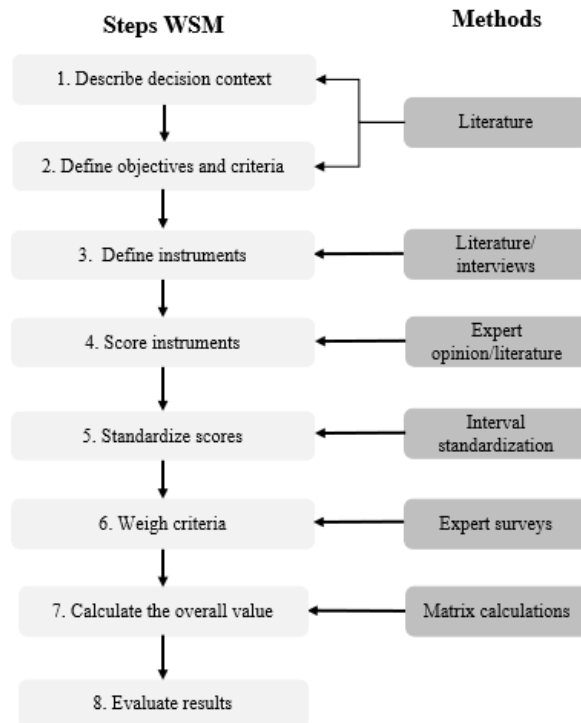


Figure 6: MCDA steps

It is a relatively easy and frequently used method but can obtain viable results (Triantaphyllou & Baig, 2005). One advantage of this method is that the different assessment criteria are weighted according to their importance, putting more emphasis on crucial parts of the decision problem. The different steps of the MCDA will now be discussed and are shown in Figure 6. The steps are adapted from Dodgson et al. (2009). The full MCDA analysis can be found in chapter 6.

1. Describe decision context

The first step of the MCDA was to fully understand the decision context. This was deemed essential to make good decisions. The scope and model definition in chapter 3 and literature review that identified the theoretical barriers in chapter 4 can be seen as descriptions of the decision context.

2. Define objectives and criteria

The objective of the MCDA was to choose the most impactful and well implementable policy intervention out of the three policy interventions proposed for critical barrier 2 – grid connection procedures for battery systems. All three policy interventions purely entail a change in current institutional arrangements. Next to this, all three policy interventions were viable, impactful policy interventions that were carefully picked through the analyses of Chapters 4 and 5. This is why the instruments were assessed only based on criteria that are often used to assess public policy proposals. These will mostly show how well a policy is designed and how implementable they are.

Seven of the eight criteria proposed by Kraft and Furlong (2010) for assessing public policy proposals were chosen for this study. These were effectiveness, efficiency, equity, liberty, and political, technical, and administrative feasibility of the proposed policy interventions. Social acceptability was disregarded, since all three proposed policy interventions are energy-sector specific and do not deal with large interference from the public (Caputo, 2013). Table 3 summarizes the criteria with their ID and definition from Caputo (2013).

Criterion	ID	Definition
Effectiveness	C1	The likelihood of achieving policy goals and objectives
Efficiency	C2	The assessment of achieving policy goals in relation to costs
Equity	C3	Fairness in the distribution of a policy's costs and benefits across population groups
Liberty	C4	The extent to which public policy enhances or restricts privacy and individual rights and choices
Political feasibility	C5	The likelihood that a policy would be adopted – in particular the extent to which officials accept and support a policy proposal
Technical feasibility	C6	The availability and reliability of technology needed for policy implementation
Administrative feasibility	C7	The likelihood that a department or agency can implement the policy well

Table 3: Criteria for policy interventions (Caputo, 2013)

3. Define policy interventions

The third step was to identify policy interventions. This was done using the approach described in section 2.1. Per critical barrier, three policy interventions were chosen based on the interviews and literature. Chapter 5 gives the full analysis.

4. Score instruments

In the fourth step, the different instruments were scored. This was done based on a literature review, expert opinion, and the rationale of the researcher.

Four sector experts were asked to give their opinion on how the policy intervention scores on the different criteria. The sector experts were selected from different key stakeholder groups, identified in the analysis in Appendix B. This was done to ensure that different perspectives on the decision problem were considered. The performance of the policy interventions on the different assessment criteria was scored on a scale from - - to ++ (-/-/0/+ /++). The highest score is ranked with a 2 (++) and the lowest score is ranked with a -2 (--).

Given the qualitative nature of the study and the lack of exact data, the choice was made to score the designs on a scale. The value given to the designs on each criterion serves as an index for the increase or decrease of the influence of the second critical barrier (grid connection procedures for battery systems). The greater the value, the bigger the positive change the policy intervention brings about in overcoming the second critical barrier.

5. *Standardize scores*

When using different measurements of scale, it is important to standardize the scores to make the criteria comparable with each other. A regular interval standardization method was chosen, often used in environmental impact assessments. This simple standardization method was chosen because the assessment criteria already have the same unit of measurement (Janssen, 2001). The standardised scores were obtained with the formula:

$$S_{st} = \frac{s_{ns} - \min}{\max - \min} \quad (2.1)$$

in which the standardised score S_{st} was determined by the unstandardised score s_{ns} and the minimum and maximum scores possible for the set of criteria, which were -2 and 2. This gave S_{st} a value on the interval [0,1].

6. *Weigh criteria*

Since not all criteria are equally important, different weights were assigned to the criteria. Hereafter it was possible to assign priorities to the different criteria. The criteria were prioritized based on expert surveys with four of the participants in step 4 of the MCDA. The participants were asked to weigh the criteria from 1 to 7, 1 being least important and 7 being most important. The average of the weights assigned to the criteria in the four surveys was calculated. The rank sum method was executed to normalize the weights. In the rank sum method, 'the weights are computed from the individual ranks by dividing with the sum of the ranks' (Odu, 2019). These averages were then converted to a number between 0 and 1, 0 being least important and 7 being most important. The weights of the criteria together amount to 1. The weighing sheet can be found in Appendix G.

7. *Calculate the overall value*

In order to rank the designs, the overall value of the different policy interventions was calculated. The overall value of the policy interventions was calculated using the weighted sum of the standardised scores. This means that for every policy intervention, the standardised score on each criterion was multiplied by the average weight of the respective criteria, whereafter all are added together and the overall value per policy intervention was obtained.

8. *Evaluate the results*

In this step, the ranking of the instruments was examined and evaluated. Given its qualitative character and the pitfalls inherent to MCDA, for instance, its tendency to deliver subjective results, it was deemed necessary to thoroughly evaluate the results. The results were once more validated by experts. This makes sure that the results are unambiguous and valid.

2.7 Assessment framework 3: Case study methodology

Assessment framework 3 consisted of a concise case study. The goal of the case study was to determine which policy intervention is the most viable option to overcome the third critical barrier (lack of local cooperation). The case study analysis is carried out based on interviews with the parties involved (IV8) and reports on the project. The pilot project that is proposed for the case study is the energy project at Schiphol Trade Park.

A case study approach ‘allows in-depth, multi-faceted explorations of complex issues in its natural, real-life context’ (Crowe et al., 2011). Local cooperation within collective battery projects comprises intricate interactions between actors in complex stakeholder networks. The influence of policy interventions on these interactions is case-specific and hard to assess theoretically, given their unique character. Conducting a case study was the perfect way to see how policy interventions could take away critical barrier 3 – lack of local cooperation and improve local cooperation in a specific case with hands-on examples. Hereafter, it could be assessed how the findings of the specific case translate to other cases.

In section 6.3, the characteristics of the Schiphol Trade Park project will be discussed, whereafter the choice for this specific project will be elaborated. Hereafter, specific hindering effects on the local cooperation of the project were identified, and it was assessed how either of the proposed policy options could have helped smoothen and accelerate the implementation process of the project. Based on this analysis, the most preferred policy intervention was selected. To conclude, it was investigated whether the results obtained in this specific case, also apply to other local energy hubs and initiatives.

Chapter 3 Scope and model

In this chapter, the scope of the thesis will be discussed first. Following that, the modelling approach will be presented. The modelling approach in this chapter aims to demonstrate the economic, energetic, and societal advantages of collective battery storage on business parks in the Netherlands. This is necessary because such systems are not yet implemented. The first section describes the scope of the thesis, followed by the second section which discusses the modelling approach and the energetic and social advantages of collective battery storage. The third section presents an economic analysis of the model, demonstrating the economic advantages of collective battery storage. It will also show that benefit stacking is necessary to create a viable business case for collective batteries. The chapter concludes with a summary. This chapter provides an answer to the first research question:

SQL – What are the benefits of implementing collective FTM battery storage in business parks in the Netherlands?

3.1 Study scope

It is of pivotal importance to clearly define the scope and system boundaries of the study. This entails the size of the battery, its type, the place of the battery in the grid, the type of grid connection of the collective FTM battery, the reason why the battery is placed in the first place (which problem does it intend to solve?) and the surrounding system of the battery. All these factors directly influence the use of the battery. First, the definition of FTM battery storage will be further elaborated.

FTM is a term frequently, but often ambiguously used. Different definitions of the term have been coined in studies. Collective FTM battery storage in this study entails battery storage that is directly connected to the grid and is used by multiple companies in a business park. The battery is not positioned at a party with an already existing grid connection, which is the case with BTM battery storage. Because of its own grid connection, the collective FTM battery system will also have its own electricity meter. The fact that the collective FTM battery system physically sits ‘behind a meter’ is important for the billing of energy but does not determine whether the battery storage is FTM or BTM despite the ambiguous name. The thing that makes it collective and FTM is its collective application and the fact that it is directly connected to the grid.

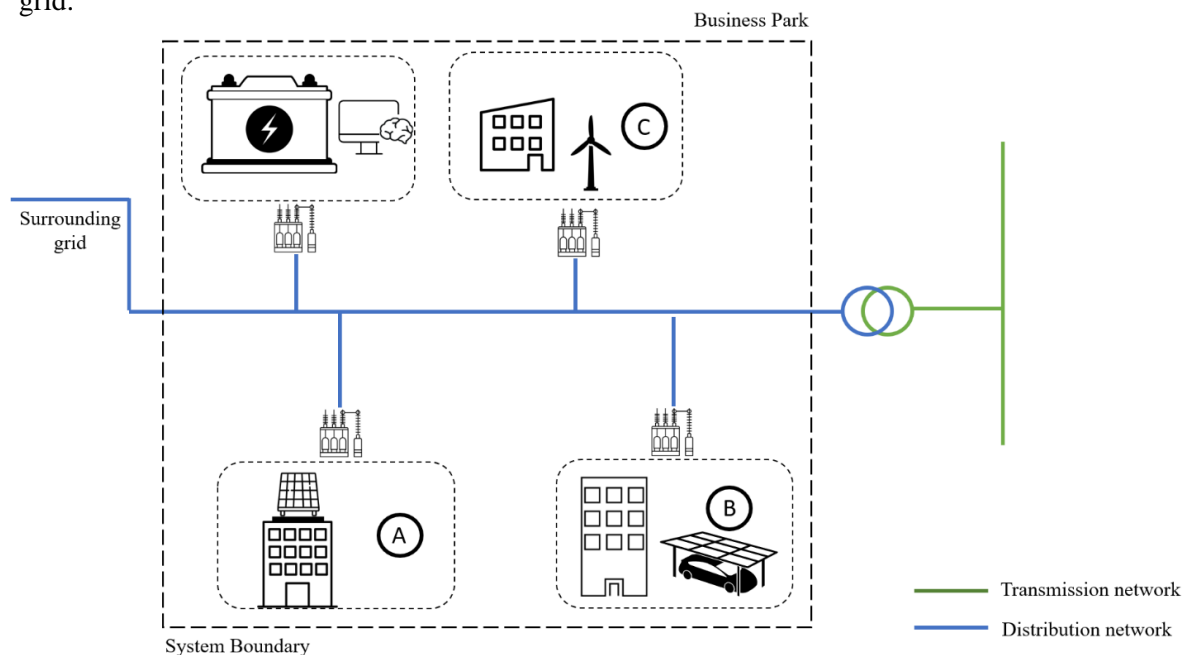


Figure 7: Schematic representation of system boundary

EQUANS Infra & Mobility is currently focusing on the business-to-business market, where it has observed a surge in demand for battery storage systems among its clients. Most of the interest is coming from companies located in business parks that aim to combine solar generation (e.g., a solar park or solar carports) with electric vehicle (EV) charging infrastructure and a battery energy storage system. These systems typically consist of medium-scale Lithium-ion (Li-ion) batteries with a capacity ranging from 500 kW to 2 MWh, depending on the grid connection, scale of the solar units, sun profile, load profile of the companies, and EV charging demand (Royal HaskoningDHV, 2021). This study focuses on collective FTM medium-scale Li-ion batteries (500 kWh - 2 MWh) that are directly connected to the distribution network of business parks in the Netherlands. The battery system is shared by commercial parties in the business park. Figure 7 provides a simplified schematic representation of the system boundaries for this study.

The figure displays the distribution network of a business park in the Netherlands. The battery storage system can be connected to either a low-voltage or middle-voltage distribution network, depending on how the distribution network in the business park is structured. A business park, or "bedrijventerrein," is an area primarily intended for the establishment of companies, located inside or outside the built-up area of a city or town. There are numerous examples of such areas in the Netherlands, with almost every town having one. The figure illustrates three different companies: company 1 has a rooftop PV system, company 2 has solar carports, and company 3 has a small wind turbine. The number of companies and their composition may vary, and this is just an example. The collective FTM battery storage system has an integrated Energy Management System (EMS) that enables intelligent (dis)charging. The companies and the collective battery have their own separate grid connections. The schematic representation of Figure 7 serves as the starting point for the model description in section 3.2.

Batteries are typically integrated into energy systems like this one due to the need to incorporate these systems. For example, net congestion on the distribution network could impede companies from electrifying their business processes and connecting renewables to the grid. A battery can provide a solution in such cases. But why would these companies opt for a collective FTM battery? Firstly, aggregating the power demands and supplies of various companies with one battery can smooth out individual supply and demand peaks due to differences in the load and generation of the different companies. This more efficient load balancing and peak shaving results in less curtailment, increased self-consumption of renewables, and thus less net congestion in the surrounding grid, as less energy is fed back into/extracted from the surrounding grid. The requirements for capacity and power of a collective FTM battery system are smaller than those for separate BTM battery storage systems due to this more efficient balancing, leading to fewer up-front capital costs that can now be shared among the different companies. The modelling approach will now provide a real-life, quantitative example of the benefits of collective FTM battery storage.

3.2 Model description

In this section, first the characteristics of the modelled companies are described. Secondly, the logic behind the model is explained. Hereafter, the characteristics of the battery are described and the validity of the model is discussed. Furthermore, the advantages of collective battery storage are laid down. The model is identical to the system description of section 3.1.

3.2.1 Company characteristics

For the modelling approach, the system of Figure 7 is modelled in Microsoft Excel. Companies A, B, and C all have different load and renewable generation profiles. All profiles consist of 15 minute real-life data from the year 2020. The profiles are adjusted slightly to make sure the confidentiality of the data is not breached.

Company A and C are both small production facilities. Because production is planned in shifts during day and night, and sometimes the facility is shut down for inspection and cleaning, both companies have an irregular load profile. Company B is an office building and thus has a more regular load profile. Company A has a rooftop PV system of 0,40 Mega Watt peak, (MWp), and company B has solar carports of 1,30 MWp. MWp is a measure for the maximum power that can yearly be generated with a solar generation unit under optimal circumstances (zonnepanelen-info.nl, n.d.). For generation output in the Netherlands, Wp can be multiplied by 0,85 to get the amount of energy that can be approximately generated with the generation unit per year (zonnepanelen-info.nl, n.d.). This comes down to 0,34 MWh for company A and 1,15 MWh for company B. Company C has a small wind turbine with 0,20 MW capacity. All three companies have a small commercial grid connection, corresponding to 3x80 Ampère transport capacity (Liander, n.d.). This corresponds to 55,2 kW. The transport capacity applies both to extraction and feeding-in of electricity from/to the grid. The characteristics of the companies can be found in Table 4.

Company	Type	Load	Generation unit (Wp / MWh)	Transport capacity (A / kW)
A	Production facility	Irregular	0,40 / 0,34	3x80 / 55,2
B	Office building	Regular	1,30 / 1,15	3x80 / 55,2
C	Production facility	Irregular	n/a / 0,2	3x80 / 55,2

Table 4: Company characteristics

The yearly energy profiles of company A, B, and C can be found in Appendix B. The figures show renewables generation, load, curtailment and feed-in of electricity per 15 minutes.

3.2.2 Modelling scenarios

Three different scenarios are modelled. The first scenario – no batteries entails the separate modelling of the three companies without a battery system. The second scenario models the three companies separately with a behind-the-meter battery system at every company. The third scenario models the three companies with one collective battery. The battery characteristics will be discussed separately in section 3.2.3.

In all three scenarios, electricity is purchased by the companies and acquired via the grid. Firstly, self-consumption of renewables is maximized. This means that per time-step, generation is subtracted from the company’s consumption. When a company has a surplus of energy, it will feed-in electricity until it reaches its transport capacity limit. In the first scenario, given that neither company has a battery system, all electricity above the transport capacity is curtailed. Figure 8 gives a schematic representation of scenario 1. In Figure 8 company A is shown but the schematic representations of company B and C are identical. The modelling of scenario 1 corresponds to the energy profiles shown in appendix B.

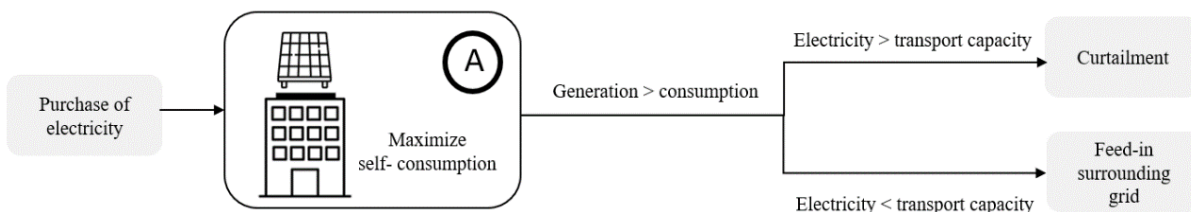


Figure 8: Scenario 1 – no batteries for company A (identical for other companies)

The second scenario – individual batteries has the same set-up as scenario 1, but unlike scenario 1, the companies in scenario 2 can charge their individual batteries if they have more electricity than their

transport capacity allows them to feed-in. Feeding-in electricity is prioritized over charging the battery, since this leaves more room for applications that strengthen the battery’s business case, like trading on different energy markets and performing energy services. If the battery is fully charged (state of charge (SoC) is 100 percent) and the company has a surplus of energy above their transport capacity, curtailment takes place. If in a timestep generation is lower than consumption and the battery contains energy, the battery is discharged and the discharged electricity is used by the company. Scenario 2 is visualized in Figure 9. Only company A is shown, but the schematic representations of company B and C are identical.

In the third scenario – collective battery, companies will also feed-in electricity until they reach their transport capacity limits. They are only allowed to feed-in electricity up to their transport capacity to the **surrounding grid** (part of the grid outside the system boundaries of Figure 7), since there is net congestion on this part of the grid. If the companies combined have more electricity than they can feed back into the surrounding grid, the collective battery is charged in that timestep. This means that the DSO allows the companies to surpass their individual transport capacity to charge the collective battery.

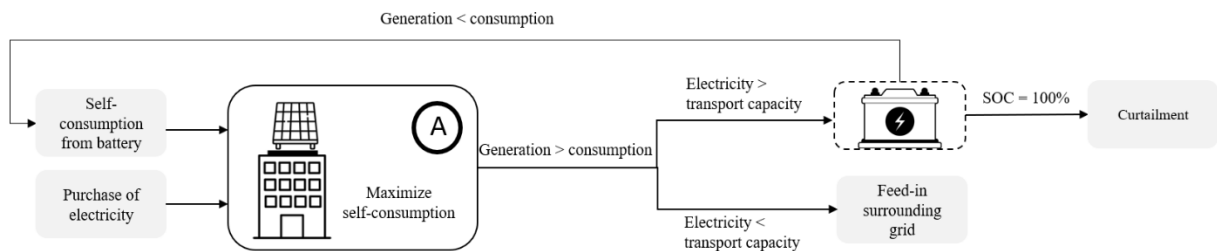


Figure 9: Scenario 2 – individual batteries for company A (identical for other companies)

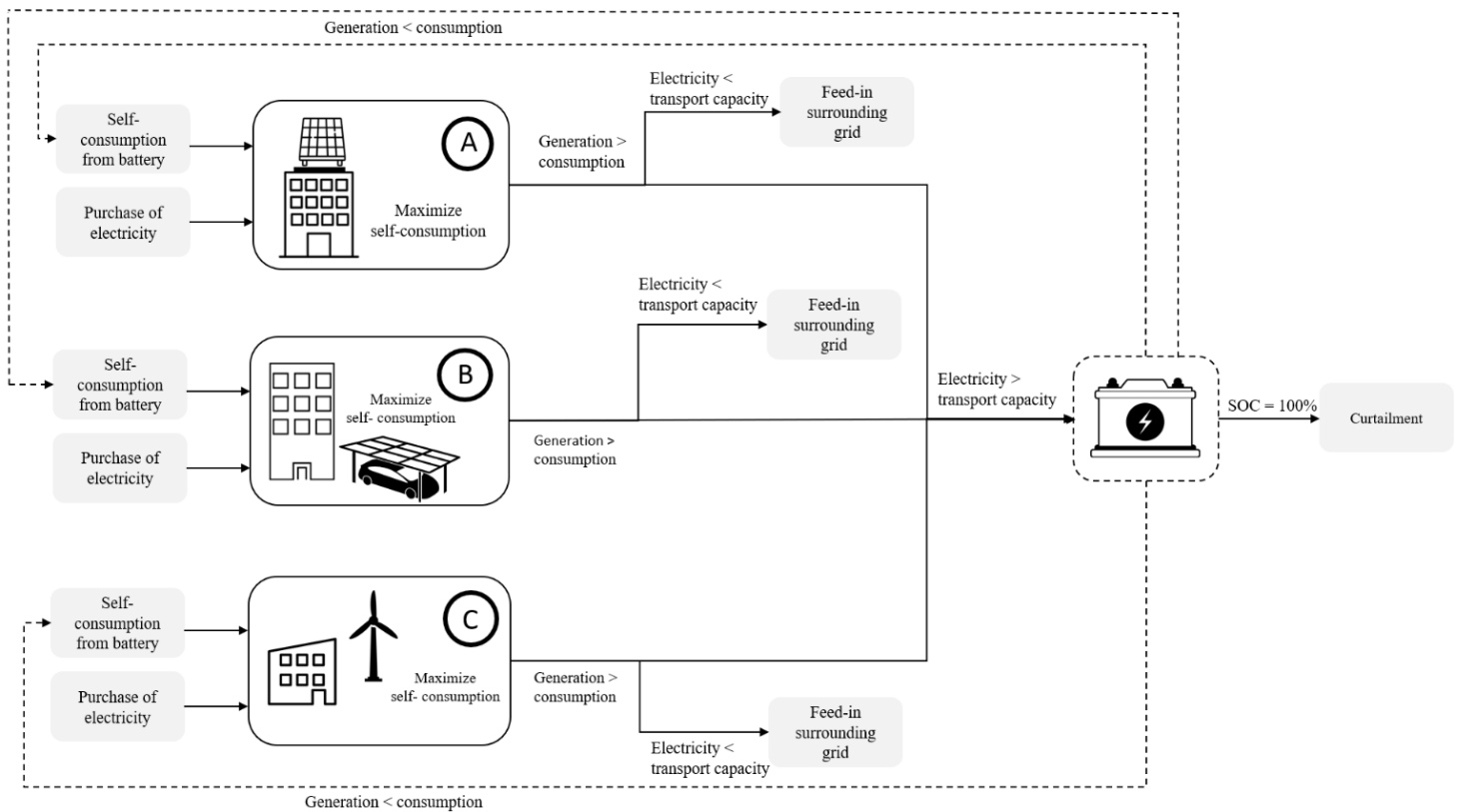


Figure 10: Modelling scenario 3 – collective battery

The DSO allows this so that the individual battery can be used efficiently. As will be shown, the effective use of the battery will balance the local grid and decrease the stress on the surrounding grid. The DSO thus benefits from permitting this. Besides, the electricity above the transport capacity is only transported from the companies to the collective battery, and not to the surrounding grid. This decision subsequently will not worsen net congestion on the surrounding grid. If the battery is full (SoC is 100 percent) and the companies combined have a surplus of electricity above their transport capacities, the excess electricity is curtailed. When in a timestep the generation of the three companies combined is less than the combined consumption and the battery contains energy, the battery can be discharged and the electricity can be used by the companies with an electricity deficit. Scenario 3 is schematically shown in Figure 10.

3.2.3 Battery characteristics

The batteries in the described scenarios are either not used, charged, or discharged in a single time step, depending on the logic described in the previous section. They cannot be charged and discharged simultaneously within the same time step. The individual batteries have a capacity of 1 MWh and power of 0,5 MW and the collective battery has a capacity and power of three individual batteries combined, respectively 3 MWh and 1,5 MW. This battery size is selected to offer balancing services to the TSO TenneT, which requires the batteries to have at least this capacity and power (TenneT, n.d.). The batteries' C-rate is 0,5C, meaning that they can provide their full capacity in two hours when fully charged. This C-rate is suitable for the possible applications of the batteries without compromising their longevity. Batteries with this C-rate are frequently combined with solar and wind generation units (Windandsun.co.uk, n.d.). The selected C-rate ensures that the battery can provide power quickly enough to trade effectively on different energy markets and perform energy services (InvestNL, 2021). However, if a higher C-rate were chosen, this could result in an accelerated capacity fade (Chelsea, 2016). The maximum depth-of-discharge (DoD), which refers to the maximum percentage that the battery can be discharged, is set at 80 percent, which correlates to a SoC of 20 percent. This DoD is chosen because the lifetime of Li-ion batteries may decrease if the battery is fully discharged (Battery University, 2021). The battery characteristics are presented in Table 5.

	Capacity (MWh)	Power (MW)	C-Rate	Maximum DoD
Individual	3 MWh	1,5 MW	0,5C	80%
Collective	1 MWh	0,5 MWh	0,5C	80%

Table 5: Battery characteristics

3.2.4 Model validation

The model is validated to confirm that the model achieves its intended purpose (Merwe, Gehring & Buur, 2018). The purpose of the model is not to precisely and quantitatively describe the energetic behaviour of the described system, but merely to give an indication of the advantages of collective battery storage compared to individual battery storage. The model was validated by randomizing the input data of the different companies and the values for the battery characteristics and thoroughly checking the outcomes on abnormalities. Besides, two integrated energy systems and battery experts of Equans were asked to validate the model. The model was deemed valid enough for the intended purpose.

3.2.5 Energetic and social advantages of collective storage

The energy benefits of collective battery storage are illustrated in graphs depicting the behaviour of the energy system on four selected days in March 2022 (14th to 17th March). These four days were chosen as they accurately demonstrate the advantages of the collective system. Figures 11, 12, and 13 display scenario 2, which features Company A with a collective battery, Company B with an individual battery, and

Company C with an individual battery, respectively. Figure 14 displays scenario 3. Each figure shows the net electricity (consumption-generation), curtailment, self-consumption from battery, feed-in of electricity, and battery state of charge. Positive net electricity values denotes consumption greater than generation, while negative values denotes generation greater than consumption. The benefits of the collective battery are examined by analysing the red area in the graphs.

Company A has surplus electricity in the red area due to ample solar generation, which it feeds into the grid until it reaches the transport capacity limit. The remaining electricity is stored in the individual battery. The generation unit is not curtailed since all electricity can be charged in the battery. The time step in which the generation becomes less than the generation, electricity from the battery is self-consumed, meaning the state of charge starts to decrease.

Similarly, Company B has a surplus of electricity due to ample solar generation. The surplus electricity above the transport capacity limit is charged in the battery until the battery is full (state of charge is 100%). After this, the electricity surplus is curtailed. The same process is followed as with Company A when the time step in which the generation becomes less than the generation is reached. Company C experiences an electricity deficit (consumption is greater than generation) since there was no wind on that day. This means that there is no feed-in or storage of electricity, and electricity is obtained from the surrounding grid.

In scenario 3 – collective battery, compared to scenario 2, Company C can utilize the excess electricity from Company B to address their electricity deficit. This results in less curtailment of renewables (as can be observed by comparing the orange curtailment data in the red area from Figure 11 to Figure 14) and more self-consumption of renewables. Only minor curtailment remains in scenario 3. The increased self-consumption also reduces net congestion in the surrounding grid as Company C no longer needs to extract the electricity it receives from the battery from the surrounding grid.

Modelling the full year of the three different scenarios demonstrates that collective battery storage offers significant energetic and environmental advantages (more self-consumption and less curtailment). Additionally, the surrounding grid is unburdened, which benefits both the DSO and society. A collective battery of 1,2 MWh accounts for the same amount of self-consumption and curtailment as three individual batteries of 1,0 MWh (3 MWh combined). This means that with a collective battery, the same level of self-consumption and curtailment can be achieved at 40% of capacity compared to the capacity of three individual batteries combined. The energy benefits of the collective battery storage system over a year are quantitatively presented in Table 6. The total generation of the three companies combined was 2,188,072 kWh, and in all three scenarios, they fed in 318,171 kWh of energy. The feed-in of electricity remains the same in all scenarios since electricity is first fed into the surrounding grid until the transport capacity limit is reached before deploying the batteries.

	Total curtailment (kWh)	Total self-consumption (kWh)	Curtailment (% of total generation)	Self-consumption (% of total generation)	Feed-in (% of total generation)
Scenario 1	950.367	919.534	43,43%	42,02%	14,54%
Scenario 2	726.213	1.143.688	33,12%	52,27%	14,54%
Scenario 3	259.686	1.610.216	11,87%	73,60%	14,54%
Change from individual to collective storage	-466.527	+466.527	-64,24%	+38,36%	0%

Table 6: Quantitative expression of modelling findings

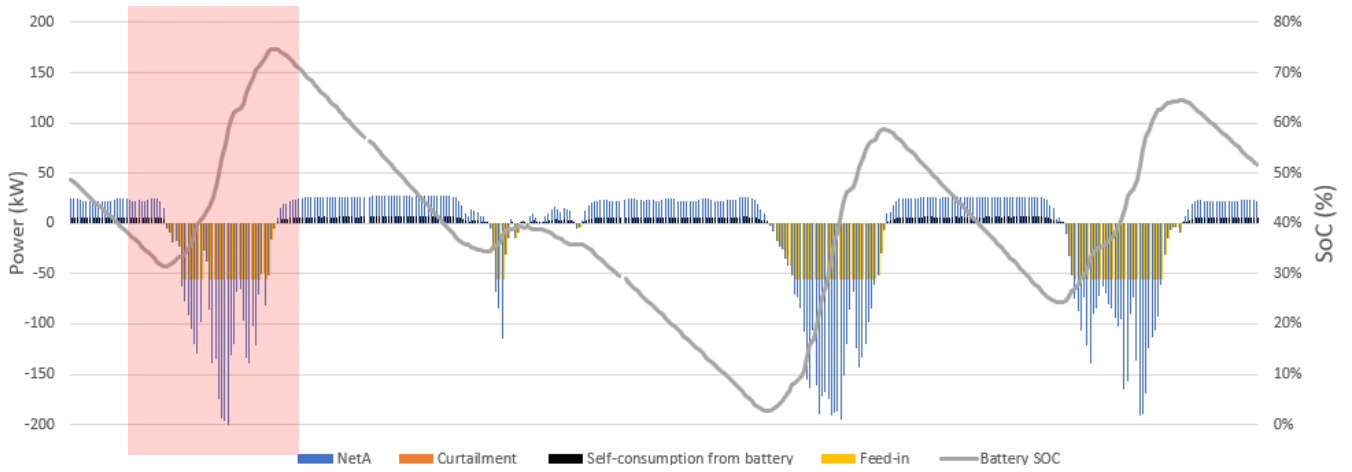


Figure 11: Scenario 2 - company A with individual battery

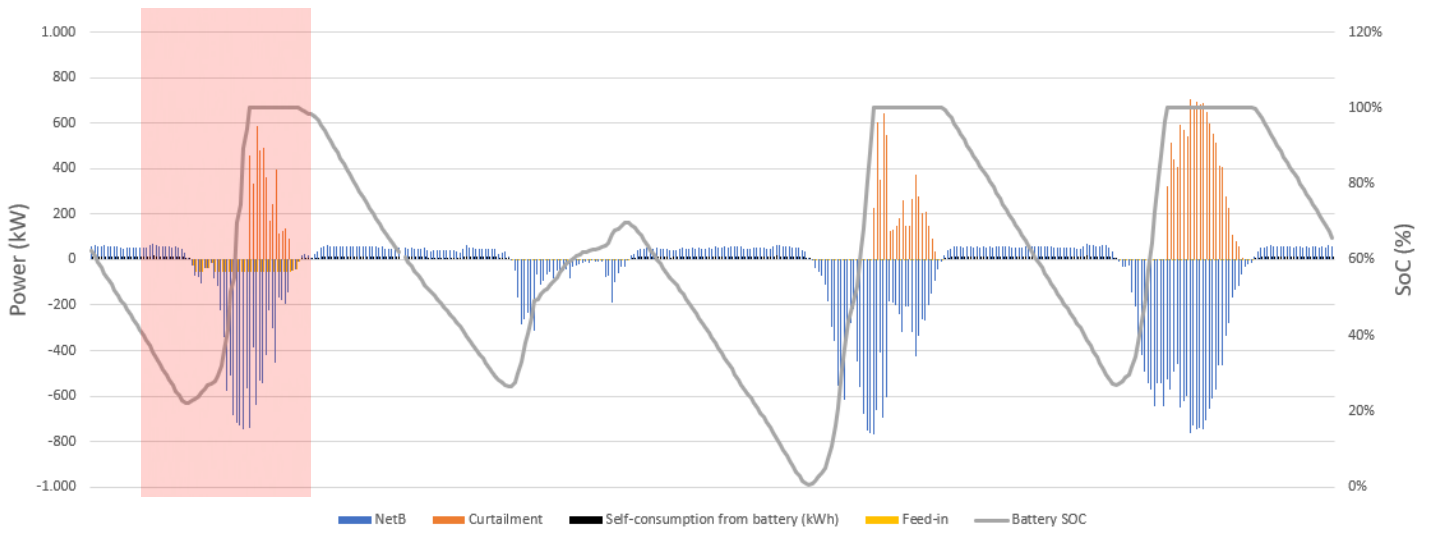


Figure 13: Scenario 2 - company B with individual battery

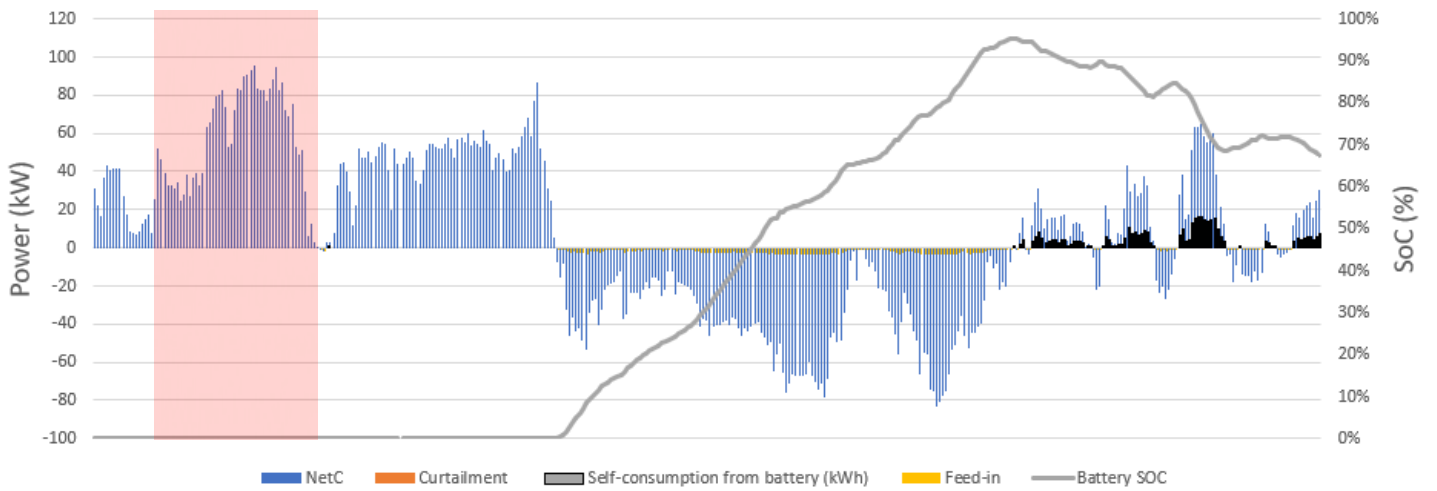


Figure 12: Scenario 2 - company C with individual battery

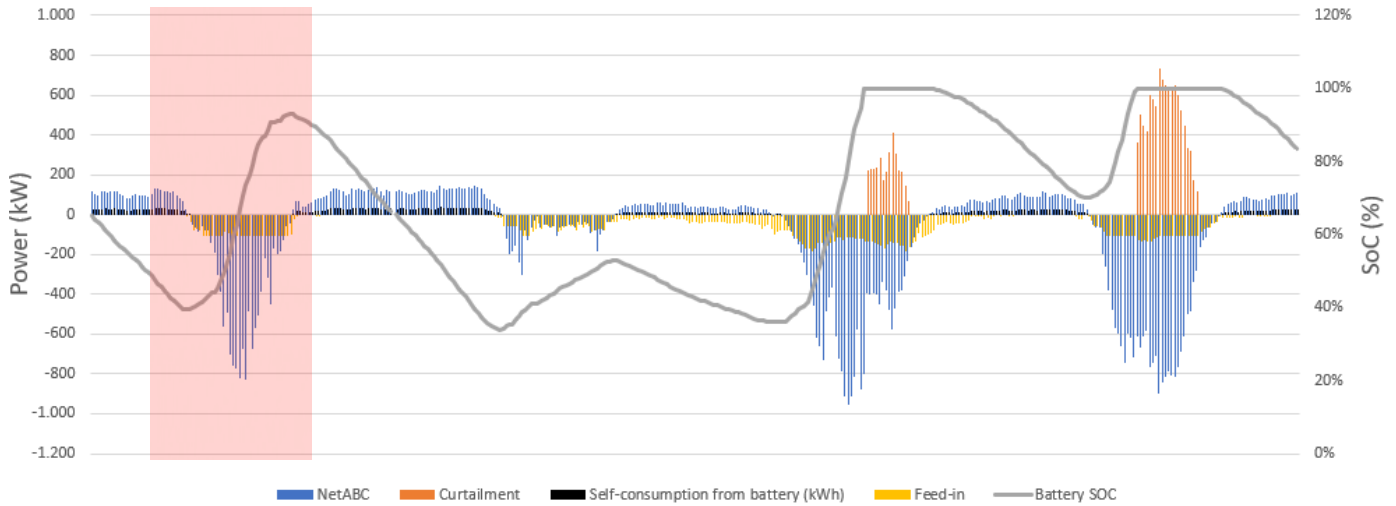


Figure 14: Scenario 3 – collective battery

3.3 Economic analysis

The economic analysis is performed to show the economic costs and benefits of the modelled collective battery system in comparison to scenario 2 – individual batteries and scenario 1 – no batteries. Furthermore, it shows that solely using the battery to increase self-consumption and reduce curtailment, will hardly ever lead to a viable business case. It should be noted that this analysis is merely to be seen as a back-of-the-envelope calculation that is performed to give an indication of the order of magnitude of the economic costs and benefits of a collective battery system. The outcomes should not be interpreted as hard research results, since they are heavily influenced by the way the model is defined and fluctuating variables like the chosen electricity price and the current battery price.

Every kWh that is self-consumed from the individual or collective battery, does not need to be purchased by the companies. The additional self-consumed electricity is calculated by subtracting the self-consumption of scenario 1 – no batteries from the self-consumption of scenario 2 – individual batteries and scenario 3 – collective batteries. Additional self-consumed kWh's can be seen as savings caused by the deployment of the battery storage systems and thus as the economic benefit of the systems. The annual savings are calculated by multiplying the additional self-consumption with the electricity price. The electricity price is set at pre-energy crisis levels (0,22 €/kWh) (Maessen, 2021). This price is chosen since the pre-energy crisis price level is seen as the last table reference point for energy price, given current high volatility of the energy prices and inflated markets. The lifetime of stationary batteries that are used to store renewable energy is currently estimated around ten years (Beltran, Ayuso & Pérez, 2021; Lane, 2023; Wolf, 2023). The economic benefits over the lifetime of the batteries are calculated by multiplying the annual economic benefits of the battery by the lifetime of the batteries, namely ten. Table 7 shows the additional self-consumption, the annual economic benefits and the economic benefits over the lifetime of the individual batteries of scenario 2 and the collective battery of scenario 3.

	Additional self-consumption compared to scenario 1 (kWh)	Savings per year/annual economic benefits battery	Economic benefits over lifetime
Scenario 2 - individual	224.145	€49.311,90	€493.119,-
Scenario 3 - collective	690.682	€151.950,04	€1.519.500,40

Table 7: Economic analysis for scenario 2 and 3

A recent battery cost analysis performed by Equans found the relation between the capacity of the battery and price per kWh shown in Figure 15. The higher the capacity of a system gets, the lower the costs per kWh are. This holds until the 1600 kWh capacity mark is reached, hereafter additional capacity will cost €350,- per kWh. The full battery cost analysis is confidential information and thus cannot be disclosed. Table 8 shows the costs of the three individual 1 MWh/0,5 MW batteries combined (€665.000 each) and the collective 3 MWh/1,5 MW battery. The shown relationship between battery capacity and costs per kWh makes the collective battery more cost-efficient than three individual batteries. As mentioned in section 2.2, the same level of self-consumption and curtailment can be reached at 40% of capacity compared to the capacity of three individual batteries combined. Instead of three 1 MWh/0,5 MW batteries of €1.995.000,-, one 1,2 MWh/0,6 MW battery of €770.000,- suffices. This is a very significant cost decrease of €1.225.000,-. Furthermore, collective batteries can be co-financed.

The payback period, ‘the number of years required to recover the original investment’, is calculated by dividing the costs of the battery systems by the annual economic benefits per scenario (Kiran, 2022). As Table 8 shows, the payback period of the individual batteries is 42 and of the collective battery 12 years. It can be concluded that the economic benefits of increasing self-consumption with individual batteries and collective battery are too low to earn back the investments in their lifetime at an electricity price of 0,22 eurocents per kWh. The electricity price at which the collective battery will reach its break-even point at the end of its lifetime can be calculated by dividing the costs of the battery by the additional self-consumption over 10 years. This calculation results in an electricity price of 25 cents. Given that this is below the current electricity price, a collective battery currently might earn itself back within its lifetime.

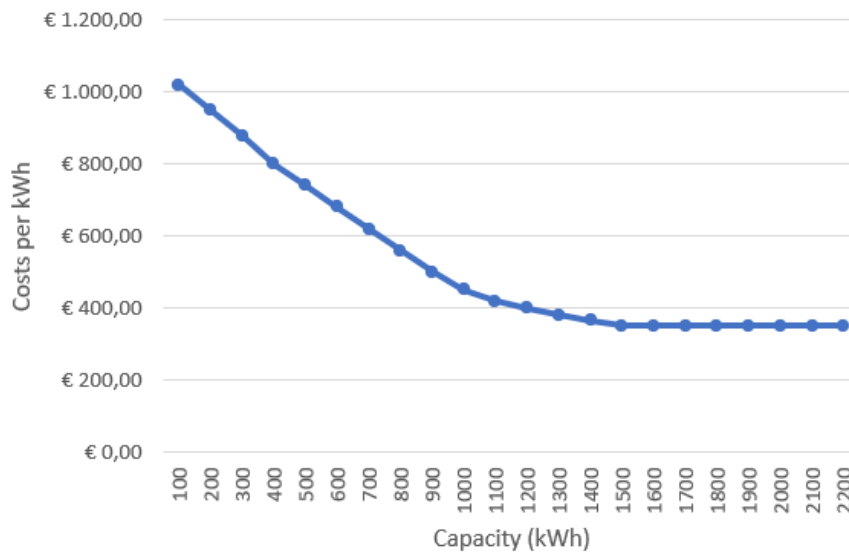


Figure 15: The costs per kWh in relation to the capacity of a battery

	Battery costs	Payback period (years)
Scenario 2 - individual	€1.995.000	41
Scenario 3 - collective	€1.719.000	12

Table 8: Battery costs and payback period

It is important to note that in these calculation, only the capital costs of the battery itself are taken into account. Additional fixed costs for wiring, software, installation etcetera also need to be taken into account. Additionally, variable costs for operations and maintenance (O&M) need to be considered. According to Cole and Frazier (2019), the O&M costs can amount to 38 euro per kW per year. IV5 points out that the operational costs of just energy tax, grid operator costs and transport tariffs for charging and discharging a single kWh of electricity already amount up to 6 eurocents. For the collective 3 MWh/1,5 MW battery, this means that the annual expenditure on O&M and on energy tax, grid operator costs and transport tariffs already consists of €98,440,72 euro. This means that almost two-thirds of the annual economic benefits of the collective battery system evaporate on operational costs.

Upon considering costs other than the battery investment, the calculation suggests that it is highly improbable to recover the battery investment within its lifespan through increased self-consumption and curtailment reduction. Nevertheless, investing in a battery storage system could offer additional benefits. In areas where congestion occurs, companies may be unable to install renewables or expand their operations without a battery. Therefore, they may opt to invest in a battery system.

In order to make collective battery systems profitable, the battery needs to be deployed in other ways than just increasing self-consumption. Batteries can be deployed on different energy markets and can perform several energy services to create a viable business case: the day-ahead and intraday markets, FCR, aFRR, passive imbalance, and congestion management via GOPACS. The collective battery of modelled scenario 3 is not used over half the time in a year, and can thus be used to create value with other applications. This is called benefit stacking. Benefit stacking can be seen as a barrier of collective battery storage, which will be discussed in section 4.3.2. Furthermore, the battery business case could be strengthened by implementing policy interventions like lowering the transport tariffs for batteries, as will be discussed in chapter 5.

The economic analysis indicates that deploying the battery on energy markets or providing energy services is necessary to create a feasible business case. However, conducting a full economic analysis of the battery business case is beyond the scope of this thesis since the battery can be utilized in various markets. Modelling the behaviour of the collective battery in the above-mentioned markets is a time-consuming task. Due to the intricacy of market functioning, price signals, weather forecasts, etc., the modelling of battery behaviour with respect to these markets is considered out of scope of this study.

3.4 Conclusion

This chapter has shown that collective battery storage systems on Dutch business parks have energetic, economic and social benefits over multiple individual batteries. This originates from the fact that they can balance out the peaks of multiple loads and generation units. In the modelled scenario with a collective battery, the curtailment of renewables is decreased from 726.213 kWh to 259.686 kWh (-64%) in comparison to the scenario with individual batteries. The self-consumption of renewables is increased from 1.143.688 kWh to 1.610.216 kWh (+38%). Additionally, with a collective battery the same level of self-consumption and curtailment can be reached at 40% of capacity compared to the capacity of three individual batteries combined. The economic analysis has shown that the business case for collective batteries that are used to just increase self-consumption and decrease curtailment is not viable and that benefit stacking is needed to create a solid business case.

Chapter 4 Barriers

The goal of chapter 4 is to identify critical implementation barriers for the proper integration of collective battery storage in business parks into the Dutch energy system. To do so, the method described in section 2.1 is carried out. First, 23 theoretical barriers are identified by means of an extensive literature study. The literature study method is described in section 2.2 and summarized in Appendix A.

The identified barriers are of technical, economic, institutional, and social origin. To give an indication of the level of the system in which the barriers occur and what can be done about the barriers, they are placed into a multi-layer analytical framework, namely the micro-meso-macro framework. To keep the analysis comprehensible, the theoretical barriers are then brought down to a few critical barriers using a funnelling approach. This funnelling approach is described in section 2.1 and will be carried out in section 4.5. The chapter ends with a short conclusion. This part of the study aims to answer the second sub-question:

SQ2 - What are the critical barriers to the implementation of collective FTM battery storage?

4.1 Explanation of the micro-meso-macro framework

A barrier in this study is defined as ‘anything that prevents, obstructs or hinders the progress, movement or development’ of successful integration of collective FTM battery storage in the Netherlands (Gupta et al., 2017). A total of 23 theoretical factors that currently represent barriers are identified with the aforementioned literature study. The barriers can be divided into four categories and nine sub-categories. This categorization is derived from Painuly (2001) and is shown in Figure 16. The barriers are numbered B1 to B23. The main and sub-categories are:

1. Battery and supporting technologies are not yet mature technologies and thus are still in development. This results in different factors that form **technical barriers**. The technical barriers are related to the sub-categories of technological uncertainty, interoperability issues, and resource constraints.
2. When developing a collective FTM battery system project, operators will encounter **economic barriers**. These barriers are related to the sub-categories difficulties in financing projects and difficulties in the battery business case.
3. Next to this, **institutional barriers** are present in the Netherlands. These market and regulatory barriers are related to the sub-categories of distribution network issues and hindering legislation.
4. To conclude, different **social barriers** can hinder the successful integration of collective FTM battery storage. Social barriers are related to the sub-categories self-governance issues and the behaviour of actors.

This subdivision of barriers does not give an indication of the level of the system in which the barriers occur, or how they can be overcome. This is why the barriers will now be placed in a theoretical framework that includes three levels of analysis: the actor level (micro), the sector-network level (meso), and the society and governmental level (macro). The micro-meso-macro framework is often used in literature to accurately delineate different layers in complex systems. An example of such a study is Garcia, Wigger & Hermann (2019). The micro level consists of the interaction between individual businesses inside the system boundary described in chapter 3. The micro level describes the application or use of the collective battery by the companies. The meso level consists of all actor interactions and transactions inside the energy sector. The meso level is thus comprised of the energy sector in the Netherlands. This includes the organization of the electricity supply system and energy markets. Actors have different market roles and interactions between actors shape the meso level. This leads to sector-specific regulations, tariff structures,

and relationships between actors (Garcia, Wigger & Hermann, 2019). The macro level consists of external social, political, economic, technological, demographic, cultural, and environmental factors.

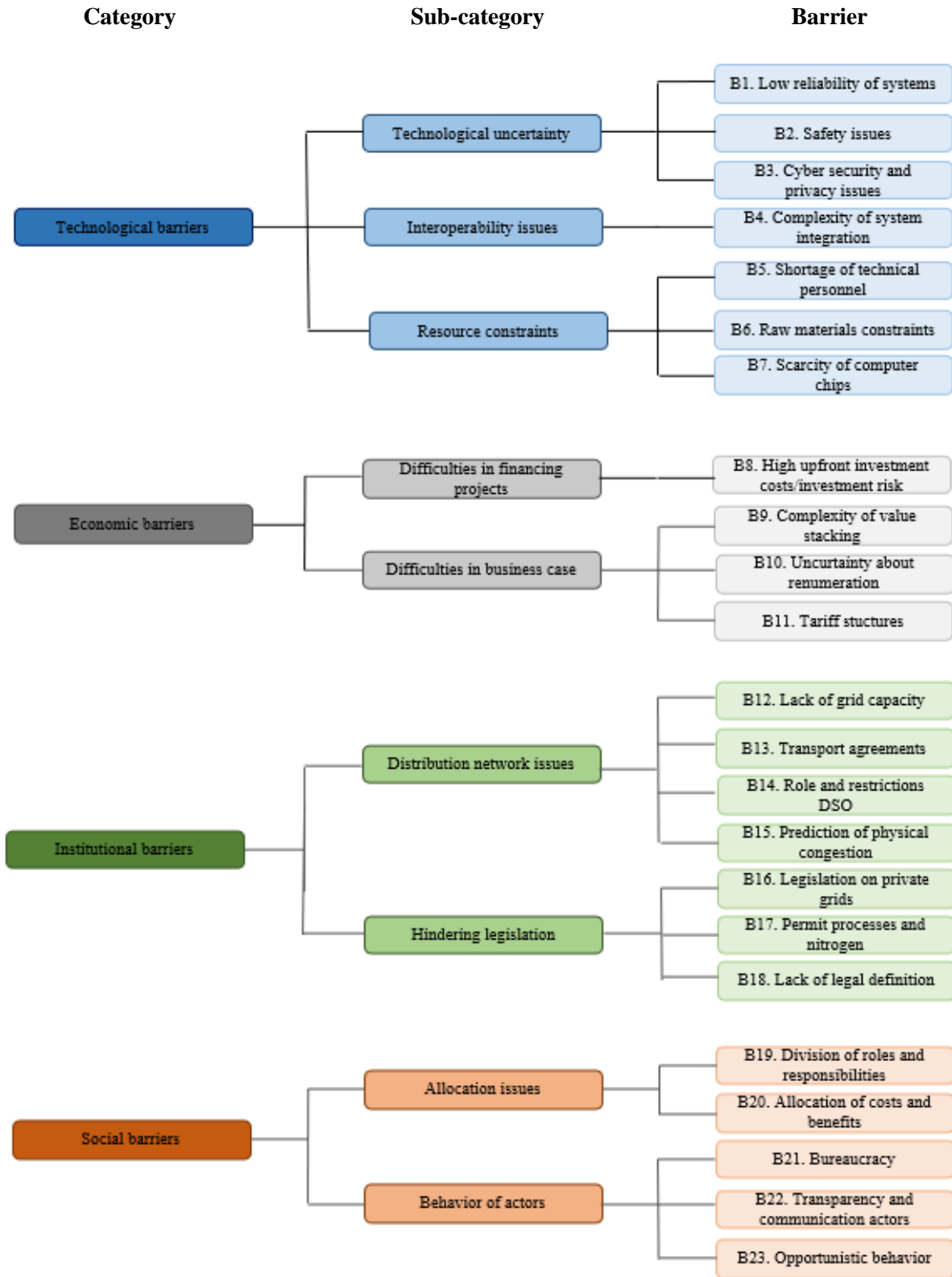


Figure 16: Barriers of collective FTM battery storage

When studying innovations that create both economic and environmental value, such as collective batteries, it is essential to consider all three levels: micro, meso, and macro (Garcia, Wigger & Hermann, 2019). At the micro level, participating companies can influence and control most factors, while at the meso level, companies have some degree of influence over certain factors (Melander & Lind, 2022). Factors at the macro level cannot be influenced or controlled by the battery operators.

By placing the barriers within the micro-meso-macro framework, it can be determined to what degree actors can control and overcome specific barriers. Furthermore, barriers on different levels should be tackled by different policy interventions as they have different natures. In the upcoming sections, the different levels of the micro-meso-macro framework will be discussed. All 23 barriers shown in Figure 16 will be described and placed within one of the three levels of the framework. The motivation for their place within the framework is given. Finally, each section will be concluded with a full overview of the micro-meso-macro framework.

4.2 Description of theoretical barriers on micro level

Micro barriers are the factors that negatively influence the integration of collective FTM battery storage within the system boundaries. These barriers stem from the interactions between individual participants. Influential factors within the micro level can often be influenced and controlled by the participating actors. The barriers found at the micro level stem from two sub-categories: self-governance issues and interoperability issues. All three barriers on the micro level (B4 – complexity of system integration, B19 – division of roles and responsibilities and B20 – Allocation of costs and benefits) arise from interactions between the companies within the system and the interaction of the technical components within the system. That is why they are placed on the micro level. The micro level is displayed in Figure 17.

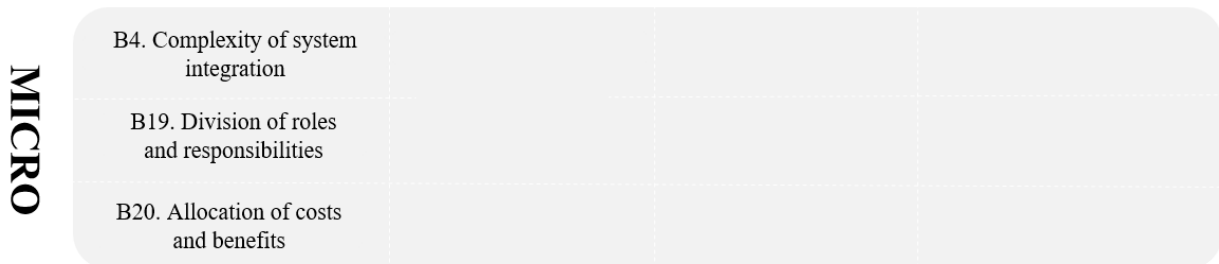


Figure 17: Micro level

4.2.1 Self-governance issues

The advantages of collective FTM storage find themselves in collective use. But with collective use, stringent self-governance issues come to life that need to be sorted in order to safeguard the proper functioning of the system. The three main self-governance issues are the division of roles and responsibilities in the system, the allocation of costs and benefits of the system, and bureaucracy. Bureaucracy is placed in the meso part of the framework, since this barrier involves interactions with the DSO and municipalities and is therefore not limited to system-only interactions and not placed on the micro level. It will thus be discussed in the next section.

B19. Division of roles and responsibilities

First of all, different ownership models of the collective FTM battery storage system can exist. The chosen ownership model influences to a large extent the strategic operation and the impact of the shared battery system (Koraila et al., 2018). Collective FTM battery storage can be mutually owned by the participants,

publicly owned, or may be developed in public-private partnerships (Haney & Pollitt, 2013). The ownership model that is chosen is affected by financing requirements and risk perceptions (Koraila et al., 2018). A wide range of models for ownership should be permitted by the legal framework in the Netherlands in order to find the optimal solution per situation (Koraila et al., 2018). Some forms of ownership are yet only allowed in demonstration projects in the Netherlands. For normal projects, this experimental legislation is not yet in place, which could form a barrier to collective FTM battery storage.

Another factor that has a big impact on the system is the allocation of liabilities and risks. Given the chosen ownership and liabilities structure, different stakeholders have different impacts on the system, are more liable than others, and are subject to different amounts of risks. If one party is exposed to too much risk, full participation might be in danger. Next to this, to collectively purchase energy, every party should be under contract at the same energy company. If parties have long-term contracts with different energy companies, this could be a problem. Finding an ownership, liability, and risk structure that every participating party agrees upon and is within the Dutch legal boundaries can be a time-intensive task and thus might slow down the integration of collective FTM battery storage.

B20. Allocation of costs and benefits

In accordance with the chosen ownership and liabilities structure, fair energy trading agreements and fair cost and benefit allocation are important conditions that need to be met in order to successfully implement collective FTM storage (Yang, Hu & Spanos, 2021). This allocation is directly related to the chosen ownership model and the way liabilities and risks are allocated. Local energy sharing is complicated due to participants' privacy, data transparency, and possible untrustworthy acting participants (Muzumdar, Modi, Mahdu & Vyjayanthi, 2021). Disputes about the fair allocation of costs and benefits could arise between participants. That is why effective reward- and punishment systems need to be in place to prevent misbehaviour (Houwin, Dukovska & Paterakis, 2022). Putting all these arrangements in place and translating them into binding contracts can be a difficult task and thus can be seen as a barrier.

4.2.2 Interoperability issues

Technical challenges encountered in energy systems with collective FTM batteries often arise from inadequate interoperability between the system's components. Integrating collective FTM battery systems (B4) into an energy system is a complicated undertaking that requires the participation of all involved actors. A battery storage system never operates independently; it is a component of a larger system (Francis et al., 2020). The battery system must be correctly integrated into the system and be compatible with other devices, storage systems, the EMS, and renewables. Only when the battery system is appropriately integrated with the other elements of the system can the safety, reliability, and efficiency of the entire system be ensured (Francis et al., 2020). The intricate system integration and the involvement of different stakeholders in this process may pose a micro-level barrier to the adoption of collective FTM battery storage. Only actors with high expertise can integrate batteries correctly and execute this "integral" project management.

4.3 Description of theoretical barriers on meso level

Barriers at the meso level originate from sector-specific transactions, market organization, and rules and regulations. All economic barriers (sub-categories difficulties in financing projects and difficulties in the business case), most of the institutional barriers (sub-categories distribution network issues and hindering legislation), and the social barriers that stem from the sub-category behaviour of actors can be found when

looking at the meso level of the multi-layer analysis. All the barriers placed on the meso level are sector-specific. The meso level is displayed in Figure 18.

MESO	B8. High upfront investment costs/investment risk	B12. Lack of grid capacity	B16. Legislation on private grids	B23. Opportunistic behavior
	B9. Complexity of value stacking	B13. Transport agreements	B18. Lack of legal definition	
	B10. Uncertainty about remuneration	B14. Prediction of physical congestion	B21. Bureaucracy	
	B11. Tariff structures	B15. Role and restrictions DSO	B22. Transparency and communication actors	

Figure 18: Meso level

4.3.1 Difficulties in financing projects

First of all, difficulties in financing battery projects can be seen as a factor that majorly influences the adoption of collective FTM battery storage in the Netherlands. These difficulties arise primarily from high upfront investment costs and high investment risk.

B8. High upfront investment costs and risk

The market for Li-ion batteries has been experiencing significant global growth in recent years. As technology advances, the prices of Li-ion batteries per kWh have been rapidly dropping, as shown in Figure 19 (BloombergNEF, 2022). It is expected that prices will continue to decrease due to ongoing technological advancements and economies of scale. Experts predict that Li-ion batteries will cost \$100/kWh by 2026 (BloombergNEF, 2022).

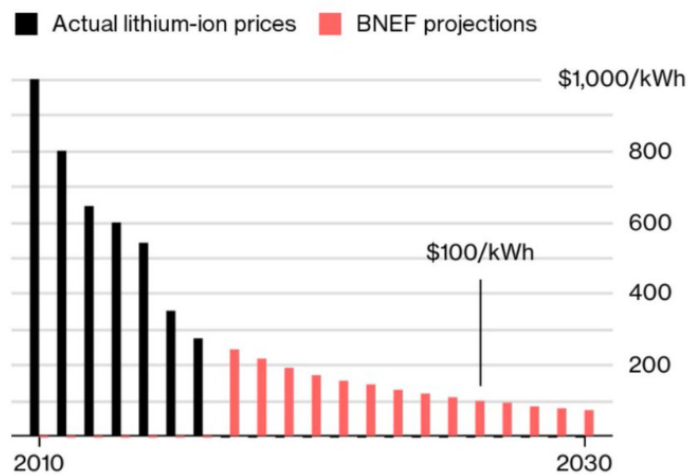


Figure 19: Li-ion battery price (\$/kWh) from 2010 to 2030 (BloombergNEF, 2022)

The capital costs of the battery itself constitute a significant portion of the overall capital expenditure of a battery project. Despite the current price reductions of Li-ion batteries, high upfront investment costs are still considered an important barrier to stationary battery storage in the literature (Pecenak et al., 2020; CE Delft, 2021). Due to these high upfront costs, external investors are often required to raise sufficient funds. This process may impede the integration of collective FTM battery systems into the Dutch energy system.

Moreover, investment in battery storage projects is still perceived as risky (Parra et al., 2017). This is due to various factors, including the need to cover high upfront investment costs without tenders or subsidies, as well as uncertainties regarding future remuneration and energy prices, the complexity of value stacking, and existing tariff structures. These factors will be further elaborated on in the following section. The combination of all these factors may deter investors from financing battery projects, thus hindering their deployment.

4.3.2 Difficulties in business case

Business models for collective FTM battery storage are often complex and it can be hard to create value with a battery on different energy markets. These difficulties come down to the three barriers mentioned in the last section: complex value stacking, a lack of/uncertainty about future remuneration and electricity prices, and current tariff structures.

B9. Complexity of value stacking

As mentioned in section 3.3, value streams of different energy markets and energy services need to be stacked to create a viable battery business case (Englberger, Jossen & Hesse, 2020; Greenwood et al., 2015; Parra et al., 2017). Collective FTM battery storage systems inside the scope of this research can create value in different markets and can perform several energy services: the day-ahead and intraday markets, FCR, aFRR, passive imbalance, and congestion management via GOPACS. A full analysis on the business case behind batteries and how batteries create value on different energy markets can be found in Appendix D. Although value stacking is currently a critical requirement for a viable battery business case in the Netherlands, efficient value stacking is often a technically and institutionally challenging task. First, a sophisticated EMS is needed to optimize the different value streams. Besides, the battery storage system needs to comply with the entry requirements of the different electricity markets and the requirements of TenneT. These are also discussed in Appendix D. On top of that, different value streams can rule each other out. For instance, a capacity that is offered on the FCR market should always be available. This capacity cannot be used anymore to trade on the EPEX SPOT markets.

Next to this, the energy contract and grid connection of the battery storage systems should allow for trading on the different markets. The energy contract should be hour-based and should give access to the different markets. The grid connection needs to have enough superfluous capacity to make energy trading possible. Besides, alternative contractual forms like non-firm ATOs can also impede the battery from creating value in electricity markets. This will be extensively discussed in section 4.3.3. A great deal of expertise is needed to make value stacking work, which forms a barrier to the implementation of these systems.

B10. Uncertainty about remuneration

The last factors that negatively influence the business case and increase the investment risk, are on the one hand uncertainty about future remuneration for energy services and future electricity prices, and on the other absence or low remuneration for energy services (Parra et al., 2017). The battery business case is almost entirely built up out of value streams that are uncertain over time. Electricity prices and price volatility dictate how much value can be created on the day-ahead and intraday market and TenneT. Factors like the amount of imbalance on the electricity grid, the number of BSPs, and their bids determine the height of the remuneration received from TenneT for delivering ancillary services and passive balancing.

Because of high electricity prices, high price volatility in electricity markets, and ample imbalance on the Dutch grid, current economic conditions for battery storage systems are excellent. But the future height of electricity prices and energy services remuneration is uncertain, which means that the battery business case is built on uncertainties. Investors often believe that this makes investing in batteries too risky. That is why often the capacity of large-scale FTM batteries is contracted by a BRP to hedge the imbalance of their own

portfolio (Zwang, 2022). This is for instance what energy company Eneco uses the Rhino battery of GIGA Storage in Smart Grid Flevoland for (GIGA Storage, n.d.).

Another sticking point in the business case in the Netherlands is that remuneration for certain energy services is not yet in place or is too low. The remuneration that the GOPACS platform offers is one example of this phenomenon. The remuneration of this market is too low and too uncertain. If trading on other markets is more profitable, battery operators are more likely to deploy their batteries on these markets. While alternatives for congestion management can still construct a viable business case, the low and uncertain remuneration causes batteries to not be deployed in favour of the grid. This issue will be more thoroughly described in the section on barrier B12. Lack of grid capacity.

B11. Tariff structures

Battery storage are now seen as consumers in the *Netcode* and pay grid connection costs and transport tariffs accordingly (Energy Storage NL, 2021). Especially transport tariffs put a big burden on business cases in the Netherlands. They can account for up to 80 percent of the operational costs of batteries (Storage Magazine, 2022). Transport tariffs are charged twice when it comes to batteries: when the battery charges, and when it discharges the same electricity. Transport costs increase significantly when battery systems have more capacity and thus charge and discharge more energy. This creates conflicting signals: bigger batteries can alleviate more net congestion, but battery operators need to pay higher tariffs in return. This is particularly counterproductive and puts the business case in jeopardy.

Furthermore, battery operators pay an additional fee for large peaks in used transport capacity (Energy storageNL, 2021). While batteries often deliver energy services that are associated with the use of high transport capacity for a short amount of time, these additional fees also heavily impede the battery business case. In countries like Belgium and Germany, batteries are already exempted from transport tariffs if they are deployed in favor of the grid (Energy Storage NL, 2021).

4.3.3 Distribution network issues

Different issues concerning the distribution network are currently slowing down the integration of in-front of the meter battery storage in the Netherlands. These issues find their origin in the lack of grid capacity, transport agreements, and the role and restrictions of the DSO barriers.

B12. Lack of grid capacity

The shortage of grid capacity already is preventing collective FTM battery energy systems from being connected to the grid. Every battery storage operator has the right to be connected to the grid by the DSO within 18 weeks under the *Elektriciteitswet* (ACM, n.d.). The grid operator is also obliged to make transport capacity available unless the grid operator ‘reasonably has no transport capacity available’. When allocating grid capacity, grid operators are also obliged by law to take the maximum capacity that all connected parties might demand at one moment as the total grid capacity (Netbeheer Nederland, 2022). The maximum capacity often is only used during a few moments per year, which means that the rest of the time a large amount of the grid is not in full use. This means that on the Dutch grid, only a few moments a year actual physical congestion exists. In the remaining time, there is only theoretical net congestion.

Because the grid capacity is almost exceeded theoretically in areas in the Netherlands, long waiting lists for grid connections and transport capacity arise (Expertgroep batterijen, 2022). Legislation of the EU states that DSOs are not allowed to discriminate when it comes to applications for grid connections and transport capacity. DSOs must enact the *first come, first serve* principle (LAN, 2022). Batteries are seen as parties that can offer flexibility and alleviate net congestion, but in the eyes of the DSO, they contribute to reaching

the maximum capacity of the electricity grid (LAN, 2022). Battery systems are not prioritized, even though they tackle the problem that causes new grid connections to be put on hold in the first place.

In fact, some Dutch DSOs have announced recently that they will not connect any large-scale battery storage systems soon (Zwang, 2022). DSOs now only allow new battery projects in areas of the Netherlands where there is enough grid capacity available. There are a few reasons. First of all, to connect a battery, double grid capacity must be reserved for the extraction and feeding-in of electricity. This puts more stress on the grid (Zwang, 2022). Another argument of the DSOs is that although battery storage systems have the potential to alleviate net congestion, they often tend to make the matter worse because of the way they are deployed (Zwang, 2022).

This phenomenon is exemplified by a scenario where high wind speeds on a warm, sunny afternoon result in negative prices on the balancing market. A battery operator has installed a battery in a business district within the Randstad area and aims to capitalize on the negative prices by charging the battery. However, due to the hot weather, air-conditioning systems in the area are in overdrive and are causing limited capacity on the local grid. As a result, charging the battery exacerbates the local net congestion problem. This issue also arises when price incentives come from the day-ahead and intraday markets. The root of these problematic situations is that batteries are deployed based on national price signals, but their deployment worsens local net congestion for the DSO. The objectives of market participants, who seek to maximize economic value, often do not align with those of the grid operator. Consequently, DSOs in the Netherlands only establish connections with batteries if specific agreements and criteria are met. This process inevitably slows down the integration of collective FTM battery storage systems.

B13. Transport agreements

Grid operators are nowadays only allowed to issue full transport agreements, which means that parties connected to the grid can always make full use of the transport capacity of their grid connection. To make smarter use of the grid, Dutch climate minister Rob Jetten has announced pilot projects to introduce alternative contract forms (Energy Storage NL, 2022). With these kinds of agreements, it will become possible for battery operators to use the grid's residual space to charge and discharge their batteries. By making use of the residual capacity of the grid, less infrastructure is needed, average costs of the grid can be reduced and congestion can be battled. Next to the normal firm capacity (the connected party has the right to use their full capacity 24/7), two alternative contracts are proposed: non-firm capacity contracts and capacity-limiting contracts (CBCs), or flexibility contracts.

Non-firm capacity contracts are contracts that only give transport capacity at certain times or when there is ample capacity available. The connected party pays for the transport capacity when it is available. Capacity-limiting contracts are signed in addition to the regular transport agreement (ATO). Under the CBC, the connected party accepts restrictions on the use of their transmission capacity at the instruction of the system operator. Instructions from the grid operator are issued prior to the closing of the day ahead market. Two forms are:

- Restriction. The customer is not allowed to do certain things at certain times (e.g., do not feed-in between 12 and 3 p.m.).
- Deployment - the customer must do certain things at certain times (e.g., feed-in a certain amount of MWh between 6 and 10 p.m.).

The connected party receives a remuneration from the DSO for the service performed. The possible fees are:

- A capacity availability fee: typically, an agreed amount (per period) or compensation for the transmission tariff.
- Compensation for restrictions (MW per hour).
- Compensation for counteractions (MW per hour).

CBC contracts are usually used to perform congestion management (Bakker, 2022). The different contract forms are displayed in Figure 20.

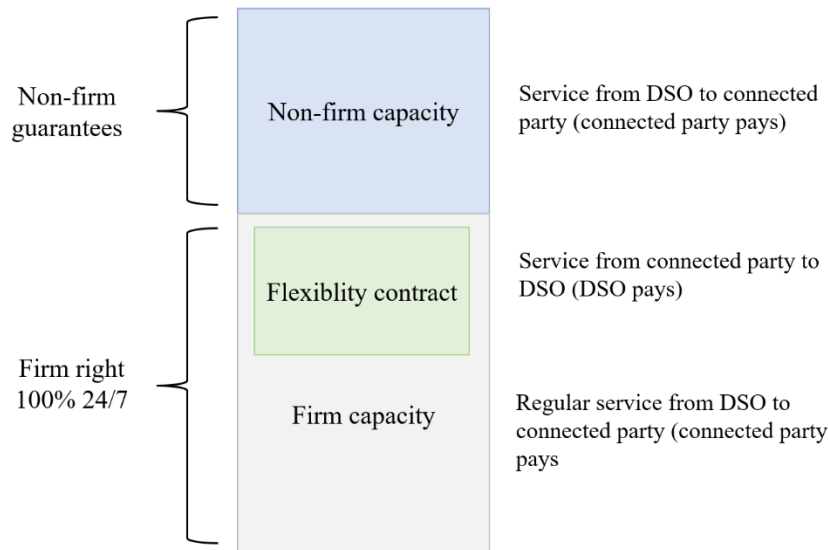


Figure 20: Alternative contract forms

On one hand, alternative contract forms can accelerate the deployment of collective FTM battery systems by providing battery operators with a "partial" grid connection instead of no grid connection at all. However, these time- and flexibility-based contracts can also pose a risk to the business case of batteries and increase investment risk. Unlike firm grid connections, batteries with alternative contract forms cannot be utilized at all times to generate value in electricity markets, and certain value streams may be obstructed, resulting in value loss during these periods. Therefore, alternative contract forms can be viewed as both accelerators and barriers to the integration of collective FTM battery storage systems. Additionally, it is important to note that new contract forms may deter investors from investing in battery projects, as they may perceive a separate agreement between two parties as being more risky than a standard ATO. The extra liability arising from modified transport agreements forms an additional obstacle.

B14. Prediction of physical congestion

Nowadays, it is often only known in which areas theoretical congestion occurs. The DSO does not yet announce where and when actual physical congestion occurs or where physical congestion might occur. By increasing the operational transport forecasts, physical congestion can be better predicted. This would immensely help with shaping agreements between market parties and the DSO. For instance: in a certain part of the medium voltage grid in Noord-Holland congestion occurs for 500 specific hours a year. This information is currently not disclosed to market parties, and thus they cannot make arrangements that the market party will help alleviate the congestion for these 500 hours in return for contractual remuneration. In the remaining time, the market party could deploy its battery on different energy markets. This structure ensures effective congestion management and takes away a big part of the insecurity for the market party.

B15. Role and restrictions DSO

The DSO is bound by strict regulations and well-defined roles, which can hinder the implementation of battery storage systems in the Netherlands. In 1996, the EU issued liberalization guidelines to enable competition in the EU electricity markets, which were adopted by the Netherlands through the *Elektriciteitswet 1998*. These guidelines prohibit grid operators from engaging in any market activities to safeguard market competitiveness. As a result, the DSOs are not permitted to be active market participants, undertake or invest in battery projects, but can only research the problems behind congestion and expand the grid as required by law. Consequently, the DSO may reinforce the grid in a location that only experiences actual congestion for a few hours per year.

The discrepancy arises that the value of congestion management lies with the DSO, but market players have to perform the congestion management. This makes it challenging to compensate market players for their congestion management efforts, leading to deployment of batteries in ways that do not align with congestion management. Therefore, it is difficult to install a battery in-front of the meter that performs actual congestion management due to the DSO's restricted role.

4.3.4 Hindering legislation

B16. Legislation on private grids

To effectively use generated energy and to locally minimize net congestion, ideally, the self-consumption of electricity is as high as possible. This self-consumption can be maximized if electricity can be shared between different companies in a business park. In an ideal situation, companies and the battery storage system would be connected behind a common allocation point with the main grid so that peak shaving and load levelling can be optimized and the strain on the local grid in front of the grid connection is as low as possible. Unfortunately, this leads to the creation of a 'mini grid' or a private grid. This is in most cases prohibited in the Netherlands by the ACM because the grid is not operated by an independent DSO (ACM, 2021).

A few exceptions are the creation of a direct line, a MLOEA, cable pooling, and a closed distribution grid (GDS) (Eijkens, van Asperen & Lindijer, 2018). A direct line is a producer with one or more consumers, of which only one has a grid connection. A MLOEA is a situation in which multiple allocation points exist behind one grid connection. A hard requirement is that the different allocations can only be placed at one legal object. Cable pooling is the exception with which multiple solar and wind farms can combine their installations behind one grid connection. A GDS is a private grid with multiple connected parties. The private network is owned by a private party.

Battery systems need to have their own grid connection, need to be placed behind the meter at the same legal object, or need to make use of one of the above-mentioned exceptions. All these exceptions come with a lot of requirements and administrative hassle. This puts an administrative burden on efficiently integrating battery storage in an FTM manner (Netbeheer Nederland, 2020; ACM, 2021).

B18. Lack of legal definition

Battery energy storage systems do not get assigned a separate legal definition in the Dutch Energy Law, the *Elektriciteitswet* (Storage Magazine, 2021). This leads to confusion when trying to take away barriers to battery storage in other legislation. Comparable to this problem is that the Dutch *Netcode* for Electricity and the *Elektriciteitswet* do not facilitate the implementation of battery energy storage (Exter, 2021). With no definition, storage assets are labelled as consumers, which leads to unfavourable regulation, because this regulation was originally defined for completely other assets in the traditional energy system (Energy storage news, 2021). This amounts to hurdles and investment insecurity. The need for a legal definition of energy storage is also addressed in the *Landelijk Actieprogramma Netcongestie* (LAN, 2022).

4.3.5 Behaviour of actors

The last factor that can negatively influence the adoption of collective FTM battery storage on the meso level is the behaviour of involved actors. This behaviour can be delineated as bureaucracy, the lack of transparency/communication of actors and the opportunistic behaviour of market players.

B21. Bureaucracy

Local bureaucracy can lead to lower participation in collective battery projects (Oteman et al., 2014). Battery operators experience hindrances from municipalities and officials in wanting to set up projects. Officials tend to take a controlling role rather than a facilitating role (Rotmans, 2011). This behaviour of officials makes it harder to realize battery projects (Rotmans, 2011). Hoppe et al. (2015) argue that a proactive role and positive interference of local governments are key in making local energy initiatives a success. Given that collective battery, projects are now often delayed due to non-proactive conduct by municipal bodies, bureaucracy can be seen as a barrier.

B22. Transparency and communication actors

First of all, the integration of collective FTM storage suffers from a lack of transparency and communication between actors. Both market players and grid operators play a role in this phenomenon. Both parties agree that battery storage is needed in the energy system to provide flexibility, but due to a lack of agreements and communication, these systems have not yet been implemented as much as needed. As discussed in the previous chapters, DSOs observe that market parties are not transparent about the way they will deploy their battery and whether this use will alleviate net congestion. This is an example that shows that more transparency, communication, and agreements between grid operators and market players could increase the proper integration of collective FTM battery storage.

B23. Opportunistic behaviour

Another behavioural factor that influences the adoption of collective FTM storage is the opportunistic behaviour of battery operators. As mentioned before, currently almost 20GW of battery storage grid connections are requested at TenneT and the different DSOs (Zwang, 2022). The requested capacity alone is more than the capacity of the whole Dutch electricity grid. It is interesting that 16GW of this capacity has been requested by only four battery operators. It is believed that these parties often request these connections without the proper knowledge about the Dutch market or without the will to actually realizing battery projects at these locations. These projects thus will probably not be realized.

The market is often plagued by opportunistic actors, commonly referred to as "cowboys," who present a skewed view of the market conditions (Zwang, 2022). These actors may lead grid operators to believe that there is a greater interest in battery projects than there actually is. Consequently, the grid operators may not collaborate with other market players to implement changes that would make collective FTM battery storage more viable, such as reducing the transport tariffs for batteries that assist with net congestion. Why make battery storage even more attractive if there are already numerous requests for battery storage systems? Thus, the opportunistic behaviour of market players obstructs the adoption of collective FTM batteries.

4.4 Description of theoretical barriers on macro level

As mentioned above, the contextual macro level consists of national and global forces like demographics, politics, technological, economic and social development, and environmental factors. Barriers placed on the macro level are hardly influenceable or controllable by battery operators and policy developers. They can merely be seen as a given. Nevertheless, it is important to name these barriers in order to deal with their consequences. The macro-level barriers find their origin in two sub-categories: technological uncertainty,

resource constraints, and the barrier permit processes and nitrogen. Every new technology faces technological uncertainty due to technological developments and low reliability of systems (B1), safety issues (B2) and cyber security and privacy issues (C3). These are thus seen as macro barriers. Furthermore, resource constraints in the form of a shortage of technical personnel (B5), raw materials constraints (B6) and scarcity of computer chips (B7) are also faced by society as a whole, making them macro barriers. The same goes for general permit processes and the current public uproar about nitrogen regulation in the Netherlands. The macro level is depicted in Figure 21.

MACRO	B1. Low reliability of systems	B5. Shortage of technical personnel	B17. Permit processes and nitrogen	
	B2. Safety issues	B6. Raw materials constraints		
	B3. Cyber security and privacy issues	B7. Scarcity of computer chips		

Figure 21: Macro level

4.4.1 Technological uncertainty

Given the fact that using batteries in power systems is a quite new concept and the relevant technologies are still undergoing development, technological uncertainty might act as a factor that limits the integration of collective FTM batteries. Technological uncertainty exists when it is uncertain whether an innovation is technically feasible, or achievable in practice. Technological uncertainty of collective FTM battery storage consists of three different influencing factors: low reliability of the systems, safety issues, and cyber security and privacy issues. Since technological uncertainty is highly dependent on global technological developments and almost every technology faces this stage, these three barriers can be seen as macro barriers. These factors will now be discussed.

B1. Low reliability of systems

For the proper integration of collective FTM battery storage systems in the energy system, it is of pivotal importance that they can be utilized reliably at any moment. A malfunction of the battery system can impact the integrity of the whole energy system. Next to that, an unreliable battery can negatively impact the business case of this battery. Battery storage systems are currently still prone to technical issues and malfunction (Exter, 2021). They are subject to failures when components of the system fail. Next to that, unreliable communication between the battery and other parts of the system, like the EMS, might jeopardize the proper functioning of the system.

B2. Safety issues

Li-ion batteries present several safety challenges, including fire risks, as they contain flammable electrolytes. In recent years, numerous incidents of Li-ion battery fires and explosions have occurred, resulting in property damage and bodily injuries (Kong, Li, Jiang & Pecht, 2018). Li-ion batteries can become unstable due to overloading, deep discharging, high and low temperatures, and forceful impacts (PublicatierEEKS Gevaarlijke Stoffen, 2022). Safety protocols in the Netherlands are struggling to keep up with the fast-paced development of the battery market, leading to the development of PGS 37-1, a guideline aiming to ensure the safety of storing electricity in Li-ion batteries by meeting specific safety requirements (PublicatierEEKS Gevaarlijke Stoffen, 2022).

Moreover, battery producers often fail to provide detailed specifications of the battery storage systems they produce, and quality standards are yet to be established. To address this issue, the EU has developed a plan for the implementation of a mandatory digital battery passport (Battery Pass, n.d.), which will be rolled out in the coming years. These guidelines are critical because the safety of these systems can impact the investment in collective FTM batteries and their integration. Furthermore, the public's perception of the safety of battery storage systems is vital to ensure their social acceptance. A suboptimal safety perception of battery systems could also dissuade insurance companies from covering the systems, which would hinder their adoption.

B3. Cyber security and privacy issues

Collective FTM battery storage in this study is realized, operated, and used by multiple parties. In order to efficiently execute these processes, the sharing of data and smart metering is required. This is why the use of battery storage is prone to privacy breaches and cybercrime since criminals could be able to access personal data. A trade-off exists between data privacy and system efficiency. The more data participants and stakeholders share with each other, the higher the transaction transparency and system efficiency (Kappagantu & Daniel, 2018; Muzumdar, Modi, Mahdu & Vyjayanthi, 2021). On the contrary, more data sharing yields more data and privacy risks.

4.4.2 Resource constraints

In addition to technological uncertainties, resource constraints can also act as barriers to the successful integration of collective FTM battery storage. In the Netherlands, three types of resource constraints are currently evident: a shortage of technical personnel (B5), lithium constraints (B6), and a scarcity of computer chips (B7). Since these barriers occur on both national and global scales, and are not energy sector-specific they are considered macro barriers that actors must acknowledge.

The demand for technical personnel in the Netherlands is currently increasing at an unprecedented rate, which could jeopardize the long-term success of the energy transition (NOS, 2021). Many renewable energy and battery projects are already experiencing delays due to the shortage of technical personnel.

Another resource constraint encountered when implementing batteries is the availability of lithium (B7). Greim et al. (n.d.) note that the supply and demand of lithium are well-balanced in the short term, as the growth in supply keeps pace with the growth in demand. However, problems with the availability of lithium are likely to arise in the foreseeable future due to increased electrification and e-mobility. This trend is evident in Figure 22 (Benchmark minerals, 2022). According to the worst-case scenario, where there are low estimates of remaining reserves, low recycling rates, no new policies, and increased electrification and e-mobility, the world's lithium reserves will be depleted before 2040 (Willuhn, 2020). This poses a significant risk to decarbonization efforts (World Economic Forum, 2022).

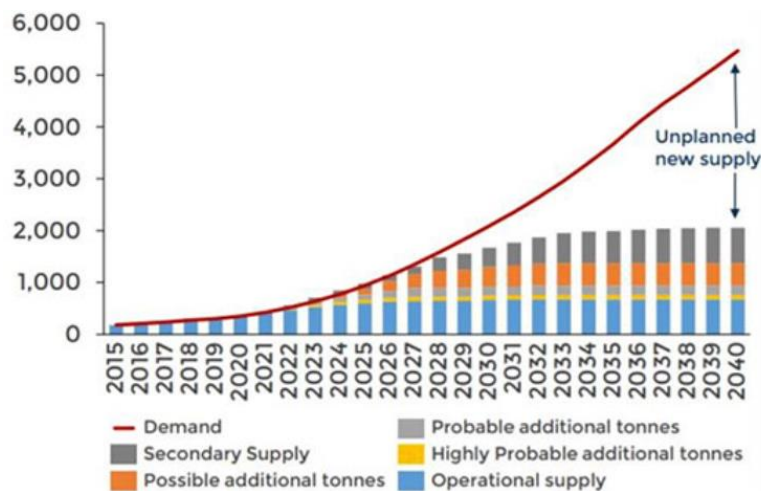


Figure 22: Lithium demand and supply forecast (Benchmark minerals, 2022)

Next to this, lithium is mined using energy-intensive methods and its supply chain is not without environmental damage and pollution. On top of that, lithium is only found in the earth's crust in a few places on the planet, making the resource supply vulnerable to geopolitical tensions. Other minerals such as cobalt, nickel, and graphite are also important in developing stationary battery systems. These minerals are also finite. The future availability of lithium and other raw materials can be seen as a macro barrier.

One barrier that might have been slowing down the integration of battery storage systems in the Netherlands is the shortage of computer chips due to increased demand and the COVID-19 pandemic. Currently, the market for computer chips seems to be returning to normal (Lustgraaf, 2022). Having said this, it is expected that a shortage will remain for the coming years. Given that computer chips are used in almost every part of an energy system, this shortage might slow down the adoption of collective FTM battery storage.

4.4.3 Permit processes and nitrogen

The last macro factor that negatively influences the adoption of collective batteries is permit processes and new nitrogen regulations (B17). Since these rules are not sector-specific, they can be seen as macro barriers. Battery projects are known to be held down by extensive permit processes. Especially applying for an *omgevingsvergunning* (environmental permit) can be a time-intensive endeavour. In 2021 the law for the reduction of nitrogen and nature improvement was enacted (Rijksoverheid, n.d.). This is why it is now needed to have an environmental permit. The nitrogen regulations have shown that they can slow down new construction projects like battery projects. This can thus be seen as a barrier.

The full micro-meso-macro framework is depicted in Figure 23.

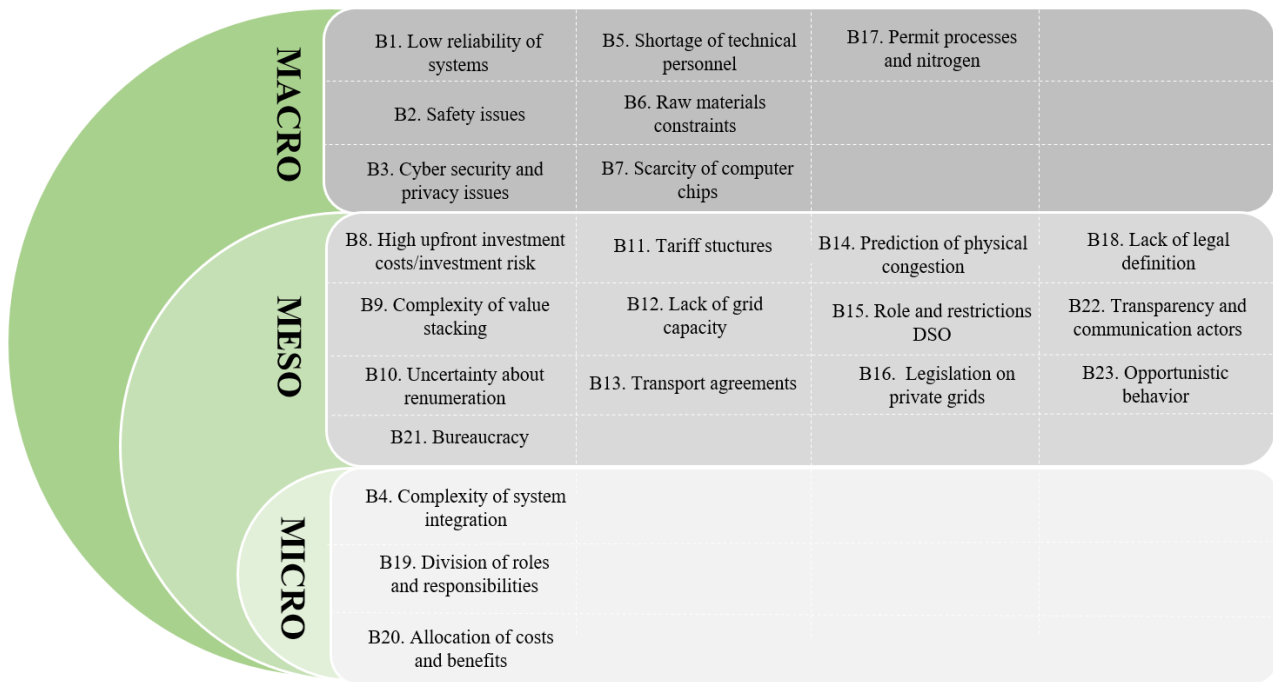


Figure 23: Micro-meso-macro framework

4.5 Deduction from theoretical to critical barriers

As mentioned in the methodology, the identified theoretical barriers are reduced to a few critical barriers based on three steps in the funnelling approach. The first step assesses whether the barriers and their possible policy instruments are inside the scope of the research. In the second step, their criticality is assessed based on the expert interviews. The interviewees have been asked to name critical implementation barriers. They have also pinpointed some barriers that are not deemed critical. The summaries of these interviews can be found in Appendix E. In the third step, the theoretical barriers are compared to the critical barriers coined in the interviews, whereafter similar barriers are grouped to eventually form three critical barriers. The funnelling process will now be discussed.

Funnelling step 1 – scope

As discussed in the preceding sections, macro-level contextual barriers represent obstacles that are generally present in the Netherlands and are also perceived by actors in other sectors. These barriers are linked to national and global forces that are largely beyond the control of energy-specific policies. Given that this thesis focuses on policies specifically designed for the energy sector, it is argued that macro-level barriers fall outside its scope. While they could potentially impede the implementation speed of collective battery systems, addressing these barriers with more general policies is not within its purview. Consequently, they should be considered a given.

The following macro-level barriers are identified as non-critical: those stemming from technological uncertainty (B1 – low reliability of systems, B2 – safety issues, and B3 – cyber security and privacy issues), resource constraints (B5 – shortage of technical personnel, B6 – raw material constraints, and B7 – scarcity of computer chips), and generic permit processes and nitrogen regulation (B17). Additionally, the complexity of value stacking (B9) is placed out of scope, as this barrier is unlikely to be addressed through policy interventions. The complexity of value stacking arises primarily from technical requirements of different energy markets and energy services, and the fact that different markets have different entry barriers, making it difficult to combine them. While policy changes could theoretically modify these technical requirements and entry barriers, it is improbable that such changes will be implemented due to the stringent technical requirements in place to safeguard the proper functioning of the markets and the adequacy of provided energy services. As most of these requirements are not asset-specific, they apply to participants with different kinds of assets. Considering the importance of the requirements and diversity of assets on these markets, it can be concluded that the entry requirements will likely not be adjusted in favour of collective battery storage systems. Hence, this barrier is not considered.

While allowing DSOs to invest directly in battery systems themselves (B15) could be an interesting and feasible solution, regulatory changes to facilitate this are unlikely, given the deep entrenchment of the role of the DSO in European and Dutch energy laws, as stated in section 4.3.3. The non-market, impartial functioning of the DSO has been a cornerstone of the liberalization of the European energy markets to ensure fair competition. As IV1 and IV3 mention, it is therefore unlikely that the role of the DSO will significantly change to permit them to invest directly. This is why this barrier is disregarded. Further elaboration on this topic can be found in section 5.1. Regarding the barrier of transparency and communication among actors (B21), it can be argued that this barrier is solely dependent on the communication between actors and is, therefore, difficult to influence with sector-specific policy measures. Thus, this barrier is also considered out of scope and is disregarded.

Funnelling step 2 – Criticality

In this step, an assessment is made of the criticality of the identified barriers using the interviews. This triangulation of the barriers ensures that only the barriers that are perceived as highly impeding in daily practice by different stakeholder groups with differing perspectives remain. Two barriers are identified as non-critical, while three overarching barrier themes are considered critical based on the views expressed by interviewees (IV1-IV6).

Technical issues are typically not the primary factors hindering the large-scale implementation of collective FTM battery storage in the Netherlands. Instead, institutional, social, and economic barriers are usually more stringent (Expertgroep Batterijen, 2022; Klimaatakkoord, 2022). This view is supported by IV3, IV4, and IV5. Consequently, the complexity of system integration (B4) is not deemed a critical barrier. Similarly, the lack of a legal definition (B18) for battery storage in the Netherlands is excluded because it would only have an indirect effect on the energy sector (Energy Storage News, 2021).

Three groups of barriers are consistently identified by interviewees as critical. The first critical factor is the weak and uncertain battery business case, which is characterized by high economic costs and low benefits. This barrier is mentioned by all interview participants (IV1-IV6). The second barrier group includes all procedures that make it challenging for battery systems to obtain a grid connection, and this is also identified by all interviewees. The third critical barrier group is the lack of local cooperation between actors in collective battery storage projects, as named by IV2, IV3, IV4, and IV5.

Funnelling step 3 – Comparison and grouping

When looking at the first critical barrier named by the interviewees, there is a strong relation between this perceived barrier and the theoretical economic barriers high upfront investment costs and risk (B8), uncertainty about remuneration (B10), and tariff structures (B11). Namely, high costs (tariff structures and high upfront investment costs) and meagre and uncertain benefits (uncertainty about remuneration) have a negative effect on the battery business case and thus initiate investment risk. This interrelationship can be summarized as one critical barrier, namely the economic costs and benefits of a battery system. As stated above, this barrier is also named critical by all six interview participants and heavily emphasized in literature. This is why the economic costs and benefits of battery storage systems form critical barrier 1 (CB1).

When it comes to the second barrier that the interviewees identify as critical (procedures that make it difficult for batteries to obtain a grid connection), one can unravel that the theoretical barriers lack of grid capacity (B12), transport agreements (B13), and legislation on private grids (B16) all encompass parts of the causes for the critical barrier named by the interviewees. These theoretical barriers all have a strong relation with how batteries currently obtain a grid connection and how these procedures currently slow down the integration of these systems. Prediction of physical congestion (B14) is also associated with this since a more adequate prediction and announcement of physical congestion would pave the way for new arrangements between market parties and grid operators and consequently the possibility to connect more batteries to the grid.. Furthermore, opportunistic behaviour (B23) can be countered with new grid connection procedures and therefore can also be grouped with these other barriers. Given that these five theoretical barriers have a strong relation with each other and together represent the second critical barrier named by the interview participants, they are merged into critical barrier 2 (CB2): grid connection procedures for battery systems.

The barriers division of roles and responsibilities (B19), allocation of costs and benefits (B20), and bureaucracy (B21) all have to do with local cooperation between participants and other actors like municipalities. As mentioned above, the lack of local cooperation and the current absence of enabling policy is mentioned by IV2, IV3, IV4, and IV5 in the interviews as a critical barrier. Because of the strong relation between the three theoretical barriers and the critical barrier mentioned by the interviewees, a lack of local cooperation is proposed as critical barrier 3 (CB3).

The described funnelling process leads to the following critical barriers, which are validated with the interviews with participant 7 and 8 (Table 9):

Barrier	ID	Description
Critical Barrier 1	CB1	The economic costs and benefits of battery systems
Critical barrier 2	CB2	Grid connection procedures for battery systems
Critical barrier 3	CB3	Lack of local cooperation

Table 9: Critical barriers

The validity of the critical barriers is strengthened because of the fact that the theoretical barriers that remain after the first two funnelling steps are strongly related to and can be grouped to the three critical barriers named by the interviewees. This means that the barriers obtained from a theoretical perspective are aligned with the barriers encountered in practice. This shows their validity. Furthermore, they are once more validated by IV7 and IV8.

4.6 Conclusion

By means of a literature study, an overview of 23 theoretical implementation barriers of collective battery storage in the Netherlands has been constructed. The scrutiny of the study makes sure that the overview is as complete as possible. To show the system orientation of the barriers, the theoretical perspective of the micro-meso-macro framework is introduced. All theoretical barriers are placed on either the micro, meso or macro level.

Subsequently, to keep the analysis comprehensible and make sure viable policy interventions are proposed in the next chapter, the theoretical barriers are brought down to three critical barriers using a funnelling approach. In the first step, barriers that are out of the scope of this thesis are disregarded. The second step involves the assessment of the criticality of the different barriers using the first six expert interviews. This triangulation of the barriers ensures that only the barriers that are perceived as highly impeding in daily practice by different stakeholder groups with differing perspectives remain. In the third funnelling step, the critical barriers identified by the interviewees are compared to the theoretical barriers and the remaining theoretical barriers are grouped. Three critical barriers are proposed: the economic costs and benefits of battery systems, the grid connection procedures for battery systems, and a lack of local collaboration.

Chapter 5 Policy interventions

In this chapter, three policy interventions per critical barrier are proposed that have the ability to overcome their respective critical barriers. The third sub-question is answered:

SQ3 - What policy interventions can overcome the critical barriers of collective FTM battery storage?

In this thesis, a policy intervention is defined as any action, program, or activity mandated by national authorities and non-state actors to overcome critical barriers to collective battery storage implementation and increase its adoption. These interventions can address various measures, including technologies, processes, practices, and behaviour. Policy interventions may be initiated by governmental bodies, provinces, municipalities, and non-state actors with authoritative power in the energy sector, such as the DSO and the ACM.

In the first three sections of this chapter, three policy options are proposed per critical barrier. For the first critical barrier (economic costs and benefits of battery systems), given the hefty amount of possible financial support measures, first policy options that are not proposed are described and motivation for these choices is given. For the second and third critical barriers (grid connection procedures for battery systems and lack of local cooperation), fewer policy options are available, and therefore, only the proposed policy interventions are discussed. The policy options are based on literature, interviews conducted, and the researcher's interpretation. The interview reports can be found in Appendix C. The chapter concludes with a brief summary.

5.1 Policy interventions for CB1: economic costs/benefits of batteries

There are numerous policy interventions that can provide financial support to battery projects and improve their business case. Governmental support and policies aimed at sustainable energy technologies include loans, tax-based incentives, subsidies, direct investments by institutional bodies, renewable portfolio standards, revised tariff schemes, and increased remuneration for energy services. Several of these schemes are already in place in the Netherlands for battery storage systems. Loans, tax-based incentives, direct investments, revised tariff schemes, and some subsidies are implemented to reduce investment and operational costs of the targeted technology. Other subsidies and increased remuneration for energy services can be used to enhance the revenue of technologies (RVO, 2017). The reasons for not proposing some financial support instruments are explained, followed by a description of the proposed instruments.

Subsidies

Multiple subsidies are already made available by the Dutch government to stimulate the energy transition. An example is the SDE++ subsidy, a subsidy for the operation of renewable energy sources (RVO, 2022). Operators of large-scale renewable energy generation units receive remuneration for the energy they produce. Another subsidy issued in the Netherlands is the ISDE investment subsidy for sustainable energy technologies and energy-saving measures for homeowners (RVO, 2023). Subsequently, HER+ is subsidy granted by the government for innovative renewable energy projects that foster the energy transition. On top of these, the SCE subsidy is an operating subsidy for cooperative energy generation by local cooperative energy initiatives (RVO, 2023a).

The SDE++, HER+, and SCE subsidies do not include energy storage, whereas the ISDE subsidy only applies to homeowners, thereby excluding commercial battery storage. This means commercial battery storage systems of any kind are not subsidized in the Netherlands. Countries like Germany, the United Kingdom, and the United States do already issue subsidies for stationary battery storage (Department for

Business, Energy & Industrial Strategy, 2022; Office of Energy Efficiency & Renewable Energy, 2023; LG Energy Solutions, 2021).

When looking at policy interventions that target the battery business case, policy developers must decide whether to issue subsidies. The intention of subsidies is to strengthen the business case of batteries by either lowering costs or increasing the revenue of the systems. While subsidies stimulate renewable energy development in this way, they might also lead to unintended consequences and distorted market functioning. This is why prominent figures in the European energy storage sector advocate against implementing subsidies on battery storage (Parnell, 2020).

The opinions of Interviewees 3, 4, and 6, along with the policy advisor, suggest that issuing subsidies for battery storage systems should be avoided due to potential unintended consequences. First, subsidies may lead to distorted electricity markets and prices, as observed by Dominguez (n.d.). For example, since a significant proportion of wind energy produced is subsidized and sold on wholesale markets, energy operators may offer their electricity at negative prices, which can result in market distortion. Second, limited governmental capital may be invested based on the preferences of officials instead of market realities, which can place new, innovative technologies that are not subsidized at a disadvantage (Dominguez, n.d.). These technologies may have to compete against publicly subsidized technologies rather than the market, and the perceived financial risks of the subsidized technologies may be distorted due to the subsidies they receive.

The third and final unintended consequence is that subsidies might harm the very industries they are intended to help (Dominguez, n.d.). Once they receive subsidies, operators of renewable energy technologies may become dependent on financial aid to stay competitive. Subsidies have the potential to obscure critical pricing information, such as the price point at which a technology becomes competitive. Furthermore, subsidies may discourage companies from being innovative, reducing costs, and exploring new markets. If a particular technology is over-subsidized and companies become dependent on the subsidy, removing the subsidy may result in the technology being abandoned. As IV4 mentioned, ensuring adequate energy supply security will then require even more public funding.

A recent study commissioned by the Ministry of Economic Affairs and Climate has concluded that including batteries in the SDE++ subsidy would be too costly per ton of CO₂ abated (Solar Magazine, 2022a). Given the costs and the opinions of the interviewees, as well as the three plausible unintended consequences of battery subsidies, it is reasonable to argue that subsidies are a suboptimal policy intervention for addressing the first critical barrier (i.e., economic costs and benefits of battery systems). As a result, subsidies are disregarded.

Tenders

A tender is a procedure in which the government purchases a certain service or product by means of a public registration (Business.gov.nl, n.d.). Tenders are commonly used in the Netherlands for large-scale wind and solar projects and offer a definite remuneration. Since Dutch governmental bodies are the issuers of tenders and this thesis focusses on battery storage operated by commercial parties, tenders are disregarded in further analysis.

Tax-based incentives

Tax-based incentives are commonly employed to promote renewable energy, taking the form of tax credits, exemptions, or deductions. In the Netherlands, various environmental taxes already exist to reduce CO₂ emissions, such as the coal and energy tax. Electricity generated from renewable energy sources (RES) is exempt from energy tax. A sustainable energy tax (ODE) is applied to the generation of natural gas and

electricity (Belastingdienst, n.d.). Taxes increase the market prices of natural gas and electricity, providing an incentive for companies to use less power and switch to RES-generated electricity due to its lower tax rates. In addition, commercial entities can apply for a tax reduction on investments in sustainable company assets that result in CO₂ reduction (Energie-investeringsaftrek or EIA). This tax reduction amounts to 45.5% of the investment costs (RVO, 2022a). As this substantial tax reduction for commercial battery systems is already in place and is deemed effective, it is not considered necessary to incorporate other tax incentives (CE Delft, 2017).

Direct investments

An alternative method to increase the adoption of battery storage systems could be for governments and grid operators to invest directly in battery systems. However, as explained in chapter 4, regulations prohibit direct investment by grid operators in battery systems. These regulations exist to establish clear distinctions between the tasks, possibilities, and obligations of grid operators. Grid operators should remain independent parties and only perform tasks that facilitate the market (Energie-Nederland, 2016). Allowing grid operators and governments to invest directly would give them an unfair advantage over market players, arising from their inside knowledge of the energy markets and congestion areas, as well as government insight into policy developments. Moreover, both parties would have a financial advantage. Direct investments may impede the development and introduction of new sustainable products and services by market parties in favour of the energy transition. This hindering effect, coupled with stringent legislation surrounding the topic, makes direct investments an unfavourable and hardly implementable policy intervention.

Capacity mechanisms

Another method of acquiring long-term revenue streams with a battery system is by offering the battery on a capacity market. A capacity market is a form of a capacity remuneration mechanism (CRM) that compensates resources for being available to meet peak electricity demand, and participants receive a capacity payment. It is used to ensure electricity supply in the medium- and long-term, particularly during a generation inadequacy (European Commission, n.d.). In the Netherlands, the market only compensates for produced power and not for power availability, which is called an energy-only market. However, interviewee 4 indicates that capacity mechanisms may be necessary in the near future to ensure the security of supply when coal- and gas-fired plants are decommissioned. While a capacity market would provide batteries with long-term revenue streams, as in the UK, their implementation is quite difficult, particularly in the EU's internal electricity market where capacity mechanisms coexist with energy-only markets (European Commission, n.d.). The difficulty of designing and implementing CRMs, along with their significant impact on the Dutch energy system, means that they are considered out of scope as a policy instrument.

It is important to note that capacity markets should not be confused with capacity-limiting contracts (CBCs). Parties only receive compensation with CBCs for making their assets available in the congestion market, while a capacity market would lead to a complete reorganization of the current energy-only system in the Netherlands. Consequently, the country would depart from its present energy-only capacity mechanism.

5.1.1 Proposed policy interventions

After having identified policy interventions that will not be selected, this section will elaborate on the proposed policy interventions. Motivation for the choices will be given. The policy interventions are summarized in Table 10 and subsequently discussed.

CB1	ID	Description
Policy intervention 1	PI1	Governmental loans
Policy intervention 2	PI2	Revised tariff structures
Policy intervention 3	PI3	Contractual remuneration for energy services

Table 10: Policy interventions for critical barrier 1

Policy intervention 1 - Governmental loans

An important policy option to promote the adoption of battery storage systems is to provide loans from the government. These loans can address a significant part of the first critical barrier, which is the lack of sufficient funds for battery projects due to investment risks. Germany already provides a loan for energy storage systems through the national bank KfW. The KfW 270 promotional loan 'Renewable Energies - Standard' can cover up to 100% of the investment costs for an energy storage system, with a cap of up to €50 million per project (KfW, 2022). As battery storage investments can be perceived as risky, interest rates for battery financing from commercial banks can be relatively high. In comparison, the KfW loan offers very favourable interest rates and a generous grace period. In 2020, the 270 promotional program reduced greenhouse gas emissions by 1.314.928 tons, equivalent to taking approximately 850,000 passenger cars off the road (KfW, 2022). Given the effectiveness of the program in Germany, a similar loan from the central bank of the Netherlands could be a highly effective policy intervention. IV7 and IV8 also suggest governmental loans as a potentially effective measure, especially considering the current upward trend in interest rates (Actuelerentestanden.nl, n.d.).

Given the impact the loan has in Germany, a similar structure is proposed for a governmental loan in the Netherlands. While the percentage of investment costs covered can be up to 100%, the KfW (2022) suggests an average coverage of around 75% for all projects. This should be done to ensure that the loan

Loan characteristic	Amount
Percentage covered	Up to 100%
Average percentage covered	75%
Maximum loan	50 million euros
Interest rate	3-4%
Payback period	Case-specific

is adequate for projects to be implemented, while also ensuring that enough funds are available for other battery projects. An interest rate of 3-4% is suggested in this thesis. This percentage is more favourable than loans from any commercial banks and comparable with the rates of effective KfW loans (Actuelerentestanden.nl, n.d.; KfW, 2022). The maximum loan is determined at 10 million euros since battery projects are not likely to exceed the 10 million in capital costs marker. The payback period is determined on a case-to-case basis. The loan characteristics are summarized in Table 11.

Table 11: Loan characteristics

Governmental loans, compared to subsidies, amount to less governmental expenditures since the loans need to be paid back. Next to that, loans interfere less with the proper functioning of the energy markets, since they only provide financing aid from the government. They do not change the operational costs or revenue of a technology compared to other technologies. Loans do not lead to skewed energy markets and prices and operators will still seek to be competitive to pay back their loans. On top of this, government loans have proven to be effective in Germany. Hence, governmental loans are chosen as the first policy intervention (PI1).

Policy intervention 2 - Revised tariff schemes

After analysing interviews with participants 2, 3, 4, 5, 6, and 7, and literature, it was found that high transport tariffs are the biggest burden on the battery business case currently, as they can amount to up to 80% of the operational costs of a battery (Solar magazine, 2022). To strengthen the battery business case, the interviewees suggest revising tariff schemes. Next to investment risk and low, fluctuating remuneration,

high operational costs make up for a big part of the first critical barrier. Thus, the second proposed policy intervention, PI2, is a revised tariff scheme for batteries.

The first part of the revised tariff scheme is that battery operators should not be considered as consumers. Currently, they are seen as such due to barrier B18, which is the lack of legal definition for battery storage. The absence of such a definition makes it difficult to regulate storage systems, taking into account their specific characteristics. According to the Tarievencode (Tariff code), the party that burdens the grid has to pay the transport tariffs (Energy Storage NL, 2021). Traditionally, it is believed that production follows demand, and thus, consumers burden the grid, and they pay the tariffs for transported power. As there is no intermediate category of storage, a battery is seen as a consumer and pays the transmission tariff on the energy that is charged. However, this tariff unfairly accrues to the storage operator since storage systems are not end-users but only temporarily store energy (Energy Storage NL, 2021).

In Germany and Belgium, batteries do not pay transport tariffs if they are deployed in favour of the grid (which means if they perform energy services to the grid operator). Given the aforementioned statement in the Tarievencode, it is suggested that batteries should not pay transport tariffs if they are used to support the grid. Currently, an incorrect price signal is given by grid operators when batteries are deployed in favour of the grid. They are charged with high transport tariffs that are designed to charge connected parties that put stress on the grid, while batteries in those situations only lessen the burden on the grid. The current tariff structure significantly impedes the battery business case and is considered one of the main factors that prevent more battery systems from being implemented in the Dutch energy system. The benefits of battery systems, such as additional flexibility, are lost due to the current tariff structure. High transport tariffs create a deadweight loss, which is the loss of total social welfare due to reasons like taxes or subsidies, price ceilings or floors, externalities, and monopoly pricing (Economic times, n.d.). Additionally, the current price signals do not incentivize batteries to be used in favour of the grid, leading to economic inefficiencies, as the battery is not allocated to its most valuable use.

The first proposed revision of the transport tariff structure is that battery operators should receive a rebate on their transport tariffs if they perform congestion management. This would tackle one of the most severe implementation barriers, which according to the ACM would result in more batteries being implemented in the Dutch energy system (Energy Storage NL, 2021). The increase in batteries increases economic transactions and takes away a part of the deadweight loss. Furthermore, the rebate on transport tariffs would provide an incentive to deploy batteries in a way that increases social welfare. It can be concluded that a rebate on transport tariffs for batteries would increase social welfare. A strict requirement must be that a rebate on the transport tariffs is only given for times that the battery is deployed in favour of the grid (Energy Storage NL, 2021).

The second proposed revision is to exempt battery systems from paying additional fees for short peaks in used transport capacity when these peaks are used to benefit the grid. These peaks are inherent to delivering energy services, and battery operators should not be charged extra for them.

Transport tariffs are crucial revenue streams for DSOs, which use these funds to cover their expenses and invest in the electricity grid. DSOs operate on a cost-based model, so if tariff structures yield fewer funds, they can invest less in infrastructure, which is highly undesirable. Therefore, determining who will pay for a revised tariff scheme is a challenging public discussion. The value that battery operators provide to the DSO is proportional to the congestion management they perform, which alleviates net congestion and subsequently costly grid reinforcements. Therefore, it can be concluded that CSPs should receive remuneration for the congestion management they perform equal to the amount of money saved by deferred grid reinforcements.

The DSO could reimburse the CSP for their transport tariffs at the end of the year based on the congestion management they have performed. The reimbursement should be equal to the alleviated grid investments. This revision of the tariff structure would be a cost-effective approach to unlocking more flexibility in the market and incentivizing battery operators to perform congestion management.

A key aspect of this tariff structure is that the value of congestion management is adequately defined and that the settlement by the DSO is adequate. If the value of congestion management is undervalued by the DSO, market parties will likely deploy their batteries in other markets instead of performing congestion management.

Policy intervention 3 – Contractual remuneration for energy services

The last part of the critical barrier, low and unsure **operational revenue** can be overcome by increasing the remuneration for energy services and increasing the surety of the remuneration by issuing long-term contracts (PI3). This is seen by IV1, IV2, and IV4 as one of the most valuable and potentially most impactful policy interventions.

Congestion management is crucial to ensure the success of the energy transition in the Netherlands and to avoid costly grid reinforcements. However, as discussed in section 4.3.2, the remuneration offered by the GOPACS platform is insufficient and uncertain due to market design issues. Long-term contracts for congestion management would benefit both battery operators and DSOs. Operators would receive a certain remuneration for their services, and DSOs could contractually ensure that the operators would assist in balancing the local grid at certain times and not trade on other energy markets that may worsen local congestion.

Contracts could have a fixed or market-based remuneration and be yearly or longer-term. They could stipulate that battery operators are required to perform local balancing services for a specific amount of electricity at a set number of hours per year, or specify a minimum amount of congestion management to be performed annually. The DSO would guarantee a yearly income for the operator, with a template contract in place, but specific agreements can be made between the operator and DSO based on their preferences. The remuneration should be high enough for operators to contract with the DSO. Even if it is slightly below the remuneration of other energy services, operators are likely to contract with the DSO because of the certainty of remuneration.

The CBC contract is the preferred contract for congestion management, as described in chapter 4. This contract form ensures that the battery will perform congestion management for the DSO, and the market party will receive a certain capacity payment and payment per MW involved in congestion management.

5.2 Proposed policy interventions for CB2: grid connection procedures for batteries

To overcome the second critical barrier (grid connection procedures for batteries), three policy interventions are proposed. The proposed policy interventions can be found in Table 12.

CB2	ID	Description
Policy intervention 4	PI4	Predict and physical congestion
Policy intervention 5	PI5	Revision of grid connection procedures
Policy intervention 6	PI6	Revision of private grid regulations

Table 12: Policy interventions for critical barrier 2

Policy intervention 4 (PI4) - Predict and disclose physical congestion to facilitate new contract forms

Chapter 4 highlights the significance of accurately predicting and disclosing physical congestion areas in real-time, which facilitates agreements between battery operators and DSOs. Currently, only theoretical congestion areas are known, and the DSO does not disclose actual or potential physical congestion areas. This information would greatly aid in shaping agreements. For instance, if the DSO discloses that congestion occurs for 400 specific hours a year in a certain part of the medium voltage grid in Noord-Holland, DSOs can arrange for the market party to help alleviate congestion for these 500 hours in return for contractual remuneration. This remuneration can take the form of a capacity payment, a payment for electricity fed in/taken from the grid, or a combination of both. In the remaining time, the market party can deploy its battery freely on different energy markets. This enables a two-way street: the uncertainty that comes with non-firm ATOs on when battery operators can use their batteries is taken away for market parties, and the grid operator ensures that in times of physical congestion, the battery operator helps alleviate net congestion instead of worsening it.

Monitoring and predicting net congestion can be seen as a key factor in making capacity-limiting contracts a success. These alternative contracts will probably be inevitable soon in the Netherlands, so a focus on the technical capabilities of the grid operators to predict physical congestion can be seen as an important improvement. Better prediction of congestion could also mean that the electricity grid is used more efficiently, thus making more grid capacity available.

Policy intervention 5 - Revision of grid connection procedures

Due to net congestion in the Netherlands, lengthy waiting lists have formed for grid connections. Although grid operators are typically not permitted to discriminate between connection applications, this already occurs in cases such as when operators decide not to connect large-scale batteries (Zwang, 2022). To increase the flexibility of the energy system, it is necessary to revise current grid connection procedures (PI5) and prioritize grid connections for flexibility-offering parties such as battery operators. To ensure that these parties actually offer flexibility and not just trade on different energy markets with their battery, agreements similar to those of policy intervention 4 must be in place between operators and DSOs.

Once these agreements are in place, it is possible to abandon the "first come, first serve" principle and prioritize batteries and other parties that offer flexibility. Applications should also be evaluated for feasibility of realisation to ensure that projects that receive a grid connection are actually implemented. When the grid connection is granted, a "use it or lose it" clause could be an effective way to make optimal use of the scarce grid capacity. This clause means that if connected parties do not fully utilize their allocated transport capacity over a certain period, they lose a portion of their capacity.

Simplifying current connection processes and grid access regulation in favour of batteries is another crucial point. The UK government's Department for Business, Energy and Industrial Strategy and Germany's grid regulator Bundesnetzagentur have already implemented simplified "fast track" processes for battery storage systems that reduce the time and transaction costs of attaining a grid connection. These processes could also help speed up the implementation of collective batteries in the Netherlands.

Policy intervention 6 (PI6) – Revision of private grid regulation

Currently, the regulations imposed by the ACM on private grids hinder the possibility of local energy hubs sharing one grid connection to operate a combination of wind, solar, and energy storage (LAN, 2022). Sharing one grid connection optimizes local self-consumption and balancing of the local grid. This means that a combined grid connection needs less transport capacity than individual ones, reducing stress on the

surrounding grid. To facilitate this sharing, appropriate contract forms should be developed, such as group/collective ATOs, and included in the *Energiewet* and *Netcodes*. A collective ATO facilitates the sharing of grid capacity for feed-in/take-out of electricity, for example, for an energy collective at a business park. To make a collective ATO possible, individual connected parties that are part of this collective need to have a non-firm capacity contract with flexible transmission capacity. This concept is currently being developed in several pilots at the three major regional grid operators. Adjusting private grid regulations would make it easier and more cost-effective to own and use a battery collectively in business parks.

5.3 Proposed policy interventions for CB3: local cooperation

In this section, three policy interventions are described that can improve local cooperation in collective battery projects. These policy interventions target the allocation of ownership, liabilities, risks, and cost/benefits of the battery storage system and the fair sharing of energy. Besides, these policy interventions can foster maximum local participation. Collaboration between companies on business parks should be stimulated, given the improved efficiency of and advantages for the grid infrastructure. Three policy interventions that can achieve this are now proposed. These can be found in Table 13.

CB3	ID	Description
Policy intervention 7	PI7	Toolkit with standardised agreements
Policy intervention 8	PI8	Improved process assistance
Policy intervention 9	PI9	Implement pilot projects

Table 13: Policy interventions for critical barrier 3

Policy intervention 7 – Toolkit for collective initiatives

A toolkit for collective energy initiatives (PI7) can help with the allocation of ownership, liabilities, risks, and cost/benefits of collective battery storage and the fair sharing of energy. Standardised documents in a toolkit can eliminate time-intensive and costly legal and administrative procedures, making it easier to realize local initiatives (European Commission, n.d.). This policy intervention aims to simplify the participation process and reduce transaction costs for stakeholders. Such a toolkit can include:

- A standard participation contract. In this contract, the mode of ownership and the allocation of risks and liabilities are pinpointed. Next to this, agreements on the way in which the costs and benefits of the battery are divided should be described.
- A standardised data-consent agreement. In this agreement, a company gives permission for sharing (parts of) its energy data with the other participating companies and a metering company. This data-consent also includes cyber security protocols and how the data is handled with regard to privacy regulation.
- A standardised contract for permission of the ACM and DSO for the sharing of energy and transport capacity.

The standardised contracts create transparency and certainty about the rights and obligations of each participant, making it easier for them to cooperate.

Policy intervention 8 – Improved process assistance

Local energy initiatives can be supported by giving process assistance in the form of governmental, administrative, legal, and technical advice. This can encourage their development. As mentioned in chapter 4, municipalities, officials and grid operators should be actively supporting local energy initiatives, and bureaucracy should be contained as much as possible. The agencies should be facilitating rather than

controlling. This is a crucial part of the success of collective battery projects. The process assistance and active attitude should include:

- Provision of information via a repository, FAQs and online service portal.
- Technical, administrative and legal support.
- Education and outreach programs on best practices.

Policy intervention 9 - Implement pilot projects

Pilot projects are an important way of collecting data and informing policymaking. Pilot projects offer a real-life assessment of what issues are encountered and what policy interventions should be implemented. Pilot projects can also be used to instigate public-private partnerships and other forms of cooperation. Pilot projects ‘enable an organization to manage the risk of a new idea before substantial resources are committed’ (APM, n.d.) The Netherlands has already instigated numerous pilot projects when it comes to local energy initiatives, like Schiphol Tradepark, Hessenpoort Zwolle, and Almelo Businesspark XL (R. Beekhuis, personal communications). On the contrary, no pilot projects have been set up that focus specifically on collective battery storage in business parks.

5.4 Conclusion

This chapter has proposed nine policy interventions that can overcome the three critical implementation barriers of collective battery storage in business parks in the Netherlands. They are summarized in Table 14. These policy interventions are once more validated with the interview with participant 8. These barriers will be assessed using the three different assessment frameworks in the next chapter.

Critical Barrier (CB)	Policy intervention (PI)	Description
CB1 – The economic costs and benefits of battery systems	Policy intervention 1	Governmental loans
	Policy intervention 2	Revised tariff structures
	Policy intervention 3	Contractual remuneration for energy services
CB2 – Grid connection procedures for battery systems	Policy intervention 4	Predict and disclose physical congestion
	Policy intervention 5	Revision of grid connection procedures
	Policy intervention 6	Adjustment of private grid regulations
CB3 – Lack of local cooperation	Policy intervention 7	Toolkit with standardised agreements
	Policy intervention 8	Improved process assistance
	Policy intervention 9	Implement pilot projects

Table 14: Critical barriers and corresponding policy interventions

Chapter 6 Assessment

In this chapter, the three assessment frameworks are elaborated. The fourth sub-question is answered:

SQ4 – How can the proposed policy interventions be assessed?

First, the three different assessment frameworks will be elaborated. For each critical barrier, the most suitable policy intervention will be selected. The chapter ends with a short conclusion.

6.1 Assessment framework 1 – Impact assessment

In the impact assessment, the three policy interventions are assessed based on their economic, social and institutional impact on the energy sector and society as a whole. The impact of the three different policy interventions will now be discussed. Hereafter, to make up the balance, the policy intervention that makes the biggest positive impact and the smallest negative impact, and thus is the most promising to overcome the first critical barrier - economic costs and benefits of battery systems, is proposed.

Policy intervention 1 – Governmental loans

Economic: The primary positive economic effect of governmental loans is their potential to benefit small and medium-sized enterprises on business parks who may be unable to obtain loans due to the perceived high investment risks of battery projects. For companies in congested areas, governmental loans could enable them to acquire a collective battery system, which enables them to further invest in renewables and the electrification of their business processes. These loans could thus also have indirect positive social and environmental impacts. Moreover, governmental loans offer benefits over commercial loans due to their more favourable interest rates and grace periods. If the interest rates of commercial loans continue to increase while the interest rate of the governmental loan remains constant, these benefits will become increasingly significant over time.

Social: While implementing governmental loans could have a positive social effect on making business parks in congested areas more sustainable, possible social downsides of the policy must also be discussed. To fund governmental loans as described in section 5.1.1, large governmental funds need to be made available, given the high investment costs of a battery storage system. These funds cannot be used for other renewable energy technologies or other socially advantageous policies, such as investments in healthcare and education. Although the governmental loans need to be repaid, they will have a generous payback time and grace period, and thus requiring significant upfront governmental funds. If the policy is to be implemented, governmental bodies should not overlook the trade-offs between policies.

Institutional: The effectiveness of the policy intervention will depend largely on the terms and conditions of the loans and their administration (OECD, 2015). Governmental bodies need to establish clear guidelines and criteria to ensure that loans are distributed fairly and effectively. In other words, implementing the policy intervention will be a time and cost-intensive procedure, significantly impacting the institutional apparatus.

Policy intervention 2 – Revised tariff structures

Economic: High and double transport tariffs have been identified in literature and interviews with participants 2, 3, 4, 5, 6, and 7 as the biggest barrier to the viability of collective batteries in the Netherlands (Solar magazine, 2022; LAN, 2022). Reducing this burden could have a significant economic impact on collective battery storage and their deployment. As described in section 5.1.1, a rebate on transport tariffs for batteries performing congestion management would provide a correct price signal by incentivizing battery operators to use their batteries to support the grid. In addition, rebates and exemptions from peak

load fees for batteries would alleviate a significant burden on the battery business case, leading to more battery storage deployment and creating additional transactions and flexibility in the energy system, which would increase social welfare and decrease deadweight loss caused by current transport tariffs. Therefore, revised tariff structures can be regarded as an economically efficient and impactful policy intervention, improving the allocative efficiency of the market.

Social: Similar to other policy interventions, the implementation of revised tariff structures can stimulate collective battery storage and contribute to decarbonizing the Dutch energy system, which can be seen as a social benefit. However, revising the tariff structure for batteries may result in decreased revenue for DSOs. To compensate for this loss, transport tariffs for other grid users and consumers may need to be increased, which can be viewed as a socially unfavourable consequence of the policy. Nevertheless, batteries offer flexibility to the grid, reducing the costs that DSOs would otherwise incur for alleviating net congestion and reinforcing the electricity grid. If the rebates on transport tariffs for battery operators are roughly equal to the costs saved by the batteries' performed congestion management, other grid users should not experience significant increases in transport costs.

Institutional: The institutional impact of the policy is expected to be minor. The policy can be implemented without changes in national energy legislation or network codes issued by the ACM. The revised tariff scheme for batteries only needs to be developed and implemented. However, one potential hurdle could be defining which systems qualify for the revised tariff schemes. Therefore, clear requirements for qualifying systems must be established. Additionally, the valuation of performed congestion management could pose a challenge. To ensure fairness to other grid users, the rebate for performed congestion should be comparable to the cost savings for the DSO, requiring some research by the DSO.

PI3 – Contractual remuneration for energy service

Economic: The economic impacts of policy intervention 3 (PI3), which involves contractual remuneration for energy services, are similar to those of policy intervention 2 (PI2), which entails a revised tariff scheme. Both policies provide incentives for battery operators to engage in congestion management, but their delivery methods differ. While the revised tariff scheme strengthens the battery business case by reducing operational costs, the contractual remuneration for energy services provides additional revenue to battery operators.

Social: The social impact of PI3 is comparable to that of the revised tariff scheme, with one notable difference. PI3 involves contractual remuneration, which could affect the development and competition within the congestion management market. This could potentially slow down the growth of the market, which is still in its early stages in the Netherlands. According to IV8, the use of contractual remuneration could result in batteries having an unfair advantage over other flexibility providers, leading to reduced competition. This could be viewed as a socially undesirable consequence of PI3.

Institutional: Implementing contractual remuneration for energy services can be more institutionally challenging than implementing a revised tariff scheme. Although both policies have similar economic impacts, PI3 requires separate contracts between each battery operator and the DSO, which can be time-consuming and costly. Although standardized contracts can be used, they will still need to be tailored to specific conditions. Additionally, the ACM may need to be involved to ensure fair competition. Drawing up personalized contracts could also potentially compromise the independence of the DSO. As a result, the negative institutional impact of PI3 could be significant.

Assessment

Economic: While government loans can be a viable policy measure for parties unable to obtain loans due to high investment risks of battery projects, revised tariff structures and contractual remunerations for energy services are preferred. Governmental loans can offer projects with suboptimal business cases much-needed funds, but revised tariff structures and contractual remunerations for energy services target and improve the actual business case itself, reducing the need for government loans. Given that revised tariff schemes and contractual remunerations address the root of the problem, they are preferred.

Revised tariff structures lower operational costs, while contractual remunerations for energy services increase revenue for the battery operator, effectively making the business case more viable. When the batteries in the current system lack a solid business case, the impact of either policy intervention on their cash flow is the same. To assess which policy intervention has a greater economic impact, economic efficiencies need to be compared.

As discussed in section 5.1.1 and briefly in this section, a revised tariff structure can reduce deadweight loss and increase social welfare. While contractual remuneration for energy services can also increase social welfare by stimulating beneficial battery use, a revised tariff scheme is believed to be more economically efficient and increase social welfare more. Transport tariffs are the biggest burden on the battery business case, and every battery application incurs these tariffs. Removing this barrier has a large stimulating effect on battery adoption in the Netherlands.

While implementing contractual remunerations for congestion management can also stimulate battery deployment, batteries are likely to be deployed on other markets if the remuneration on those markets remains higher. If battery operators decide to do so, batteries could still have a negative influence on the grid. Furthermore, battery operators will not want to get into contractual agreements with the DSO if they do not know for sure that the remuneration offered by the DSO is higher than the energy- and imbalance prices. In contrast, with a revised tariff scheme, the battery operator profits from every application of its battery, as long as it is deployed in favour of the grid. Therefore, revised tariff structures are more effective and are likely to have a bigger positive influence on the implementation of collective batteries in the Dutch energy system and the amount of time batteries are used in favour of the grid. Social welfare is increased more with revised tariff structures (and deadweight loss reduced more) than with contractual remunerations for energy services, making revised tariff schemes the preferred policy instrument for economic impact.

Social: Revised tariff schemes and contractual remuneration for energy services have less negative social impact than contractual remunerations for energy services have, since they require relatively smaller amounts of public money, if the financial compensation is more or less equal to the performed congestion management. That is why revised tariff schemes and contractual remuneration for energy services are preferred over governmental loans when looking at social impact. Furthermore, revised tariff schemes are preferred over a contractual remuneration for energy services, since revised tariff schemes do not interfere as much with the congestion management market as contractual remunerations do. Revised tariff schemes are subsequently also pinpointed as the preferred policy instrument looking at social impact.

Institutional: Implementing a system of governmental loans requires establishing clear guidelines and criteria, which can be a time and cost-intensive procedure that has a relatively large negative impact on governmental institutions. Contracts need to be drawn up separately between DSOs and each battery operator for contractual remunerations, whereas revised tariff schemes are created uniformly for every battery party. Revised tariff schemes are the most easily implementable, making them the preferred policy instrument when looking at institutional impact.

To conclude, revised tariff structures have the most positive impact economically, socially, and institutionally, making them the preferred policy intervention to overcome the first critical barrier of the economic costs and benefits of battery systems. If interest rates continue to rise and battery projects become more difficult to finance, governmental loans could be implemented as an addition to revised tariff schemes.

6.2 Assessment framework 2 – MCDA

The first three steps of the MCDA 1. *Describe decision context*, 2. *Define objectives and criteria* and 3. *Define instruments* are already performed in the previous chapters. This section will perform the final five steps of the MCDA.

Step 4 – Score instruments plus motivation

In this section, policy interventions 4, 5, and 6 are evaluated against predefined assessment criteria, as shown in Table 13. As previously mentioned, a plus and minus scale is used to evaluate the instruments, indicating their qualitative performance relative to the criteria. The performance scale ranges from ++ to --, representing excellent, above average or good, average, below average or poor, and very poor. The value scale serves as an index for the evaluated performance of the policy intervention, with higher values indicating a more preferred instrument (Kim et al., 1998). This scale is primarily used to determine the relative differences between policy instruments to assess them. Therefore, precise definitions of the different values are not provided.

The instruments' scores are based mostly on literature and expert interviews, and for some criteria, the researcher's rationale is included to ensure a sound assessment. The scores are presented in Table 15, and it is important to note that they are preliminary. The final ranking and scores will be further evaluated in step 8 of the MCDA, and their validity will be discussed in the subsequent discussion section. The following paragraphs provide the motivation behind the scores for each criterion.

Criteria	ID	Unit	PI4 Disclose physical congestion	PI5 Revise grid connection procedures	PI6 Revise private grid regulation
Effectiveness	C1	-- /++	++	+	-
Efficiency	C2	-- /++	0	++	0
Equity	C3	-- /++	++	--	+
Liberty	C4	-- /++	0	--	0
Political feasibility	C5	-- /++	++	0	0
Technical feasibility	C6	-- /++	-	++	++
Administrative feasibility	C7	-- /++	+	--	--

Table 15: Score matrix

[C1] Effectiveness – The likelihood of achieving policy goals and objectives

PI4 - Predicting and disclosing physical congestion (++): Predicting and disclosing physical congestion is considered a highly effective policy intervention. By improving operational transport forecasts, physical congestion can be more accurately predicted (LAN, 2022). Better prediction of congestion allows for more efficient use of the grid's residual capacity. Additionally, disclosing physical congestion promotes improved collaboration between DSOs and battery operators and facilitates alternative contract forms. During local congestion, the market party deploys its battery to support the grid. During non-congested times, the market party is free to deploy its battery on various energy markets. This reduces uncertainty for both the DSO and the battery operator. Implementing this policy intervention on its own can effectively address local grid

congestion issues and enable the adoption of battery systems in the Dutch energy system. Moreover, this policy intervention can serve as a stepping stone for other enabling policy interventions, such as PI5 – revising grid connection procedures, which will be discussed in the following paragraph. IV5, IV7, and IV8 also rate PI4 as highly effective.

PI5 – Revise grid connection procedures (+): Revising grid connection procedures is also effective in overcoming grid connection barriers for batteries and flexibility providers. However, it is considered less effective than predicting and disclosing physical congestion, which is seen as a prerequisite for the implementation of revised grid connection procedures. To prioritize batteries in congested areas, there needs to be a clear agreement between the operator and DSOs on where batteries can be located and when they can be used to avoid exacerbating congestion due to the battery. Such agreements can only be established when it is clear when and where congestion arises. Without implementing PI4, the effectiveness of revising grid connection procedures may be reduced, and thus it is scored as only a +.

PI6 – Revise private grid regulation (-): Implementing revised private grid regulation (PI6) reduces transaction costs associated with implementing energy hubs or collective energy projects. Sharing transport capacity with others becomes less time-consuming and costly. Although it currently requires significant time and effort to find the right legal framework for a collective energy project (e.g., MLOEA, GDS, group-ATO, etc.), there are already possibilities for cooperation with DSOs and the ACM on a case-by-case basis, as explained by IV7 and IV8. Standardizing new legal frameworks for energy hubs and local initiatives can significantly reduce transaction costs, but because much can already be accomplished through pilots, this policy intervention is considered less effective and is thus given a - score.

[C2] Efficiency – The assessment of achieving policy goals in relation to costs

When assessing the efficiency of policy interventions, it is necessary to estimate their costs. Due to the complexity of the procedures and factors involved, it can be challenging to estimate the absolute costs of individual policy instruments. Therefore, only the relative costs of the policy interventions will be discussed.

PI4 - Predicting and disclosing physical congestion (0): This policy intervention is the most effective, but it is also likely to be very expensive to implement. Increasing operational transport forecasts requires significant investments in measurement techniques, particularly in older parts of the grid, as mentioned by IV8. The high effectiveness of PI4 comes with high costs, which results in a score of 0.

PI5 – Revise grid connection procedures (++): While being slightly less effective than PI4, PI5 is expected to be less expensive to implement. It involves making adjustments to the current Netcode, and although these changes come with costs, it is evident that the Netcode and Elektriciteitswet have already been amended quite frequently (Overheid.nl). These changes are likely to be less expensive for society than implementing a system that can predict physical congestion, which would require providing technical measuring equipment to all parts of the grid in potential congestion. Therefore, PI5 is expected to be more cost-effective than PI4 and scores a ++ on efficiency.

PI6 – Revise private grid regulation (0): Similar to PI5, implementing PI6 involves changing existing regulations, making it a more cost-effective policy intervention than predicting and disclosing physical congestion. However, its effectiveness is below average, resulting in a score of 0.

In summary, PI5 is expected to be the most efficient policy intervention, with a high effectiveness and relatively low costs compared to PI4. PI6 is cost-effective but less effective than average, and PI4 is highly effective but very expensive.

[C3] Equity – fairness in the distribution of a policy’s costs and benefits across population groups

When assessing policy interventions for their equity or fairness in the distribution of costs and benefits, it is important to evaluate whether all relevant population groups receive the benefits they are entitled to and are not exposed to above-average levels of costs. Equity involves examining who pays and who benefits from policy interventions. Proposed policy interventions can affect equity by altering the distribution of burdens and benefits in society.

The costs of the three proposed policy interventions are equivalent, as the costs incurred by the DSO to change their procedures are passed on to grid users, while the costs of changing *Netcodes* are covered by government revenues, partly funded by taxpayers. Since the costs are recovered from the same groups, there is no differentiation possible between the policy interventions regarding equity of costs.

However, when examining the distribution of benefits, there are differences between the policy interventions.

PI4 – Predicting and disclosing physical congestion (++): Not only battery operators reap the benefits from PI4. By improving the prediction of physical congestion, other parties with projects that are valuable for society and the energy transition, like hospitals and renewable generation units can be connected to the grid more quickly. The benefits of this policy trickle down to society as a whole and the benefits can be seen as an accelerator of the Dutch energy transition. Since PI4 provides additional benefits for various groups, it scores a ++ on equity.

PI5 – Revision of grid connection procedures (--): Letting DSOs discriminate behind the meter favours battery operators. On the other hand, prioritizing batteries might negatively affect other parties, as mentioned by IV7 and IV8. It is hard to come up with a dividing line between parties that do get prioritized and the ones that do not. Should we also prioritize large consumers in the horticulture sector that can offer flexibility by ramping their assets up or down? This depends on the definition of what type of batteries and which flexibility-offering parties are prioritized. If this measure gets implemented, it could happen that a battery project gets prioritized over other project that also have a positive contribution to society, like apartment buildings that decrease the current housing crisis in the Netherlands. This could be seen as an unfair distribution of the benefits of the revision of grid connection procedures. Therefore, the intervention scores a - - on equity.

PI6 – Revise private grid regulation (+): Just like PI4, revising private grid regulation aims to increase the adoption of collective battery storage, but can also benefit other groups and technologies like solar PV and wind projects and their developers. Although the additional benefits of PI6 do not trickle down as much as the benefits of PI4, as they are only reaped by groups interested in energy hubs and not Dutch society as a whole, PI6 does not disadvantage any particular population group. That is why revising private grid regulation receives a + for equity.

[C4] Liberty – The extent to which public policy enhances or restricts privacy and individual rights in and choices

Predicting and disclosing physical congestion (PI4) and revising private grid regulation (PI6) do not significantly impact individual privacy or rights and choices. Rather, they ensure that all eligible parties have access to a grid connection as required by the *Elektriciteitswet* and European energy legislation. Therefore, both PI4 and PI6 are scored with a 0.

However, the revision of grid connection procedures (PI5) may potentially limit the individual rights and choices of parties that are not granted a grid connection due to discrimination by the DSO in favour of a battery party. This violates the *first-come-first-serve* principle, which is the default rule to ensure impartiality in assigning grid connections. Disregarding this principle may compromise the impartiality of the DSO, leading to infringement on the rights of market parties. Hence, PI5 is scored with - - to reflect its potential adverse impact on individual liberty.

[C5] Political feasibility – The likelihood that a policy would be adopted – in particular the extent to which officials accept and support a policy proposal

Based on the equity criterion, Policy Intervention 4 – predict and disclose physical congestion (PI4) can have a significant impact on resolving the net congestion issues in the Netherlands. Given the urgent nature of the net congestion problem and the attention it receives from political authorities, it is likely that officials will readily accept and support this policy proposal. Therefore, it is given a score of ++.

Although revising private grid regulations and grid connection procedures can also increase the flexibility of the Dutch grid, their positive effects may not be as widespread as those of PI4. Additionally, these interventions may be more challenging to implement administratively. This aspect will be discussed further in the scoring section of criterion 7. Nonetheless, these policies are expected to have moderate political support. Therefore, both revising grid connection procedures and revising private grid regulation are given a score of 0.

[C6] Technical feasibility – The availability and reliability of technology needed for policy implementation

For the prediction and disclosure of physical congestion, metering technology is readily available and reliable. But it is an immense task to implement the technology and make the prediction of physical congestion in the entire Dutch grid possible. It is advisable to first start with the roll-out of technology in areas where there is an urgent need, like heavily congested areas. This will make the process more manageable. The policy intervention will still be technically challenging to implement. That is why PI4 scores a – on technical feasibility. For the revision of private grid regulation and grid connection procedures no innovative technologies are needed. That is why they score a ++ on technical feasibility.

[C7] Administrative feasibility – The likelihood that a department or agency can implement the policy well

Some changes in legislation are more easily implementable than others. In order to implement the prediction and disclosure of physical congestion, the ACM needs to issue a code decision in collaboration with the umbrella organization of the Dutch grid operators, Netbeheer Nederland, on the adjustment of ACM regulations concerning predicting and disclosing physical congestion by DSOs. An example is the code decision on congestion management of last year issued by the ACM (ACM, 2022). This takes some time and effort but is easier implementable than PI5 and PI6 and is scored with a +.

Grid connection procedures are enshrined in European energy derivatives, and the Dutch *Elektriciteitswet*. These laws state that the DSO is not allowed to discriminate when allocating grid connections (European Union, 2019; Recht.nl, 2020). Private grid regulations are also incorporated in European legislation and the *Elektriciteitswet* (European Union, 2019; ACM, 2021). Because adjusting these regulations involves adjusting national- and international law, their administrative feasibility is low, and they are both scored with a - -.

Step 5 – Standardize scores

The scores are standardised using equation 2.1 of section 2.6. By standardizing the scores, they all range from 0 to 1. The minimum corresponds with -2, and the maximum with 2. The final, standardised performances are shown in Table 16.

Criteria	PI4 Disclose physical congestion	PI5 Revise grid connection procedures	PI6 Revise private grid regulation
Effectiveness	1,00	0,75	0,25
Efficiency	0,50	1,00	0,50
Equity	1,00	0,00	0,75
Liberty	0,50	0,00	0,50
Political feasibility	1,00	0,50	0,50
Technical feasibility	0,25	1,00	1,00
Administrative feasibility	0,75	0,00	0,00

Table 16: Standardised scores

Step 6 – Weighting of criteria

Four experts in the battery development field were asked to rank the criteria from 1 to 7 based on the perceived importance of the criteria. To safeguard different perspectives on the decision problem, the experts are chosen from different stakeholder groups. An overview of the ranks can be found in Appendix F. The average weight is calculated, whereafter the weights are transformed to a number between 0 and 1, using the rank sum method (Odu, 2019). All weights combined amount to 1. The final weights of the criteria can be found in Table 17. The ranking will be evaluated in the next paragraph.

Criteria	ID	Average rank	Weight
Effectiveness	C1	7	0,250
Efficiency	C2	6	0,214
Equity	C3	2	0,071
Liberty	C4	2	0,071
Political feasibility	C5	4	0,143
Technical feasibility	C6	4	0,143
Administrative feasibility	C7	3	0,107

Table 17: Weighting of criteria

Looking at the average ranks, effectiveness is seen as the most important criterion and efficiency comes in second. Since effectiveness and efficiency both give an indication of the actual achievement of the end goals of the policies, it is no surprise that these criteria are regarded highly by the experts. The three feasibility criteria come next. Political- and technical feasibility are equally ranked above administrative feasibility. The rationale behind this could be that without political and technical feasibility, the policy intervention would not even be considered. The technical and political appraisal of a policy intervention is done before the instrument is implemented, whereas the administrative feasibility of a policy intervention often comes into play later on in the development process. In the policy design phase, more emphasis is thus laid on technical- and political feasibility, and it thus is perceived as more important. Equity and liberty come in last. This does not come as a surprise, since the proposed policies are energy sector-specific and not aimed at the public at large. Equity and liberty are ranked last, which is understandable as the policies are specific to the energy sector and do not significantly impact the general public. As a result, equity and liberty are perceived as less relevant.

Step 7 – Calculate overall value

In this step, the overall value for every policy intervention is calculated and the overall ranking is derived. The overall value is calculated by multiplying the standardised scores on each criterion with the weight of the respective criteria, whereafter these are added together and the overall value per policy intervention is obtained. The overall value and rank of the three policy interventions can be found in Table 18.

Policy intervention	ID	Overall score	Ranking
Predict and disclose physical congestion	PI4	0,723	1
Revise grid connection procedures	PI5	0,616	2
Revise private grid regulation	PI6	0,489	3

Table 18: Overall value and ranking of policy interventions

As can be seen in the table, predicting and disclosing physical congestion is the preferred policy intervention when looking at the MCDA scores, trailed by number 2 revise grid connection procedures and number 3 revise private grid regulation.

Step 8 – Evaluation of results

As can be seen in Table 16, predicting and disclosing physical congestion (PI4) ranks first with an overall score of 0,723, followed by revising grid connection procedures (PI5) with a score of 0,616. Revising private grid regulation (PI6) is the worst-scoring scoring policy alternative with a score of 0,489. The difference between the scores is quite significant, which means that the policy interventions can be ranked in this order. PI4 ranking first is predominantly caused by its superior performance on the criteria effectiveness, administrative feasibility, and political feasibility. Effectiveness is rated as the most important criterion and administrative- and political feasibility are rated as the third most important criterion, thus having a major impact on the ranking of PI4. PI4 also scores best when looking at equity and scores best jointly with PI6 on equity. PI5 scores best on efficiency and jointly with PI6 on technical feasibility. PI6 scores relatively high on criteria with low weights and relatively poor on criteria with high weights. This explains its bottom position.

To validate the ranking of the policy interventions, IV7 and IV8 were asked to also rank the three policy interventions. Both experts ranked the instruments the same as the outcome of the MCDA. PI4 was deemed very valuable for enabling new contract forms and accelerating the energy transition. PI5 was seen by both participants as an optional addition to IV4. It could be effective, but only in combination with PI4. They also point out that it is hard to discriminate between batteries and other flexibility-offering parties and the policy intervention is hard to implement. PI6 is regarded by both as the least viable policy option since it is also hard to implement and group-ATOs are in some cases already possible. Group-ATOs are described by IV7 as very promising and should be stimulated. This can be done without extensively altering private grid regulation. The fact that both experts rank the policy interventions the same way as the MCDA, increases the validity of the MCDA.

6.3 Assessment framework 3 – Case study

Assessment framework 3 consists of a concise case study of the Schiphol Trade Park project. The characteristics of the project will be discussed first, whereafter the choice for this specific project will be elaborated. Hereafter, specific hindering effects on the local cooperation of the project are identified, and it is assessed how either of the proposed policy options, namely a toolkit with standardised contracts (PI7), improved process assistance (PI8), and implementing pilot projects (PI9) could have helped smoothen and accelerate the implementation process of the project. Based on this analysis, the policy interventions are ranked. To conclude, it is investigated whether the results obtained in this specific case are generalizable to

other local energy hubs and initiatives. Information in this section mostly originates from personal communications about the project and the interviews with IV7 and IV8, as well as project reports.

Schiphol Trade Park (STP)

The Schiphol Trade Park (STP) is a large business and logistics hub located next to Schiphol International Airport in the municipality of Haarlemmermeer, southeast of Amsterdam (Spectral, 2021). However, the continued real-estate development at STP was threatened by an announcement made by the local DSO, Liander, in October 2020. Liander stated that the Haarlemmermeer area would become a congestion "red zone," meaning that no additional transport capacity would be available on the mid-voltage network that supplies the area (Spectral, 2021). In order to ensure the further development of the STP area, the landowner, Schiphol Area Development Company (SADC), decided to create a virtual, collective energy system in collaboration with Liander and the participating companies, called the Schiphol Trade Park Energy Cooperation. Spectral Energy, a system integrator that provides software solutions for integrated energy systems, is also involved in this collaboration (Liander, 2022).

Currently, the local electricity grid on STP is only fully utilized during peak times. However, not all companies use their full capacity simultaneously, and some have additional transport capacity for future expansions, which often leaves residual space on the local grid. The implementation of the Spectral Smart Grid Platform allows companies to share their transport capacity virtually (SADC, n.d.). This is a form of a virtual group-ATO, where the platform connects all energy assets of the companies, such as battery systems, generators, renewable generation units, and charging infrastructure. It balances energy demand and supply virtually in real-time, allowing even companies that have not yet contracted transport capacity to use the residual space on the local grid (Topsector Energie, n.d.). If the total energy demand exceeds the available capacity, batteries charged with solar energy are deployed, and if the battery deployment is insufficient, gas generators are switched on. Assets can also be switched off by the platform if the group-ATO is at risk of being exceeded. The energy system has been operational for over a year now, and the first asset has yet to be switched off.

Without collective energy management, companies would not have been able to utilize the residual transport capacity of other companies, resulting in each company implementing its own solution in the form of a behind-the-meter gas generator or battery. Moreover, the business park became more energetically efficient, resulting in a significant reduction in CO₂ emissions, as demonstrated in the economic analysis of section 3.3. Additionally, the investment needed decreased by 35% (SADC, 2023). Without the pilot project and the implementation of the collective solution with smart metering and management, several companies would not have been able to connect to the grid. Without the pilot project, the other collective benefits would have also been diminished.

Why STP?

Schiphol Trade Park was chosen for the case study analysis due to its status as the first collective, virtual grid in the Netherlands. Although there have not yet been any projects with collective battery storage units in business parks in the Netherlands, the behaviour of the batteries in the STP Energy Cooperation closely resembles the system described in this thesis. Each company has its own grid capacity, and the Liander distribution grid is used for energy sharing between them. While the STP incorporates multiple batteries placed behind-the-meter, they operate as a single, collective battery on the virtual grid, making their behaviour comparable to that of the system outlined in this thesis. Subsequently, STP illustrates the benefits of collective projects over individual energy solutions.

Moreover, the STP project serves as a prime example of a pioneering endeavour that required extensive local cooperation among numerous stakeholders for its successful implementation. The realization of the project necessitated the establishment of a variety of institutional arrangements to enable the sharing of transport capacity. Therefore, the STP project is an ideal candidate for evaluating the effectiveness of the three policy interventions that could have eliminated obstacles to local cooperation.

Hindering effects on local cooperation

Firstly, the developers of the STP project encountered complex stakeholder management. IV7, the project manager of the system integrator of the project, confirmed that it took more than six months to align with all stakeholders. The stakeholder network involved the battery operators, energy companies, system integrator, Liander, municipality, real estate developer, project developer, and tenants of the offices. Liander and the real estate developer needed to be convinced that the virtual grid was a reliable, sustainable, and cost-effective solution. Additionally, the battery operators needed to give permission for their batteries to be used in favour of the local grid, which might prevent them from creating value in different energy markets with their batteries. Therefore, remuneration for the operators should be in place.

As part of the stakeholder management, STP needed to be acknowledged by Liander as a pilot project so that the sharing of transport capacity was allowed. The proposal was taken up to the board of directors of Liander before a decision was made, demonstrating the cautious attitude of the DSO. The contracts on the sharing of transport capacity and energy between the different parties and Liander took months and cost 400.000 euros of attorney hours due to the rules and regulations on private grids in the Netcode enforced by the ACM, discussed in section 4.3.4 (ACM, 2021). Although the virtual grid is a type of private grid, it cannot be classified under one of the exceptions to the rule (cable pooling, direct line, MLOEA, or GDS). Therefore, permission was required for this new exception, which made the procedure complicated and time-consuming, indicating a definite hindering factor.

Another hindering factor in local cooperation was the lack of expertise among participating companies to initiate or actively participate in the local energy initiative. This inexperience combined with the lack of standardized contracts and agreements made individual parties hesitant to cooperate. Having a share in a collective battery was deemed riskier than purchasing a gas generator individually.

Policy interventions

In this section, the influence the three policy interventions could have had on the STP project is discussed.

[PI7] Toolkit with standardised agreements

A toolkit with standardized contracts, particularly a blueprint of an agreement between Liander and participating companies for energy and transport capacity sharing, could have reduced transaction costs by up to 80%, according to IV7. IV7 and IV8 also suggest that standard contracts for group-ATOs, developed in collaboration with Netbeheer Nederland, can be effective. Additionally, the exception described in the standardized contract for energy and transport capacity sharing should be embedded in the private grid regulation as a new exception to smoothen the application process for virtual grids and collective battery projects. Without embedding the new contract forms into private grid regulations, DSOs and the ACM could still hinder the application process based on legal terms. IV8 highlights that implementing these contracts also stimulates attracting investments, as the legal foundation of the standardized contracts offers security to investors. A standard data consent agreement for sharing energy data of the different participants would also be helpful.

Furthermore, a standard participation contract could alleviate the hindering effect of inexperience with and hesitance toward collective solutions. Standard participating contracts offer a clear legal framework that promotes transparency about the rights and obligations of the participating companies. However, according to IV7's experience with collective energy projects, standardized contracts for the settlement of costs, benefits, and allocation of ownership are currently less needed in the Netherlands. In the case of the STP project, the allocation of costs and benefits was relatively easy to implement in the Spectral platform. The ownership of battery systems can be arranged through standard legal ownership models already provided by market parties like Joulz, as was done at STP. Thus, the most valuable standard arrangements are those for sharing energy, group-ATOs, sharing transport capacity, and data consent.

[PI8] Improved process assistance

Improved process assistance could have helped to smooth the local cooperation at STP, especially through an information portal that provides relevant support documents upon request. IV7 also suggests that funding for research and development (R&D) on local energy initiatives could foster their implementation. R&D could optimize the technical performance of local energy initiatives and enable feasibility studies of community battery storage.

However, a toolkit with standardized agreements (PI7) has an advantage over improved process assistance (PI8). Both IV7 and IV8 argue that in real-life situations that require an urgent collective solution, such as STP, a toolkit with standardized agreements would have a bigger impact on the initiation of local cooperation than improved process assistance. Given the novelty of local energy communities and community battery storage, it is not realistic to expect extensive process assistance from governmental bodies. Additionally, IV7 and IV8 point out from their experience with multiple projects that bureaucracy in governmental bodies and a lack of process assistance are not the decisive factors when a project is not realized. The lack of standard arrangements hinders local cooperation more. While PI8 can be helpful, it must be seen as an addition to PI7.

[PI9] Implement pilot projects

Currently, there are many pilot projects that involve local energy initiatives in the Netherlands. The STP project, which received partial funding from the Taskforce Energy of the province of Noord-Holland, is also considered a pilot project by Liander (Liander, 2022). While pilot projects can assess the viability of a project idea and should thus arguably be initiated, the STP project is an example that pilot projects often arise naturally once there is a local, urgent need for a collective energy solution. Therefore, instead of actively setting up pilot projects themselves, municipalities, provinces, and grid operators should recognize projects with a necessity for a collective solution like STP as pilot projects. By doing so, grid operators and the ACM can give the project institutional room for experimentation (like transport capacity sharing at STP). In this way, solutions can be brought up for real-world problems in our current energy system.

The number of pilot projects nowadays is not the sore point, but the limited room for experimentation for pilot projects granted by the grid operators and ACM is. IV7 describes current pilot projects issued by grid operators as small, risk-averse, and cautious. By setting up pilot projects in this way, less viable solutions are obtained.

When looking at collective battery storage in business parks, in particular, pilot projects should be set up. Pilots have proven the viability of neighbourhood batteries, but pilot projects on the implementation of these systems in business parks lack behind (DNV GL, 2018). Pilot projects are seen by IV7 and IV8 as a measure that could stimulate local cooperation, but in the way they are set up now, a lot of opportunities are lost. If pilot projects for collective battery storage are set up and the already existing and future local

energy initiatives are granted more experimental freedom, pilot projects are valuable. But since pilot projects often arise naturally and are nowadays often limited in their set-up, a toolkit with standardised agreements (PI7) is preferred over implementing pilot projects (PI9), as IV7 and IV8 confirm. Pilot projects do have the opportunity to act as a supporting measure to PI7. Namely, pilot projects could be used to test standard agreements between stakeholders.

Generalizability

Based on the analysis of the STP project, it can be argued that a toolkit with standard agreements and contracts would have had the greatest positive impact on local cooperation. Although the evaluation of policy interventions was specific to this case, the findings are likely to be applicable to other collective battery initiatives. Despite STP involving multiple behind-the-meter batteries, the system's operation is similar to that of a collective battery storage system in a business park. Moreover, STP faced similar stakeholder management and local cooperation challenges as other new local energy initiatives, such as pilot projects in Schieoovers (Delft) and Hessenpoort (Zwolle). The preference for PI7 as the most valuable policy option is supported by IV7 and IV8, who also suggest that a toolkit with standard contracts would significantly benefit other projects. Additionally, the fact that standard contracts are a key aspect of the LAN and European Union policies on local energy cooperation underscores the generalizability of the case study results (LAN, 2022; European Commission, n.d.).

6.4 Conclusion

By means of the impact assessment, MCDA and case study, three policy interventions are proposed that are most capable of overcoming the three respective barriers. They are summarized in Table 19.

Critical Barrier (CB)	Preferred policy intervention	Description
CB1 – The economic costs and benefits of battery systems	Policy intervention 2 (PI2)	Revised tariff structures
CB2 – Grid connection procedures for battery systems	Policy intervention 4 (PI4)	Adjustment of private grid regulations
Critical barrier 3 – Lack of local cooperation	Policy intervention 7 (PI7)	Toolkit with standardised agreements

Table 19: Preferred policy interventions

Chapter 7 Discussion and conclusion

Chapter eight lays down a discussion and conclusion. The chapter also gives several policy recommendations. In this chapter, the main research question is answered:

What policy interventions can be implemented to overcome critical barriers of collective in-front of the meter battery energy storage systems in Dutch business parks?

First, the conclusion and the final results of the analyses performed in this thesis is laid down, whereafter the discussion is elaborated on. To conclude, the way in which the study is embedded into the current policy debate is described and policy recommendations are given.

7.1 Conclusion

In this section, the conclusion of the thesis is laid down. Both the sub-questions and the main research questions are answered in this section. Furthermore, policy recommendations are given to conclude the thesis.

SQ1 – What are the benefits of implementing collective FTM battery storage in business parks in the Netherlands?

The current situation of collective FTM battery storage is that they are not yet implemented in business parks due to several implementation barriers. That is why the modelling approach was designed to first show the advantages of these systems. In the modelled scenario with a collective battery, the curtailment of renewables is decreased from 726.213 kWh to 259.686 kWh (-64%) in comparison to the scenario with three individual batteries that amount to the same capacity as the collective battery. The self-consumption of renewables is increased from 1.143.688 kWh to 1.610.216 kWh (+38%). This comes with the societal advantage of less net congestion in the surrounding grid. Additionally, with a collective battery the same level of self-consumption and curtailment can be reached at 40% of capacity compared to the capacity of three individual batteries combined. The economic analysis of section 3.3. shows that solely using a collective battery for increasing self-consumption and decreasing curtailment does not lead to a viable business case. Benefit stacking or policy interventions are needed to strengthen the business case.

SQ2 – What are the critical barriers to the implementation of collective FTM battery storage?

To answer the second sub-question, 23 theoretical barriers are identified in chapter 4. Based on the funnelling approach that uses the multi-layered theoretical micro-meso-macro framework and eight expert interviews, the theoretical barriers are reduced and grouped into three critical implementation barriers: the economic costs and benefits of battery systems (CB1), grid connection procedures (CB2) and a lack of local cooperation (CB3). The critical barriers selected barriers have a significant negative impact on the integration of collective batteries, and they are influenceable by policy.

SQ3 – What policy interventions can overcome the critical barriers of collective FTM battery storage?

To answer the third sub-question, in chapter 5, nine policy interventions are proposed that can overcome the three critical barriers. This proposition is done based on literature and expert interviews. The proposed policy interventions can be found in Table 20.

Barrier	Policy intervention	ID	Description
CB1 – Economic costs/benefits of battery systems	Policy intervention 1	PI1	Governmental loans
	Policy intervention 2	PI2	Revised tariff structures
	Policy intervention 3	PI3	Contractual remuneration for energy services
CB2 – Grid connection procedures of battery systems	Policy intervention 4	PI4	Predict and disclose physical congestion
	Policy intervention 5	PI5	Revision of grid connection procedures
	Policy intervention 6	PI6	Adjustment of private grid regulations

CB3 – Lack of local cooperation	Policy intervention 7	PI7	Toolkit with standardised agreements
	Policy intervention 8	PI8	Improved process assistance
	Policy intervention 9	PI9	Implement pilot projects

Table 20: Proposed policy interventions

SQ 4 – How can these policy interventions be assessed?

The policy interventions can be assessed using three different assessment frameworks. Given that PI1, PI2, and PI3 are financial stimuli involving public money, they are assessed using an impact assessment to make sure the policy intervention with the most positive effect on the energy sector is chosen. The MCDA is chosen because the method is perfect for assessing proposals for institutional changes, as PI4, PI5, and PI6 are. The last three policy interventions are assessed using a case study since the way in which policy interventions influence local cooperation within energy initiatives is case-specific and hard to assess theoretically.

The outcome of the assessment frameworks is that a revised tariff scheme has the highest potential to overcome CB1, predicting and disclosing physical congestion has the biggest change of overcoming CB2 and a toolkit with standardised agreements is the most suited to eradicate CB3.

Main RQ – What policy interventions can be implemented to overcome critical barriers of collective in-front of the meter battery energy storage systems on Dutch business parks?

To stimulate the integration of battery energy storage systems in the Netherlands, three different policy interventions are proposed to overcome the three identified critical barriers. First of all, a revised tariff scheme should be implemented to decrease the operational costs of the collective battery business case and thus strengthen the business case. The revised tariff scheme should include that battery operators should receive a rebate on their transport tariffs for the moments they perform congestion management. Secondly, batteries should be exempted from the additional fees for peak uses of transport capacity.

Secondly, physical congestion should be predicted and disclosed more accurately by the DSO. This takes away a large part of the second barrier, namely barriers in the grid connection procedures. Nowadays, the DSO does not yet announce where and when actual physical congestion occurs or where it might occur. When this is disclosed, alternative contracts can be shaped between the DSO and market parties that state that in times of local congestion, the market party will deploy its battery in favour of the grid. In the remaining time, the market party can freely deploy its battery on different energy markets. This takes away unsurety for both the DSO and the battery operator.

Thirdly, it is proposed to develop an online toolkit with standardised agreements for local energy initiatives to foster local cooperation. The toolkit should include a standard participation contract, a data-consent document, and a standard contract between the DSO and different parties for the sharing of transport capacity and energy. The latter construct should also be incorporated into the private grid regulations in the *Netcode* as an exception, just like a direct line, cable pooling, MLOEAs and GDSs.

These policy interventions together can stimulate the integration of collective battery storage on business parks in the Netherlands. In this way, the policy interventions foster the Dutch energy transition.

7.2 Discussion

This section entails the discussion of the study. First, the reflection of the study approach and methods is carried out. Limitations of the study design are pinpointed. Based on the reflection, recommendations for further research are given. Hereafter, the practical and scientific contribution of the study is described, whereafter the societal relevance of the study is laid down.

7.2.1 Reflection and limitations

This section reflects on the limitations of the executed research methods and the viability of the assumptions that were made throughout the research process. It also reflects on how the assumptions and limitations of the study have influenced the results. The limitations of the overall research approach are described, as well as the limitations of the research methods used in the different assessment frameworks.

Scope of the thesis

The first critical decisions that significantly influenced the results of this thesis were made during scoping and the chosen research perspective. The thesis focused solely on commercially owned collective battery storage in business parks, excluding a variety of other viable collective battery storage alternatives, such as neighbourhood batteries in residential areas. Although scoping a thesis too narrowly can result in the loss of essential results, in this case, the scoping decisions were necessary. This was because publicly owned collective battery projects in residential areas face different stakeholder networks and actor interactions than commercially owned collective battery projects in business parks. The two situations cannot be easily compared, and local cooperation and stakeholder networks largely influence the implementation of these projects and the results of the thesis. Thus, making these scoping decisions was necessary to obtain viable and unambiguous results.

Barriers

The thesis takes a broad perspective when identifying barriers to collective battery storage implementation. This approach aims to capture all relevant economic, institutional, social, and technical barriers across different system levels (micro, meso, and macro). However, it may be difficult to determine if all barriers were identified despite the extensive literature review, which could be considered a limitation of the barrier identification process.

To make the analysis comprehensible and develop specific policy interventions, the theoretical barriers were narrowed down using the funnelling approach. The deduction process was mainly based on expert interviews, in which subjectivity was minimized by conducting interviews with eight experts from different stakeholder groups. However, it is important to acknowledge that subjectivity cannot be completely eliminated from this process, which is a limitation of the deduction process from theoretical to critical barriers.

Policy interventions

The same goes for the proposition of policy interventions. This process was also influenced by the opinion of experts. One should keep in mind that the results of the thesis could have been different if other policy options were proposed. Since this is a pitfall of the chosen method, a few methods were applied to give the policy identification process a solid scientific foundation. Next to the diverse perspective of the interview participants, the opinion of experts was triangulated with information found in scientific literature and reports on the effect of different policy interventions to eradicate subjectivity as much as possible.

To give the policy interventions selection more substantiality, for the first critical barrier (economic costs and benefits of battery systems), not only the proposed policy interventions were discussed, but it was also pinpointed why other policy interventions were not chosen. This gives the process more validity. On top of this, the policy interventions were validated by two other experts (IV7 and IV8) after they were chosen.

Another limitation of the research is that the way barriers and policy interventions influence each other and possible trade-offs are underexposed in the thesis. Although it is recognized that the influence they have on

each other can play a significant role, the methodology and scope of the thesis is structured so that it is possible to arrive at the three most promising policy interventions through varied research methods and thorough research. Investigating and exhibiting how 23 barriers and 9 policy instruments affect each other and what trade-offs exist was therefore deemed out of scope.

Model

A model is a description of phenomena in the real world that is used to make predictions. As with all scientific models, the model constructed in this thesis has its limitations, because it is merely a simplified representation of the natural situation (Buchanan, 2021). The model used in this thesis has two goals: to show the energetic, social and economic advantages of a collective battery system over multiple individual systems in business parks, and showing the low viability of battery business cases in the Netherlands that are not deployed on energy markets nor perform energy services. Since the applications of the model do not require very precise modelling results, the choice was made to make a strongly simplified model of reality in Microsoft Excel. By repeatedly adjusting the model variables and model input, like the generation and load profiles of the three companies, the model's validity was tested. Next to this, the model was validated by two battery experts from Equans. Although the validity of the model was deemed up to the required standards to meet the model's goal, missing details and the shortcomings of Microsoft Excel can be seen as a limitation of the research method. Furthermore, the dependency of the economic model on energy prices and battery prices is evident. Not including the modelling of the different markets can also be seen as a limitation.

Impact assessment

A limitation of the conducted impact assessment is the generic approach of the assessment. A more in-depth approach could have strengthened the analysis. This approach was chosen since the goal of the impact assessment was merely to select the most impactful policy intervention and not to give a full analysis of the impacts of implementing a policy. It is advisable to perform such an analysis once a policy will be implemented in the foreseeable future. The future research section will go into this more in-depth. Another limitation to the impact assessment, as well as the assessment of policy interventions using the MCDA, is that no actual economic cost or benefit estimates are given. The policy interventions are merely compared based on their relative costs to make an assessment, but not on their absolute costs.

MCDA

First of all, other criteria could have been chosen. Since other criteria might have yielded different results in the MCDA, the dependency of the results on the selection of criteria can be seen as a weakness of the MCDA method. Criteria that are often used for the assessment of policy interventions were chosen. Another criteria-selecting method could have been to draw up criteria based on the objectives of collective battery systems. By using an objective tree, in which the overall objective is broken down into high-level objectives, lower-level objectives, and fundamental objectives, assessment criteria can be derived from the fundamental objectives (Dodgson et al., 2009). An example of an objective tree with assessment criteria for a collective battery storage system is shown in Appendix G.

The common policy criteria were chosen because the performance of the chosen policy interventions is better assessed with these criteria than with economic and environmental criteria or criteria derived from an objective tree. To illustrate, predicting and disclosing physical congestion (PI4), revision of grid connection procedures (PI5), and revision of private grid regulation (PI6) all score differently on the chosen assessment criteria and thus can be assessed with these criteria. On the contrary, it would be impossible to score the chosen policy interventions on performance criteria like *renewable energy used (C4)* and *social*

operability (C6) from the objective tree in Appendix G, because the chosen policy interventions do not have an influence on these criteria.

Like the deducing process of the barriers and the policy intervention identification, expert opinions were used in the scoring of the policy interventions and the weighting of the criteria. These processes are thus subject to the same limitations as earlier described. Choosing other, or more experts for the weighting of the criteria might have yielded other results. This can be seen as a limitation.

One way of adding additional viability to the MCDA method could have been to perform a sensitivity analysis to investigate the effect of different weights and scores on the outcome of the MCDA. While the final ranking is heavily dependent on both the weights and the scores, changes in these may result in a different final policy ranking (Janssen, 2001). In the end, it was not deemed necessary to perform a sensitivity analysis, given the clear significant difference in the final score for the different policy interventions.

Despite these limitations, the MCDA still obtained viable results. For one, this is because the outcome of the MCDA was significant. Secondly, the goal of the MCDA was not only to rank the policy interventions distinctively, as much as it was to show how policy interventions that can stimulate renewable energy technologies in the Netherlands can be assessed with a structured, thorough approach. When looking at the MCDA in such a way, the limitations become less stringent.

Case study

When looking at the case study, a few limitations become apparent. First of all, it is hard to assess the generalizability of the result of the case study. The generalizability of the case study can also be questioned because of the case selection: only one case is analysed instead of multiple, and the analysed case differs from the system described in this thesis. The second limitation of the case study might be that the method of the case study is not rigorous enough and thus the results are hard to replicate.

In section 6.3, it is already argued why the results of the case study will most likely be generalizable. As for the second limitation, it is argued that the case study only covered a small part of the study, its goal being just to select the best option out of the three policy interventions. Because the preference for one policy intervention was quite apparent, a more rigorous approach was not deemed necessary.

7.2.2 Future research

In this section, recommendations for future research that build on this thesis are given, based on the discussed limitations of the research:

- Keeping the limitations of the current assessment frameworks in mind, future research should be aimed at assessing the policy interventions in different ways and more thoroughly. As an example, multiple case study analyses could be conducted. Furthermore, the assessment frameworks are interchangeable. For instance, the policy interventions for critical barrier 3 – lack of local cooperation could also be assessed by means of an MCDA, as well as that the policy interventions for critical barrier 2 – grid connection procedures for battery systems could be studied using a case study approach. This would yield more insights into the impact of the different policy interventions and even more knowledge about the performance of the policy interventions.
- Future research should be aimed at varying the MCDA method. The policy interventions can be assessed with different criteria. Additionally, different policy interventions could be studied. These policy interventions could be attained by looking at policies that have had a positive effect in countries that are further along when it comes to collective battery storage, like the UK and

Germany (DNV GL, 2018; Lewis, 2021; Klimaatakkoord, 2022). Varying the MCDA can provide additional viable results.

- Future research should also be aimed at trade-offs and complementarities between policy interventions and barriers. When looking at complementary policy interventions, the proposed toolkit with standardised contracts can be strengthened by also providing process assistance and allowing pilot projects to have more intuitional experimentation room to try out the toolkit. Furthermore, prioritizing flexibility-offering parties is strongly dependent on the implementation of processes that can predict and disclose physical congestion to market parties. Trade-offs between policy interventions and barrier are underexposed in this thesis and future research could be aimed at assessing the implications of possible trade-offs.
- Further research can also assess the generalization of the results of this thesis to collective battery storage in different environments, like neighbourhood batteries in residential areas. Although the conditions for these batteries are substantially different, some results of this study might be a useful starting point for future research about these systems. For instance, it is probable that neighbourhood batteries are faced with the same kind of barriers as collective batteries in business parks. Since the thesis is not of a technical nature, the result might also be a starting point for similar research on overcoming social, economic, and institutional barriers to other forms of energy storage, like heat or hydrogen storage.
- While this study assesses policy interventions that can overcome the critical implementation of collective battery storage, less attention is paid to the actual implementation of the policy interventions. Future research should be focused more on the implementation phase of the policies, narrowing down for instance how the policies precisely should take shape, what institutions are going to implement them, and which stakeholder groups in the energy sector should be targeted. Such a more in-depth impact assessment can provide a baseline for evaluating the effectiveness of the policy interventions over time, which can inform future policy decisions and improve policy outcomes (European Parliament, 2016).

7.2.3 Practical contribution

When looking at how urgent the net congestion problems are in the Netherlands, solutions that involve collective energy initiatives succeed one another at such a rapid pace, that practice sometimes outruns science and policy development. The STP project is a prime example of this development. When real-world solutions outrun science and policy development, often institutional and scientific guidance is missed in practice by several stakeholder groups. This thesis offers different stakeholder groups handles to make well-thought-out decisions based on academic research.

This study has taken a broad notion of stakeholder perspectives into account. With the stakeholder analysis of Appendix B, key and relevant stakeholders were identified. When selecting interview participants and weighing the criteria, all relevant stakeholder groups were represented. This is why the thesis could form the basis for policy developers at municipalities, provinces, the government, and the ACM to draw sound conclusions on the implementation of different policy interventions. For market parties like battery project developers and operators, system integrators, energy companies, and investors, this thesis spreads out implementation barriers that need to be monitored and circumvented. This can help them to realize collective battery projects. For the DSO, this thesis is valuable because it lays down the sore points in their operations and can act as the basis for improving their cooperation with market parties in overcoming net congestion problems.

7.2.4 Societal relevance

A continuous increase of installed renewable capacity is needed in the Netherlands to reach sustainability goals. A shortage of flexibility and net congestion on the electricity grid is already hindering the speed of the energy transition. Net congestion is nowadays a major issue in the Netherlands and already prevents new neighbourhoods, EV charging infrastructure, and large solar and wind parks from being connected to the grid. Furthermore, net congestion forms a definite barrier to the necessary electrification of industries and housing. Net congestion thus forms a threat to the progression of the energy transition.

Collective battery storage projects in business parks are a promising way of delivering much-needed power system flexibility. They can balance the local grid in a cost-effective and energy-efficient way. Unfortunately, they still face critical barriers that refrain them from truly delivering their value. This study has laid down how these hurdles can be overcome and how the success of these systems can be increased via policy interventions. By increasing the proper integration of these systems in our electricity grid, power system flexibility can be increased, and net congestion problems can be decreased. This can be seen as socially relevant given the current stringent problems on the Dutch electricity grid.

Collective battery storage can help to effectively integrate renewables into the local grid, aiding in making the Dutch electricity network carbon-free. There are approximately 3500 business parks in the Netherlands and they often house energy-intensive companies (TNO, n.d.). Making these business parks more sustainable with collective battery storage units can have a major impact in making the Netherlands carbon-free. Besides, the implementation of collective FTM storage goes hand in hand with the increased use of decentralised energy sources and the self-consumption of green energy. Further research into battery storage can thus act as a steppingstone for the adaptation of a lot of other distributed renewable energy sources. This makes the study socially relevant. Furthermore, the projections of the European Association of Energy Storage (EASE) project a large annual growth in the upcoming years for especially FTM battery storage systems (EASE, 2022). This significant rise shows that the subject at hand becomes more and more relevant.

7.2.5 Scientific contribution

The scientific contribution of this thesis entails next to addressing the identified knowledge gaps and the fulfilment of the research objective, the use of the mixed methods research approach. First, the research gaps will be discussed. The research objective was to address two knowledge gaps: (1) the lack of scientific research on the identification of implementation barriers of collective battery systems on business parks in the Netherlands and (2) the lack of scientific research on policy interventions that can overcome these critical barriers and stimulate the successful integration of these systems in the Dutch energy system.

In chapter 4, an extensive literature study was conducted to find 23 theoretical barriers to the implementation of collective battery storage. Because little to no research is done on this topic, this identification can be seen as the first scientific contribution. Using the micro-meso-macro framework and confronting the theoretical barriers with the differing views of various experts from different stakeholder groups that have hands-on experience with barriers in battery environments, three critical implementation barriers were found. By doing so, the thesis added value by constructing an organized approach to deduce the wide array of implementation barriers of collective battery storage in the Netherlands. Both the theoretical, as well as the critical barriers can be used for reference in further academic research. As for the second research gap, nine policy interventions were proposed that can overcome the aforementioned critical barriers. Proposing these policy interventions based on a well-structured analysis is a scientific contribution

since no research has been done on which policy interventions can overcome critical barriers in the niche research area of collective battery storage in business parks in the Netherlands.

While filling the research gaps is of scientific value for further research on collective battery storage, the true scientific contribution of this thesis lies in the innovative mixed research methods approach. While many policy assessments only consider one particular method, such as cost-benefit analysis, this study combines different perspectives and multiple research methods into three assessment frameworks to evaluate policy interventions. This unique approach provides a distinct combination of frameworks to identify the most viable policy interventions for collective battery storage and showcase its advantages. The impact analysis demonstrates how policy can be evaluated based on its potential impact. The multi-criteria decision analysis (MCDA) reveals a more abstract approach to policy development for promising renewable energy technologies in the Dutch energy landscape. The modelling and case study approach provides specific and viable results in case-specific circumstances, which can be translated to other situations.

This mixed methods analytical framework can inspire research on evaluating policy interventions to stimulate other viable renewable energy technologies in the Dutch energy sector. Parts of this study can be implemented in other research to interpret the different perspectives, research methods, and results in light of various scientific or practical situations.

Although each of the four methods has its limitations, as discussed in section 7.2.1, combining them offers an innovative and substantiated approach to assessing policy interventions. This study forms a solid foundation for other research that aims to assess technologies that can stimulate the Dutch energy transition from multiple perspectives.

In conclusion, this thesis contributes to the scientific literature by addressing research gaps and demonstrating an innovative approach to combining different research methods and perspectives in the evaluation of policy interventions for promising renewable technologies. This paves the way for further research to assess policy interventions based on different perspectives.

7.3 Embedment of study in current policy debate and policy recommendations

In this section, first the current policy debate in the Netherlands on relevant topics in the energy transition like net congestion problems, battery systems, new regulations and smart energy solutions on business parks like energy hubs will be discussed. Hereafter, the results and the contribution of the study will be evaluated in relation to the current policy debate in the Netherlands. Describing the way in which the study is embedded into the current policy debate is essential to give relevant and adequate policy recommendations. These recommendations will conclude the section.

7.3.1 Current policy debate

Currently in the Netherlands, there is a fierce public and policy debate held on the major challenges of the energy transition and the resulting increased pressure on the electricity grid and net congestion. In order to sustain or even increase the pace of the energy transition and safeguard economic growth, we must find solutions that relief pressure on the grid. Action agendas (e.g. on net congestion and on battery systems) issued by the government in collaboration with other authorities like Netbeheer Nederland and the ACM, and frequent proposals for changes in the *Netcode* show the urgency of the problems. Several solutions in different areas make the headlines on a recurring basis.

When thinking of net congestion, reinforcing the grid comes to mind. Several reasons exist why only reinforcing the grid will not be enough to facilitate the energy transition. Firstly, grid reinforcements are costly and take several years to complete. They thus cannot keep track with the pace of growth of installed

renewable capacity and electrification. Furthermore, when looking at electrification, it becomes even more apparent why other solutions are also needed. The current gas infrastructure has fifteen times the capacity of the electricity network (IV1, personal communication). This means that to fully face out gas use in the Netherlands and switch to electricity, the electricity grid must grow in capacity in impossible pace. The inadequacy of grid reinforcements is shown by the fact that 25 billion euros have been invested in reinforcing the grid between 2015 and 2022 by the TSO and DSOs combined, while net congestion problems have only increased over that timespan (Zwang, 2023).

That is why the crucial issue that is spoken about in the policy debate is to unlock more power system flexibility in the Dutch energy system. Flexibility can be delivered among others by energy storage, demand response (consumers changing their power consumption to better match the demand for power with supply) and vehicle-to-grid technology. Several pilots have been instigated to further unlock flexibility (Liander, 2021; TenneT, 2022; Accenture, 2021).

The severe net congestion problems show that grid reinforcements and power system flexibility do not keep up with the pace of the energy transition. That is why we must use energy and our grid infrastructure in a different way. It is evident that a shift in the rights and obligations regarding the use of the energy structure is inevitable. Where connected parties used to have firm rights to use their transport capacity to its maximum round the clock, discussions on new regulations and tariff structures (like non-firm ATOs) that make more efficient use of the sparse capacity of the Dutch grid are at the order of the day.

The final debating point is the creation of smart energy hubs on business parks in the Netherlands. Inside a smart energy hub, several energy flows come together in a decentralised network that balances generation, storage and consumption (Oostnl.nl, 2022). Since these hubs balance the grid locally, they alleviate net congestion in the surrounding grid. Schiphol Trade Park and the system described in section 3.1 are examples of smart energy hubs. Smart energy hubs are seen as a viable solution for business parks in congestion areas (LAN, 2022).

7.3.2 Embedment of study in current policy debate

All parties involved in the energy transition acknowledge that batteries can play a vital part in bringing the Dutch energy transition a step further by offering additional flexibility to the grid and by possibly becoming an important part of local energy hubs. Despite this consensus, a clear and stimulative approach towards collective batteries and batteries in general is missing in current governance. Batteries are still not being connected to the grid by DSOs, sometimes not even in non-congested areas (Zwang, 2023). Batteries are still subject to counterproductive and non-stimulating tariff schemes and grid regulations, opposing to far more innovative legislation and pricing already implemented in our neighbouring countries. Although solutions are being coined, for example the ACM is currently investigating a change to the *Netcode* that would allow non-firm transport capacity, true governmental guidance and initiative is missing. Insecurity in the market about batteries would diminish if a clear vision on the implementation of batteries in the Dutch energy system and their future role in the system would be presented and followed, leading to a certain implementation increase of batteries.

This thesis can be seen as very relevant when looking at the current policy debate. All the aforementioned policy debates are discussed in the thesis. First of all, the thesis shows that collective battery storage systems are a viable way to add more flexibility to the current energy system. In the next research step, it is shown why, despite their potential in reducing current issues and the enormous amount of grid connection applications from battery operators, batteries do not yet get implemented. In this part of the thesis, various new contract forms (e.g. non-firm ATOs and CBC contracts) and other relevant tariff schemes are discussed. The implementation of these new contract forms, that change the rights and obligations of

connected parties fundamentally, are still very much under discussion nowadays in the Netherlands. The thesis then shows how policy interventions that accelerate the energy transition can be assessed. In this way, the thesis adds value to the public debate by offering a full policy analysis from different perspectives based on scientific methods. The systemic analysis also touches upon factors that are not only slowing down battery implementation, but also slowing down the energy transition as a whole.

By means of thorough scientific research, different policy instruments are proposed that can overcome barriers that fundamentally impede batteries from aiding the energy transition in the Netherlands. When looking at the three policy interventions that are proposed, they are all recently considered or even on the verge of being implemented. The ACM recently announced that batteries that are deployed in favour of the grid must receive a rebate on their transport tariffs (ACM, 2023). Furthermore, InvestNL is currently developing a toolkit with standardised agreements for local energy initiatives and energy hubs, as IV8 mentioned. The regional DSOs, and especially Liander, are considering investing in advanced measurement techniques to more accurately predict physical congestion and disclose this to market parties, to make alternative contract forms and more cooperation between DSOs and battery operators possible. The fact that the research process has produced three policy interventions that are seen by authorities and market players as viable ways of stimulating battery storage, gives the study validity and shows its relevance.

It is important to note that next to the identified critical barriers, other barriers can still interfere with the implementation of collective battery storage and should not be neglected in the public debate. For instance, the current nitrogen crisis in the Netherlands and the shortage of technical personnel are out of scope of the thesis, but are likely to still have a major influence on the adoption of collective batteries and the progression of the energy transition in the Netherlands. That is why governmental bodies and other authorities should not turn a blind eye on the other barriers.

Furthermore, other policy instruments than the three most Suitable ones still hold value in the public debate. Governmental loans could be a valuable addition to the revised tariff scheme if the interest rates of commercial loans keep increasing. When alternative contract forms are facilitated by predicting and disclosing physical congestion, batteries can temporarily be prioritized in grid connection procedures. Another example is that improved process assistance and implementing pilot projects could strengthen the impact of a toolkit with standardised agreements.

7.3.3 Policy recommendations

In this section, policy recommendations are given based on the findings of the thesis and the way the results fit into the current policy discussion in the Netherlands:

- **Design, Analyse & Implement.** The three proposed policy interventions are proven to be able to overcome the critical barriers of collective battery storage on business parks. But before implementing the policies, first they need to be further designed and the impact of the separate policy interventions need to be assessed. Policy design questions like the height of the rebate on transport tariffs for performed congestion management, the way in which DSOs will predict and disclose physical congestion and the contents of the toolkit first need to be answered. Thereafter, a concise impact assessment of the policy interventions should be carried out. With the conclusion of this step, the policy interventions are ready to be implemented and stimulate the integration of collective battery storage. As is mentioned in the last paragraph, all three policy interventions are already being considered. This shows their importance in the current policy discussion.
- **Take the lead.** The net congestion problems in the Netherlands are severe. To safeguard the economic development and the development of the energy transition, DSOs, municipalities, governmental bodies, and ACM should take a proactive approach enabling collaborative, local energy solutions to thrive. Currently, battery operators are eager to fulfil the potential of battery storage in the energy transition, but are hold back by institutions. The DSO and battery operators should actively seek agreements that make it possible to connect batteries again. An underlying requirement is that physical congestion is predicted more accurately. Netbeheer Nederland, the ACM and the government should implement changes to the *Netcode* that make non-firm capacity agreements possible and make changes in private grid legislation that facilitate the creation of local energy hubs. A rebate on transport tariffs for batteries that are deployed in favour of the grid should be rolled out rapidly. Furthermore, grid operators should investigate if it is deemed necessary to prioritize grid connections for flexibility-offering parties. Municipalities should be facilitating battery operators in permit processes and should facilitate local cooperation. The government should invest in the creation of a toolkit for standardised agreements, as well as it should formulate a clear vision on the role battery storage will play in the energy system of the future. If these authorities take the lead, a significant amount of new flexibility will be unlocked and the Netherlands will be one step closer to being fossil-free.
- **Do not sleep on other options and barriers.** While three policy interventions are proposed, the other policy interventions are also carefully selected and hold value, either as a stand-alone policy or as a supporting policy to one of the three proposed policies. Furthermore, barriers that are not labelled as critical, can still have a significant effect on the implementation of collective battery storage. These should thus still be considered. Furthermore, a lot of the barriers are not only applicable to battery storage, but describe fundamental shortcomings of current institutions that also limit other viable renewable technologies.
- **Be consistent.** A more generic recommendation is that whatever path is taken, it is important to remain consistent in developing policy. Stability and sustainable vision is currently lacking in the Netherlands, creating insecurity in the energy sector on where the system is heading and what technologies will safeguard the proper functioning of the system in the future. A certain institutional guidance is needed in the uncertain times the energy world is currently facing. Stability in policy and governance ensures that market players and the energy sector can develop optimally towards a more sustainable Netherlands.

References

- Accenture (2021). De inzet van warmtepopen voor een duurzaam energiesysteem. <https://www.accenture.com/nl-en/blogs/insights/warmtepompen-duurzaam-energiesysteem>. (Accessed : December 26th 2022).
- Ackermann, F., Eden, C. (2011). Strategic Management of Stakeholders: Theory and Practice. *Long Range Planning* 44, 179-196. [https://www.acm.nl/nl/organisatie/onze-organisatie/de-autoriteit-consument-en-markt#:~:text=De%20Autoriteit%20Consument%20%26%20Markt%20\(ACM,specifieke%20sectoren%20en%20het%20consumentenrecht](https://www.acm.nl/nl/organisatie/onze-organisatie/de-autoriteit-consument-en-markt#:~:text=De%20Autoriteit%20Consument%20%26%20Markt%20(ACM,specifieke%20sectoren%20en%20het%20consumentenrecht). (Accessed: March 12th, 2023).
- ACM (n.d.). Vragen en antwoorden transportschaarste: Rechten en plichten van afnemers en netbeheerders. <https://www.acm.nl/sites/default/files/documents/q-a-transportschaarste.pdf> (Accessed: October 17th 2022)
- ACM (n.d.) De Autoriteit Consument & Markt. [https://www.acm.nl/nl/organisatie/onze-organisatie/de-autoriteit-consument-en-markt#:~:text=De%20Autoriteit%20Consument%20%26%20Markt%20\(ACM,specifieke%20sectoren%20en%20het%20consumentenrecht](https://www.acm.nl/nl/organisatie/onze-organisatie/de-autoriteit-consument-en-markt#:~:text=De%20Autoriteit%20Consument%20%26%20Markt%20(ACM,specifieke%20sectoren%20en%20het%20consumentenrecht). (Accessed: March 12th, 2023).
- ACM (2021). Beslisboom zal er sprake zijn van een illegaal privaat net? <https://www.acm.nl/nl/publicaties/beslisboom-zal-er-sprake-zijn-van-een-illegaal-privaat-net> (Accessed: October 17th 2022)
- ACM (2022). Codebesluit congestiemanagement. <https://www.acm.nl/nl/publicaties/codebesluit-congestiemanagement> (Accessed: January 7th 2023)
- Actuelerentestanden.nl (n.d.). Actuele rentestanden. <https://www.actuelerentestanden.nl/> (Accessed: February 15th)
- Adobe Stock (n.d.) Battery storage [Profile Picture]. https://stock.adobe.com/nl/search/video?filters%5Bcontent_type%3Avideo%5D=1&hide_panel=true&k=battery+storage&search_type=usertyped (Accessed: 4th April, 2023)
- APM (n.d.). What is the difference between a trial and a pilot? <https://www.apm.org.uk/resources/find-a-resource/what-is-the-difference-between-a-trial-and-a-pilot/#:~:text=The%20pilot%20project%20enables%20an,before%20substantial%20resources%20are%20committed>. (Accessed: March 2nd, 2023)
- Arent, D. J., Wise, A., & Gelman, R. (2011). The status and prospects of renewable energy for combating global warming. *Energy Economics*, 33(4), 584–593. <https://doi.org/10.1016/j.eneco.2010.11.003>
- Bakker (2022). ACM maakt regels congestiemanagement begrijpelijk. *Koninklijke VEMW*. <https://energeia.nl/energeia-artikel/40097914/kabinet-maakt-einde-aan-dubbele-heffing-van-energiebelasting-bij-opslaan-elektriciteit> (Accessed: 2022, October 20th)
- Battery University (2021). How to Prolong Lithium-based Batteries. <https://batteryuniversity.com/article/bu-808-how-to-prolong-lithium-based-batteries> (Accessed: March 15th, 2023)
- Bell, M., Hobbs, B., Elliott, E., Ellis, H., Robinson, Z. (2002). An evaluation of multi-criteria methods in integrated assessment of climate policy. *Journal of Multi-Criteria Decision Analysis*, 10(5). 229-256.
- Belton, V., Stewart, T.J. (2002). Multiple Criteria Decision Analysis: An Integrated Approach. *Kluwer Academic Publishers: Dordrecht*
- Beltran, H, Ayuso, P., Pérez, E. (2021). Lifetime Expectancy of Li-ion Batteries used for Residential Solar Storage. *Energies* 13(3), 568.
- BloombergNEF (2022, 6th december). Lithium-ion Battery Pack Prices Rise for First time to an Average of 151\$/kWh

- Bonte, R., van den Burg, J., Janssen, R., Mooren, R., & de Smidt, J. (1997). Notitie over multicriteriaanalyse in milieueffectrapportage. *Commissie voor de milieueffectrapportage*. <https://research.vu.nl/en/publications/notitieovermulticriteriaanalyseinmilieueffectrapportage> (Accessed: October 21st)
- Buchanan, M. (2020). The limits of a model. *Nature Physics*, 16(605), 5407
- Business.gov.nl (n.d.). Working for the government via a tender. [https://business.gov.nl/running-your-business/products-and-services/public-tenders/working-for-the-government-via-a-tender/#:~:text=A%20tender%20\(aanbesteding\)%20is%20a,carried%20out%20by%20a%20company](https://business.gov.nl/running-your-business/products-and-services/public-tenders/working-for-the-government-via-a-tender/#:~:text=A%20tender%20(aanbesteding)%20is%20a,carried%20out%20by%20a%20company). (Accessed: February 24th, 2023).
- CSU – California State University (n.d.) PPA 670 Policy Analysis. <https://home.csulb.edu/~msaintg/ppa670/p&sch5.htm#:~:text=EQUITY%20CRITERIA,-Efficiency%20and%20effectiveness&text=Equity%20asks%20about%20the%20social,burdens%20and%20benefits%20in%20society>. (Accessed: May 4th, 2023).
- Caputo, R.K. (2013). Policy Analysis for Social Workers. *SAGE Publications*, 1st edition.
- Castillo, A., Gayme, D.F. (2014) Grid-scale Energy Storage Applications in Renewable Energy Integration: A Survey. *Energy Conversion and Management*, 87, 885 – 894. <https://doi.org/10.1016/j.enconman.2014.07.063>
- CE Delft (2017). Beleidsevaluatie Energie-investeringsaftrek. <https://www.rvo.nl/sites/default/files/2018/06/rapport-beleidsevaluatie-eia-2012-2017.pdf> (Accessed; February 24th, 2023).
- CE Delft (2021). Omslagpunt grootschalige batterijopslag. https://cedelft.eu/wp-content/uploads/sites/2/2022/02/CE_Delft_210361_Omslagpunt_grootschalige_batterijopslag_Hoofdrapport_Def.pdf (Accessed: October 17th)
- Chelsea, S. (2016). The effect of charge/discharge rate on capacity fade of lithium ion batteries. *Dissertations Abstracts International*, 78(06).
- Chang, L., Zhang, W., Xu, S., Spence, K. (2017). Review on Distributed Energy Storage Systems for Utility Applications. *CPSS Transactions on Power Electronics and Applications*, 2(4), 267-276.
- Cohen, B., Blanco, H., Dubash, N. K., Dukkipati, S., Khosla, R., Scricciu, S. (2018). Multi-criteria decision analysis in policy-making for climate mitigation and development. *Climate and Development*, 11(3).
- Cole, W., Frazier, A.W. (2019). Cost Projections for Utility-Scale Battery Storage. *National Renewable Energy Laboratory*. <https://www.nrel.gov/docs/fy19osti/73222.pdf> (Accessed: April 10th, 2023)
- Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., Sheikh, A. (2011). The case study approach. *BMC Medical Research Methodology*, 11(100).
- Department for Business, Energy & Industrial Strategy (2022). Energy storage backed with over 32 million pound government funding. <https://www.gov.uk/government/news/energy-storage-backed-with-over-32-million-government-funding> (Accessed: February 2nd).
- DNV GL (2018). Buurtbatterij: Haalbaarheid en Schaalbaarheid van de Buurtbatterij. *Rapport nr 18-0126*.
- Dodgson, JS, Spackman, M, Pearman, A and Phillips, LD (2009) Multi-criteria analysis: a manual. Department for Communities and Local Government: London. ISBN 9781409810230
- EASE (2022). EMMES 6.0 – June 2022. <https://ease-storage.eu/publication/emmes-6-0-june-2022/>.
- Economic Times (n.d.). What is ‘Deadweight loss’. <https://economictimes.indiatimes.com/definition/deadweight-loss> (Accessed: April 9th, 2023).
- Eijkens, J., van Asperen, P., Lindijer, V. (2018). ‘Net Anders: een overzicht van de ontwikkeling van de regulering van private netten’. *Nederlands Tijdschrift voor Energierecht*

- Energie-Nederland (2016, May 11th). Reactie op de internet consultatie over het Wetsvoorstel Voortgang Energietransitie [Mail].
<https://www.internetconsultatie.nl/wijzigingregelingafsluitbeleidwarmteregeling/reactie/92744/bestand> (Accessed: February 4th)
- Energy Storage News (2022). Germany finally gives energy storage its own legal definition.
<https://www.energy-storage.news/germany-finally-gives-energy-storage-its-own-legal-definition/>. (Accessed: February 8th, 2023).
- Energy Storage NL (2016). Nationaal Actieplan Energieopslag. Geraadpleegd van
https://www.energystoragenl.nl/wp-content/uploads/2016/10/2016-12-15-ESNL_Nationaal-Actieplan-Energieopslag.pdf (Accessed: November 20th, 2022)
- Energy Storage NL (2021). Transporttarieven voor opslag elektriciteit mogelijk op de schop.
<https://www.energystoragenl.nl/transporttarieven-voor-opslag-elektriciteit-mogelijk-op-de-schop/> (Accessed: April 9th, 2023).
- Energy Storage NL (2022, 29th September). Veel vragen tijdens online bijeenkomst Non-Firm ATO. (Accessed: January 2nd, 2023)
- Englberger, S., Jossen, A., Hesse, H. (2020). Unlocking the Potential of Battery Storage with the Dynamic Stacking of Multiple Applications. <https://doi.org/10.1016/j.xcrp.2020.100238>
- European Commission (2020). Study on Energy Storage – Contribution on the security of electricity supply in Europe. <https://op.europa.eu/en/publication-detail/-/publication/a6eba083-932e-11ea-aac4-01aa75ed71a1/language-en>. (Accessed: September 14th 2022)
- European Commission (n.d.). Energy communities. https://energy.ec.europa.eu/topics/markets-and-consumers/energy-communities_en (Accessed: February 20th)
- European Parliament (2016). Evaluation and ex-post impact assessment at EU level.
[https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI\(2016\)581415](https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2016)581415) (Accessed: March 12th, 2023)
- European Union (2019). Directive (EU) 2019/944.
- European Union (2022). Interne Energiemarkt.
[https://www.europarl.europa.eu/factsheets/nl/sheet/45/interne-energiemarkt#:~:text=De%20eerste%20liberaliseringsrichtlijnen%20\(eerste%20energiepakket,energiepakket%20werd%20in%202003%20aangenomen](https://www.europarl.europa.eu/factsheets/nl/sheet/45/interne-energiemarkt#:~:text=De%20eerste%20liberaliseringsrichtlijnen%20(eerste%20energiepakket,energiepakket%20werd%20in%202003%20aangenomen). (Accessed: January 2nd)
- European Union (n.d.) Capacity Mechanisms. https://energy.ec.europa.eu/topics/markets-and-consumers/capacity-mechanisms_en#:~:text=Capacity%20mechanisms%20are%20temporary%20support,term%20security%20of%20electricity%20supply.&text=Capacity%20mechanisms%20enable%20power%20plants,for%20generating%20electricity%20when%20needed.. (Accessed: February 5th 2023)
- Expertgroep Batterijen (September, 2022). Actieagenda batterijsystemen. *Holland High Tech*.
<https://www.rijksoverheid.nl/documenten/rapporten/2022/09/23/2022195013-1-nationale-actieagenda-batterijsystemen>. (Accessed: Oktober 12th, 2022)
- Exter, den, R. (2021). ‘Wat zijn de kansen en barrières in de businesscase voor energieopslag?’ *Energy Storage Day 2021 – Energievakbeurs Den Bosch*.
<https://www.vakbeursenergie.nl/files/54events/energie/Programma/2021/4.%20StoredEnergy%20-%20Rob%20den%20Exter.pdf> (Accessed: October 17th 2022)
- Fitzgerald, G., Mandel, J., Morris, J., Touati, H. (2015). The Economics of Battery Energy Storage. *Rocky Mountain Institute*. <https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf> (Accessed: October 14th)
- Francis, N., ‘t Hoen, R., Broess, K., Roggekamp, W., Prinszen, W. (2020). Smart Grid Ready Energy Storage. DNV GL & Technolution.

- <https://www.topsectorenergie.nl/sites/default/files/uploads/Urban%20energy/publicaties/Rapport%20SmartGridReadyEnergyStorage.pdf> (Accessed: January 1st, 2023)
- Garcia, R., Wigger, K., Hermann, R.R. (2019). Challenges of creating and capturing value in open eco-innovation: evidence from the Maritime industry in Denmark. *Journal of Cleaner Production*, 220, 642-654.
- GIGA Storage. Rhino. <https://giga-storage.com/projecten/rhino/> (Accessed : January 1st, 2023).
- Government of the Netherlands (2017). The integrated impact assessment framework for policy and legislation. https://www.kcbr.nl/sites/default/files/iak_english_incl_corrections_02-11-2017.pdf (Accessed: January 29th, 2023)
- Göss, S. (2022, 6th September). Spot market prices for electricity break all records. *Energy Brainpool*. <https://blog.energybrainpool.com/en/spot-market-prices-for-electricity-break-all-records/> (Accessed: December 26th)
- Greening, L., Bernow, S. (2004). Design of coordinated energy and environmental policies: use of multi-criteria decision-making. *Energy Policy*, 32. 721-735.
- Greenwood, D.M., Wade, N.S., Heyward, N., Mehta, P., Papadopoulos, P., Taylor, P.C. (2015). Scheduling Power and Energy Resources in the Smarter Network Storage Project. *CIREN 23rd International Conference and Exhibition on Electricity Distribution, Lyon*. <https://doi.org/10.1016/j.apenergy.2017.08.143>
- Gupta, P., Anand, S., & Gupta, H. (2017). Developing a roadmap to overcome barriers to energy efficiency in buildings using best worst method. *Sustainable Cities and Society*, 31, 244–259. <https://doi.org/10.1016/J.SCS.2017.02.005>
- Greim, P., Solomon, A. A., & Breyer, C. (n.d.). Assessment of lithium criticality in the global energy transition and addressing policy gaps in transportation. <https://doi.org/10.1038/s41467-020-18402-y> (Accessed: January 18th, 2021)
- Guitouni, A., Matel, J.M. (1998). Tentative guidelines to help choosing an appropriate MCDA method. *European Journal of Operational Research*, 109(2). 501-521
- Haney, A.B., Pollitt, M.G. (2013). New models of public ownership in energy. *International Review of Applied Economics* 27(2), 174-192.
- Hoppe, T., Graf, A., Warbroek, B., Lammers, I., Lepping, I. (2015). Local governments supporting local energy initiatives: Lessons from the best practices of Saerbeck (Germany) and Lochem (The Netherlands). *Sustainability*, 7, 1900-1931.
- Houwing, M., Dukovska, I., Paterakis, N.G. (2022). A Reputation Management System for the Fair Utilization of Community Energy Storage. *IEEE Transactions on Smart Grid*. DOI: [10.1109/TSG.2022.3197355](https://doi.org/10.1109/TSG.2022.3197355)
- IAIA (International Association for Impact Assessment) (n.d.). Impact Assessment. [https://www.iaia.org/wiki-details.php?ID=4#:~:text=Impact%20assessment%20\(IA\)%20is%20a,from%20policies%20to%20specific%20projects](https://www.iaia.org/wiki-details.php?ID=4#:~:text=Impact%20assessment%20(IA)%20is%20a,from%20policies%20to%20specific%20projects). (Accessed: March 10th, 2023). [https://www.iaia.org/wiki-details.php?ID=4#:~:text=Impact%20assessment%20\(IA\)%20is%20a,from%20policies%20to%20specific%20projects](https://www.iaia.org/wiki-details.php?ID=4#:~:text=Impact%20assessment%20(IA)%20is%20a,from%20policies%20to%20specific%20projects). (Accessed: March 10th, 2023).
- IEA (n.d.). Data statistics. www.iea.org/data-and-statistics. (Accessed: September 12th 2022)
- IEA (2019). The who and how of power system flexibility. <https://www.iea.org/commentaries/the-who-and-how-of-power-system-flexibility>. (Accessed: September 14th 2022)
- IEA (2020). The Netherlands 2020. Energy Policy Review. <https://www.iea.org/reports/the-netherlands-2020> (Accessed: October 20th)
- InvestNL (2021). De financierbaarheid van een batterij in een gesloten distributie systeem. <https://www.invest-nl.nl/media/attachment/id/1464> (Accessed: March 3rd, 2023)

- Janssen, R. (2001). On the use of multicriteria analysis in environmental impact assessment in the Netherlands. *Journal of MultiCriteria Decision Analysis*, 10(2), 101–109. <https://doi.org/10.1002/mcda.293>
- Klimaataakkoord (2022). Opslag energie: technisch veel mogelijk, maar regelgeving is barrière. <https://www.klimaataakkoord.nl/actueel/nieuws/2022/04/01/webinar-opslag>. (Accessed: October 17th 2022)
- Kappagantu, R., Daniel, S.A. (2018). Challenges and issues of smart grid implementation: A case of Indian scenario. *Journal of Electrical Systems and Information Technology*, 5(3), 453-467. <https://doi.org/10.1016/j.jesit.2018.01.002>
- Keeney, R.L., Raiffa, H. (1976). Decision Making with Multiple Objectives Preferences and Value Tradeoffs. *Wiley, New York*.
- KfW (2022, July). Green Bonds – Made by KfW. <https://www.kfw.de/PDF/Investor-Relations/PDF-Dokumente-Green-Bonds/Impact-and-Allocation-Reporting/Impact-Report-2019-2020.pdf>. (Accessed: February 4th, 2023).
- Kim, T. Y., Kwak, S. J., & Yoo, S. H. (1998). Applying multiattribute utility theory to decision making in environmental planning: a case study of the electric utility in Korea. *Journal of Environmental Planning and Management*, 41(5), 597–609. <https://doi.org/10.1080/09640569811470>
- Kiran, D.R. (2022). Machinery replacement analysis. *Principles of Economics and Management for Manufacturing Engineering*. 2022, 259-267.
- Koirala, B.P., van Oost, E.C., van der Windt, H.J. (2018). Community energy storage: A responsible innovation towards a sustainable energy system? *Applied Energy*, 231, 570-585. <https://doi.org/10.1016/j.apenergy.2018.09.163>
- Koirala, B.P., Hakvoort, R.A., van Oost, E.C., van der Windt, H.J. (2019). Community Energy Storage: Governance and business models. *Consumer, Prosumer, Prosumer: How Service Innovations will Disrupt the Utility Business Model, Chapter 10*. [10.1016/B978-0-12-816835-6.00010-3](https://doi.org/10.1016/B978-0-12-816835-6.00010-3)
- Kong, L., Li, C., Jiang, J., Pecht, M. (2018). Li-ion Battery Hazards and Safety Strategies. *Energies*, 11(9), 2192.
- Kraft, M.E., Furlong, S.R. (2010). Public Policy: Politics, Analysis, and Alternatives. *CQ Press, 2007*
- Landelijk Actieprogramma Netcongestie, LAN (2022).
- Lane, C. (2023). Are lithium-ion solar batteries the best energy storage option? *Solar Reviews*. <https://www.solarreviews.com/blog/are-lithium-ion-the-best-solar-batteries-for-energy-storage> (Accessed: April 12th, 2023)
- Lewis, C. (2021). Front-of-meter (FOM) energy storage interconnection needs serious policy innovation. *Clean Coalition*. <https://clean-coalition.org/news/front-of-meter-energy-storage-interconnection-case-study/> (Accessed: October 17th 2022)
- LG Energy Solution (2021). Electricity storage subsidies in Germany. <https://lghomebatteryblog.eu/en/electricity-storage-subsidies-in-germany/#:~:text=This%20subsidy%20starts%20at%20500,Maximum%20capacity%20%3D%2030%20kWh>. (Accessed: February 2nd, 2023)
- Liander (2021). Marktconsultatie in Amsterdam-West. <https://www.liander.nl/MarktconsultatieAmsterdamWest> (Accessed: April 12th, 2023)
- Liander (2022, 15th of April). Eerste bedrijven Schiphol Trade Park aangesloten op uniek virtueel stroomnet. <https://www.liander.nl/nieuws/2022/04/15/eerste-bedrijven-schiphol-trade-park-aangesloten-op-uniek-virtueel-stroomnet> (Accessed: March 9th)
- Liander (n.d.). Typen aansluitingen. <https://www.liander.nl/consument/aansluitingen/typen> (Accessed: March 3rd, 2023)
- Lopes, J.A.P., Madureira, A.G., Moreira, C.C.L.M. (2012). A View of Microgrids. *WIREs Energy and Environment*, 2(1). <https://doi.org/10.1002/wene.34>

- Lustgraaf, R. (2022). Het einde van het chiptekort komt langzaam in zicht. *Trouw*.
<https://www.trouw.nl/economie/het-einde-van-het-chiptekort-komt-langzaam-in-zicht~b6c4dfbd/?referrer=https%3A%2F%2Fwww.google.com%2F> (Accessed: January 1st, 2023).
- Mair, J., Suomalainen, K., Eysers, D.M., Jack, M.W. (2021). Sizing domestic batteries for load smoothing and peak shaving based on real-world demand data. *Energy and Buildings*, 247, 111109.
- Maessen, H. (2021). Data energietarieven najaar 2021: forse stijging.
<https://www.atrion.nl/nieuwsbericht-data/energietafzet-najaar-2021-forse-stijging#:~:text=De%20gemiddelde%20tarieven%20per%201,%3A%20%E2%82%AC%20%2C24%2FkWh> (Accessed; April 11th, 2021)
- McIntosh, M. J., & Morse, J. M. (2015). Situating and Constructing Diversity in Semi-Structured Interviews. *Global Qualitative Nursing Research*, 2, 233339361559767.
<https://doi.org/10.1177/2333393615597674>
- Melander, L., Lind, F. (2022). A start-up's collaboration in networks for sustainable freight transportation: a micro-meso-macro approach to innovation. *Supply Chain Management*, 27(7).
- Mundaca, L. (2023). International and national policy intervention. *The International Institute for Industrial Environmental Economics, Lund University*.
<https://www.iiiee.lu.se/research/international-and-national-policy-intervention#:~:text=Policy%20interventions%20involve%20any%20course.and%20the%20provision%20of%20infrastructure>. (Accessed: April 6th, 2023)
- Muzumdar, A., Modi, c., Madhu, G.M., Vajayanthi, C. (2021). A trustworthy and incentivized smart grid energy trading framework using distributed ledger and smart contracts. *Journal of network and Computer Applications*, 183, 103074. <https://doi.org/10.1016/j.jnca.2021.103074>
- Netbeheer Nederland (2022). Regionale netbeheerders onderzoeken tijdsgebonden contract voor grootschalige batterijopslag. <https://www.netbeheernederland.nl/nieuws/regionale-netbeheerders-onderzoeken-tijdsgebonden-contract-voor-grootschalige-batterijopslag--1543> (Accessed: October 17th)
- Next Kraftwerke (n.d.). Wat is de Regelvermogen (aFRR)? <https://www.next-kraftwerke.nl/kennis/regelvermogen-afrr> (Accessed: January 2nd, 2023).
- Netbeheer Nederland (2020). 'Cable Pooling: update factsheet & verdieping'.
https://www.netbeheernederland.nl/upload/Files/Netcapaciteit_60_5de4ca08ea.pdf (Accessed: October 17th)
- Next Kraftwerke (n.d.). What is aFRR and how does it work? <https://www.next-kraftwerke.com/knowledge/afrr> (Accessed: November 20th)
- NOS (2021, December 5th). 'Snelheid van energietransitie in gevaar door tekort technisch personeel'.
<https://nos.nl/nieuwsuur/artikel/2408261-snelheid-van-energietransitie-in-gevaar-door-tekort-aan-technisch-personeel> (Accessed: January 2nd, 2023)
- Office of Energy Efficiency & Renewable Energy (2023). Battery Policies and Incentives Search.
<https://www.energy.gov/eere/vehicles/battery-policies-and-incentives-search#/> (Accessed: February 2nd)
- Odu, G.O. (2019). Weighting Methods for Multi-Criteria Decision Making Technique. *Journal of applied scientific environmental management*, 23(8), 1449-1457.
- OECD (2015). OECD Guidelines on Corporate Governance of State-Owned Enterprises.
<https://www.oecd.org/corporate/guidelines-corporate-governance-soes.htm> (Accessed: March 12th, 2023)
- Oostnl.nl (2022). 25% CO2-reductie en 330 miljoen euro besparing op netuitbreiding mogelijk in Oost-Nederland. <https://oostnl.nl/nl/nieuws/smart-energy-hubs-als-basis-voor-het-energiesysteem-van-de->

- [toekomst#:~:text=In%20een%20Smart%20Energy%20Hub,de%20productie%20van%20duurzame%20energie.](#) (Accessed: April 12th, 2023)
- Oteman, M., Kooij, H., Wiering, M.A., Helderma, K. (2014) The institutional space of community initiatives for renewable energy: a comparative case study of the Netherlands, Germany and Denmark. *Energy, sustainability and society*, 4(11), 1-17.
- Overheid.nl (n.d.). Elektriciteitswet 1998. <https://wetten.overheid.nl/BWBR0009755/2022-10-01> (Accessed: January 2nd 2022).
- Parnell, J. (2020, March 5th). No Subsidies Please, Says Europe's Struggling Energy Storage sector. *Green Tech Media*. <https://www.greentechmedia.com/articles/read/no-subsidies-please-says-europes-energy-storage-sector> (Accessed: February 12th)
- Parra, D., Swierczynski, M., Stroe, D.I., Norman, S.A., Abdon, A., Worlitschek, J., O'Doherty, T., Rodrigues, L., Gillott, M., Zhang, X., Bauer, C., Patel, M. (2017). An interdisciplinary review of energy storage for communities: Challenges and perspectives. *Renewable and Sustainable Energy Reviews*, 79, 730-749. <https://doi.org/10.1016/j.rser.2017.05.003>
- Pecenak, Z., Mathiesen, P., Fahy, K., Cannon, C., Ayandele, E., Kirk, T.J., Stadler, M. (2020). The Impact of Project Financing in Optimizing Microgrids. *Journal of Renewable and Sustainable Energy*, 12. <https://doi.org/10.1063/5.0026187>
- Publicatiereeks gevaarlijke stoffen (2022). Lithium-houdende energiedragers: Energie Opslag Systemen – EOS. <https://publicatiereeksgevaarlijkstoff.nl/publicaties/PGS37.html> (Accessed: January 2nd, 2022)
- Recht.nl (2020). Parket bij de Hoge Raad 23-10-2020, 20/00262. <https://www.recht.nl/rechtspraak/uitspraak/?ecli=ECLI:NL:PHR:2020:987> (Accessed: March 1st, 2023).
- Rijksoverheid (2021). Klimaatbeleid. <https://www.rijksoverheid.nl/onderwerpen/klimaatverandering/klimaatbeleid>. (Accessed: 12th September 2022)
- Rijksoverheid (n.d.). Aanpak stikstof. <https://www.rijksoverheid.nl/onderwerpen/aanpak-stikstof> (Accessed: January 4th, 2023)
- Rotmans, J. (2011). Staat van de Energietransitie in Nederland. *Drift*. Erasmus Universiteit Rotterdam.
- Royal HaskoningDHV (2021). Verbeteren netinpassing zonne-energieprojecten. <https://www.rvo.nl/sites/default/files/2022/02/Verbeteren-netinpassing-zonne-energieprojecten-10-toepassingen-in-kaart-gebracht.pdf> (Accessed: January 2nd, 2023).
- RVO (2017). Beoordelingscriteria Hernieuwbare Energietransitie (HER+). <https://www.rvo.nl/subsidies-financiering/her/beoordelingscriteria> (Accessed: February 2nd, 2023)
- RVO (2022). Sustainable energy transition subsidy scheme (SDE++). <https://business.gov.nl/subsidy/sustainable-energy-production/> (Accessed: October 17th 2022)
- RVO (2022a). Energie-investeringsaftrek (EIA) voor ondernemers. <https://www.rvo.nl/subsidies-financiering/eia/ondernemers> (Accessed: October 21st, 2022)
- RVO (2023). Investeringssubsidie duurzame energie en energiebesparing (ISDE), <https://www.rvo.nl/subsidies-financiering/isde> (Accessed: October 18th 2022)
- RVO (2023a). Subsidieregeling Coöperatieve Energieopwekking (SCE). <https://www.rvo.nl/subsidies-financiering/sce> (Accessed: February 20th, 2023)
- SADC (n.d.) Virtueel net. <https://www.sadc.nl/innovatie/> (Accessed: March 10th, 2023)
- Sekaran, U., & Bougie, R. (2016). Research methods for business: A skill building approach: John Wiley & Sons
- Solar Magazine (2022). 'Onredelijke en onterechte transportkosten blijven doorbraak grot batterijsystemen blokkeren'. <https://solarmagazine.nl/nieuws-zonne-energie/i26441/onredelijke-en->

- onterechte-transportkosten-blijven-doorbraak-grote-batterijsystemen-blokkeren (Accessed: October 17th 2022)
- Solar Magazine (2022a). Minister Jetten : ‘Geen subsidie voor batterijen via SDE++, kosten te hoog’. <https://solarmagazine.nl/nieuws-zonne-energie/i26752/minister-jetten-geen-subsidie-voor-batterijen-via-sde-kosten-te-hoog> (Accessed: 3rd of February, 2023)
- Spectral (2021). Schiphol Trade Park Smart Grid. <https://spectral.energy/project/schiphol-trade-park-smart-grid/> (Accessed: March 6th, 2023).
- Storage Magazine (2021). Energy Storage NL pleit voor opname definitie energieopslag in nieuwe Energiewet. <https://solarmagazine.nl/smart-storage/i23585/energy-storage-nl-pleit-voor-opname-definitie-energieopslag-in-nieuwe-energiewet> (Accessed: October 17th 2022)
- Thaler, R.H., Sunstein, C.R. (2008). Nudge: improving decisions about health, wealth and happiness. *Penquin Group*.
- Tennet (2021). TenneT start landelijk onderzoek naar flexibel vermogen. <https://www.tennet.eu/nl/nieuws/tennet-start-landelijk-onderzoek-naar-flexibel-vermogen> (Accessed: April 12th, 2023).
- TenneT (2022). Onbalansprijsystematiek. <https://www.tennet.eu/nl/balanceringsmarkten> (Accessed: October 16th 2022)
- TenneT (2020). Dutch Grid Operators Launch GOPACS: a Smart Solution to Reduce Congestion in the Electricity Grid. <https://www.tennet.eu/news/detail/dutch-grid-operators-launch-gopacs-a-smart-solution-to-reduce-congestion-in-the-electricity-grid/> (Accessed: October 16th 2022)
- Tennet (n.d.). Market Types. <https://www.tennet.eu/market-types> (Accessed: December 10th 2022).
- Tickler, P. (2020). Maximising battery value: a commercial analysis of front-of-meter vs behind-the-meter storage. *Gridcognition*. <https://gridcognition.com/maximising-battery-value-a-commercial-analysis-of-front-of-meter-vs-behind-the-meter-storage/> (Accessed: October 13th).
- <https://projecten.topsectorenergie.nl/projecten/collectieve-energievoorziening-schiphol-trade-park-36298> (Accessed: March 10th, 2023).
- TNO (n.d.). Bedrijventerreinen verduurzamen. <https://www.tno.nl/nl/duurzaam/systeemtransitie/energietransitie-wijken/bedrijventerreinen-verduurzamen/> (Accessed: March 24th, 2030)
- Topsector Energie (n.d.). Collectieve Energievoorziening Schiphol Trade Park. <https://projecten.topsectorenergie.nl/projecten/collectieve-energievoorziening-schiphol-trade-park-36298> (Accessed: March 2nd, 2023)
- Triantaphyllou, E., Baig, K. (2005). The impact of aggregating benefit and cost criteria in four MCDA methods. *IEEE Transactions on Engineering Management*, 52(2), 213-226.
- United Nations Environment Programme (2002). Environmental Impact Assessment Training Resource Manual – Second Edition. <https://wedocs.unep.org/handle/20.500.11822/26503> (Accessed: March 16th, 2023)
- Vargas, M., Davis, G. (2016). World Energy Scenarios 2016. *World Energy Council, London, UK*.
- Warneryd, M., Hakansson, M., Karltorp, K. (2020). Unpacking the Complexity of Community
- Willuhn, M. (2020). How long will the lithium supply last? *PV magazine*. <https://www.pv-magazine.com/2020/09/15/how-long-will-the-lithium-supply-last/> (Accessed: Januari 1st, 2023)
- Windandsun.co.uk (n.d.). Battery capacity. <http://www.windandsun.co.uk/information/batteries/battery-capacity.aspx#.ZBt7HHbMJaS> (Accessed: March 12th, 2023).
- Wolf, S. (2023). What’s the Lifespan of a Solar Battery? *Paradise Energy Solutions*. <https://www.paradisolarenergy.com/blog/how-long-do-solar-batteries-last> (Accessed: April 11th, 2023)

- World Bank (2018). Publication: Environmental and Social Impact Assessments. <https://openknowledge.worldbank.org/entities/publication/2be4e33f-3d91-54b3-9a7f-0ad21e92148a> (Accessed: March 14th, 2023)
- World Economic Forum (2022). The world needs 2 billion electric vehicles to get to net zero. But is there enough lithium to make all the batteries? <https://www.weforum.org/agenda/2022/07/electric-vehicles-world-enough-lithium-resources/>. (Accessed: January 1st, 2022)
- Yang, Y., Hu, G., Spanos, C.J. (2021). Optimal Sharing and Fair Cost Allocation of Community Energy Storage. *IEEE Transactions on Smart Grid*, 12(5). 4185-4194. Doi: [10.1109/TSG.2021.3083882](https://doi.org/10.1109/TSG.2021.3083882)
- Zonnepanelen-info.nl (n.d.) Wat is Wattpiek? <https://www.zonnepanelen-info.nl/wat-is-wattpiek/> (Accessed; March 3rd, 2023)
- Zwang, J.W. (2022, October 12th). Batterijen dreigen energiemarkten te overspoelen: 20GW in de pijplijn. *Strategy*. <https://www.strategy.nl/post/batterijen-dreigen-energiemarkten-te-overspoelen-20-gw-in-pijplijn>. (Accessed: October 28th)
- Zwang, J.W. (2023, April 13th). Batterijen kunnen congestie wél oplossen. <https://www.strategy.nl/post/batterijen-kunnen-congestie-w%C3%A9l-oplossen> (Accessed: April 13th, 2023)

Appendices

Appendix A Literature review process

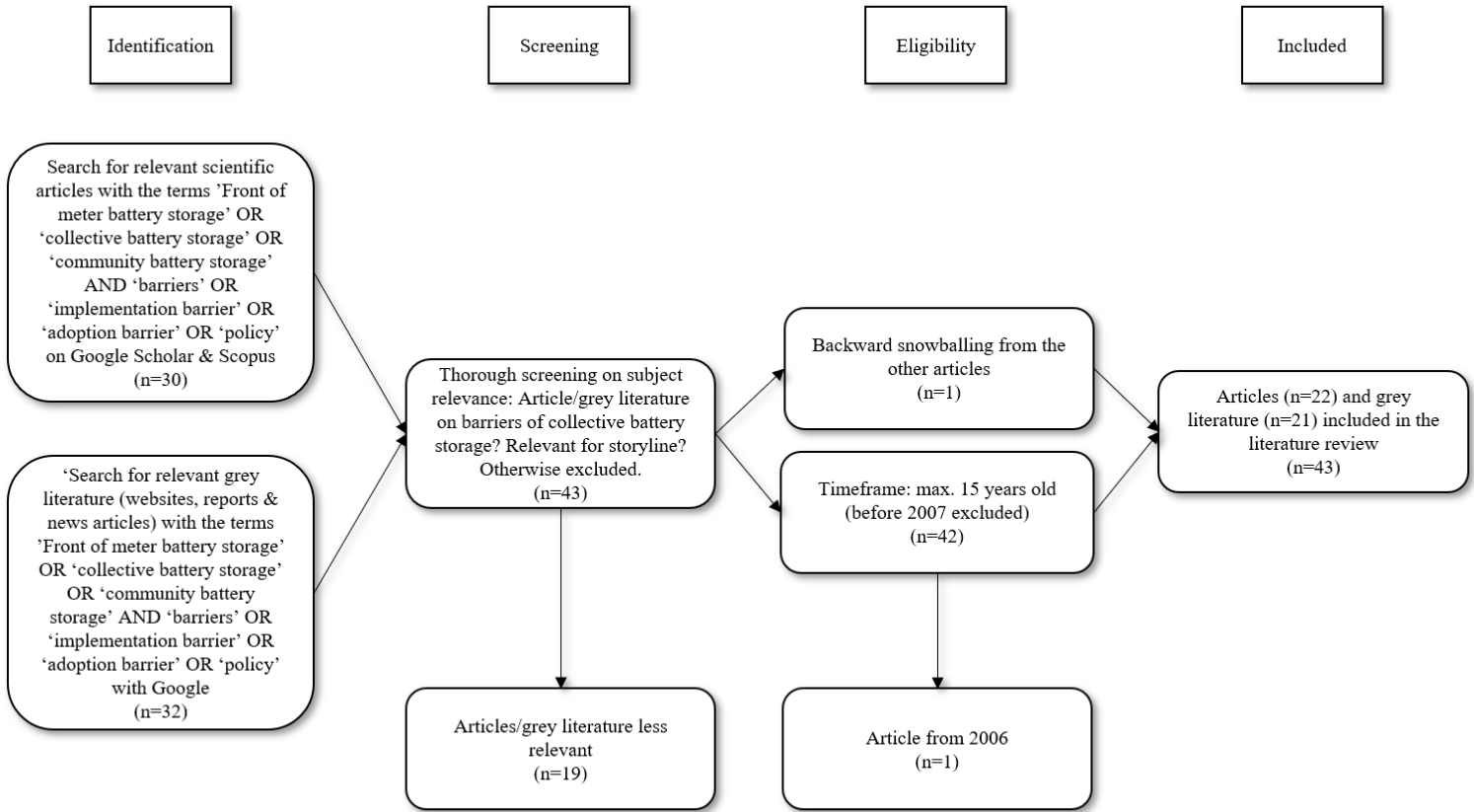


Figure 24: Literature review process for chapter 4

Appendix B Stakeholder analysis

In this section, the stakeholder landscape will be elaborated. Conducting a stakeholder analysis is deemed necessary since it provides the decision maker with viable strategic information about the groups that might affect the successful integration of collective FTM battery storage. Next to that, research methods in the remaining study will primarily be focused on key stakeholders.

The power-interest grid is a tool that uses the dimensions of power and interest of different stakeholders in the system to differentiate influential stakeholders that need to be managed closely from stakeholders that have less influence on the company or system (Ackermann & Eden, 2011). The power-interest grid of this thesis is used to direct further analysis toward key stakeholders while still taking a broad definition of all stakeholders. Interviews are conducted mostly with key stakeholders. It is important to note that the power-interest grid is derived mainly from conversations with sector experts and the researcher's own interpretation. This means that the power-interest grid's goal is not to give definite results, but it is merely used to support further analyses in this thesis. The power-interest grid is depicted in Figure 25. Table 21 enlists all relevant stakeholder groups, their roles in the system, and their relative importance in the system.



Figure 25: Power-interest grid of battery landscape

Stakeholder group	Role	Power/interest
Battery project developer	The battery project developer is the party that initiates and realizes battery storage projects. The battery project developer usually outsources multiple tasks to other parties. This party might also be the operating company after the realization of the project.	Key stakeholder. High power and high interest. Manages the battery development and is ultimately responsible.
Technical service provider	The technical service provider is responsible for the installation process and maintenance of the battery project.	High interest, but less power. Acts more as a technical subcontractor.

Battery operator	The battery operator is the party that controls the battery assets and determines the way the battery is deployed on different electricity markets. The battery operator can be an energy company that hedges its imbalance with the battery. This party can also be a balancing service provider (BSP) or the battery project developer itself. The battery operator often also is the owner of the battery, but this is not exclusively the case.	Key stakeholder. High power and high interest. Decides how the battery is used and on which electricity markets are traded.
System integrator (EMS)	The system integrator develops the software that controls the energy system and battery (the EMS).	High interest, but less power. Delivers turnkey software to battery projects.
Hardware manufacturer	Manufacturer of the battery cells and accompanying hardware, like cables etc.	High interest, but less power. Delivers battery and accompanying hardware.
Energy company	An energy company can have multiple roles. They can act as the battery operator or are the party that supplies the battery operator with an energy contract.	Moderate interest and moderate power. It depends on the role the energy company takes in specific battery projects.
Investor	The external investor of the project. Given the high upfront costs of battery projects, external investors are needed. These investments usually come from banks.	High power, but less interest. Investors are pivotal to facilitate battery projects, but they see batteries just as a lucrative investment.
TSO	Transmission System Operator. The role of the TSO is to safeguard the proper functioning of the high-voltage grid and that the electricity transmission standards are met.	Little interest and little power. This thesis focusses mostly on batteries connected to the LV/MV networks of the DSOs.
DSO	Distribution System Operator. The DSO is responsible for maintaining and developing the distribution system.	Key stakeholder. High power and high interest. The DSO ‘rules’ the distribution network and needs flexibility to alleviate congestion problems.
Municipality	The municipality is an important stakeholder in the processes of granting permits for battery projects.	Moderate power and moderate interest. Wants to reach municipal sustainability goals and is important in permit processes.
Government	The government lays down the institutional conditions for battery storage projects. The way in which the government tries to reach its sustainability goals influences the battery landscape in the Netherlands to a large extent.	High power but less interest. Wants to reach governmental sustainability goals but focusses on a broad spectrum of renewable energy technologies. Batteries are solely a means to an end and not a priority.
ACM	The ACM is the Dutch market supervisor. The ACM plays an important role in the construction and changing of the <i>Netcodes</i> and controls market players if they act compliant with legislation.	High power but less interest. Lays down a lot of the institutional conditions and <i>Netcodes</i> for fair competition between market players but has less interest in the application of batteries.
Industry associations (Energy Storage NL /Netbeheer Nederland)	Industry association that lobbies for the increased use of battery storage in the Dutch energy system/umbrella organization of the TSO and DSOs in the Netherlands.	High interest but less power. Lobbies for increased use of batteries, but only has moderate power/high interest but moderate

		power. Netbeheer Nederland has high interest due to the net congestion problems and can influence for instance policy development by the ACM.
--	--	---

Table 21: Relevant stakeholders

Three key stakeholders are identified: the battery project developer, the battery operator, and the DSO. Given the sheer institutional influence of the government and the ACM and the policy viewpoint of the analyses, these are also considered.

Appendix C Energy profiles companies

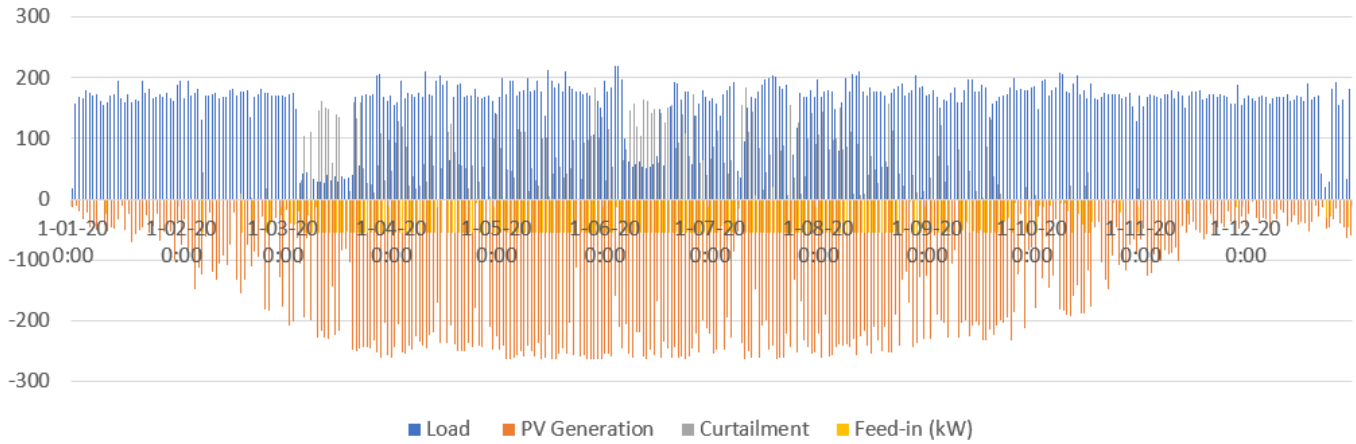


Figure 26: Yearly energy profile company A (in kW)

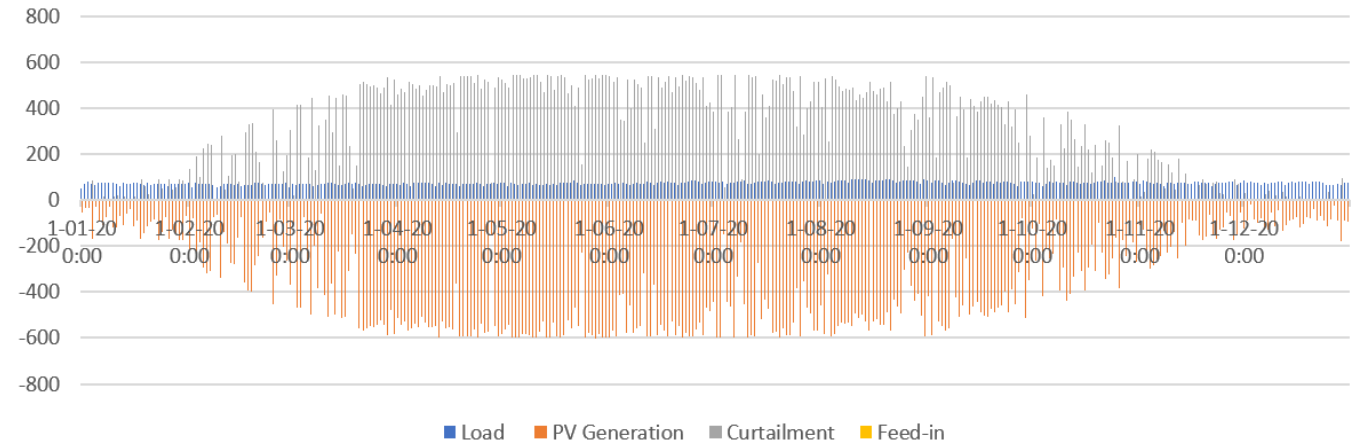


Figure 27: Yearly energy profile company B (in kW)

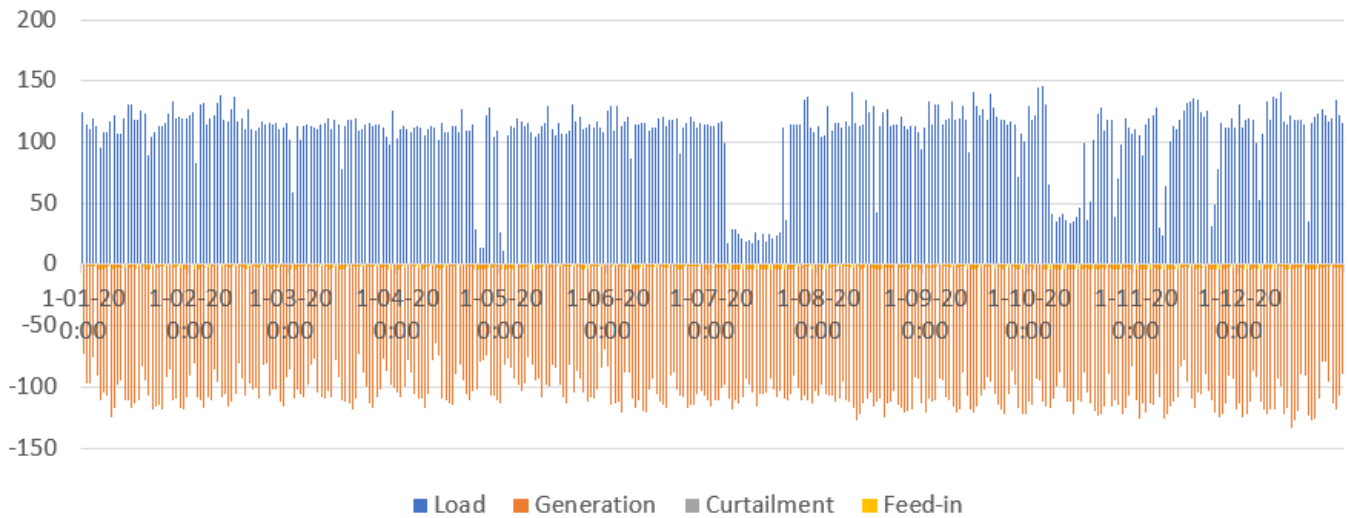


Figure 28: Yearly energy profile company C (in kW)

Appendix D Batteries in electricity markets

The current battery landscape in the Netherlands is rapidly developing. Currently, a battery power combined of almost 20 GW has been requested at the Dutch grid operators (Zwang, 2022). In order to understand why battery storage has seen a surge in interest over the last couple of years, one needs to understand how economic value is created with these systems. FTM battery systems can create value on different electricity markets. In the upcoming section, the Dutch energy system and different relevant electricity markets will be discussed.

Electricity markets

The electricity system of the Netherlands is comprised of a lot of different actors with specific roles. These roles are legally defined. An important role is played by the *balance responsible parties* (BRPs). BRPs are market parties, or representatives elected by market parties, who must inform TenneT on a daily basis about their planned energy transactions with other BRPs for the next day. This is because these transactions lead to transmissions in the electricity grid (Energy Storage NL, 2016; Tennes, 2019). These transactions are bundled into the BSP's Energy Program (E-program). The value of electricity changes per hour depending on the current demand, outages, weather forecasts, fuel and CO₂ costs (Tennes, n.d.). This is why different markets exist with different purposes and timeframes. Figure 29 gives an overview of the different electricity markets (derived from Energy Storage NL (2016) & TenneT (n.d.)).

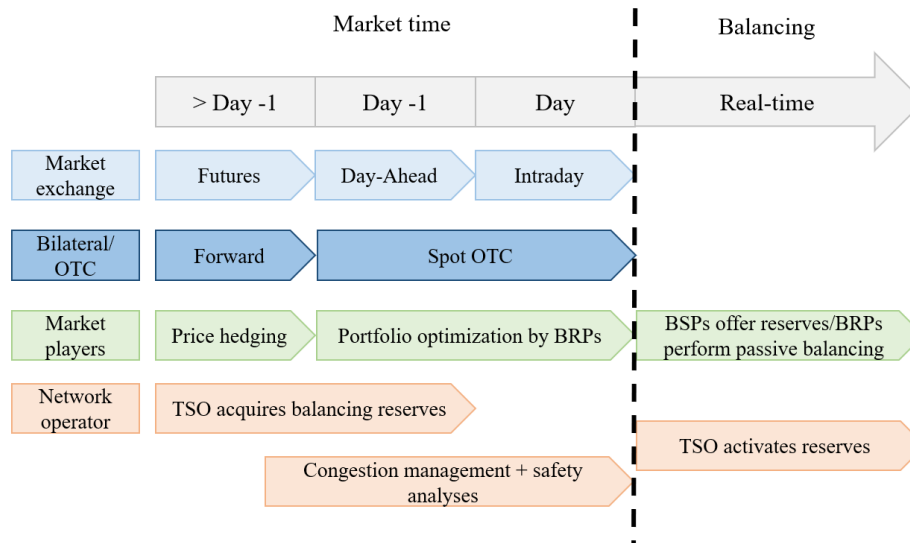


Figure 29: Electricity markets in the Netherlands

Forward and Futures Market

On the forward and futures market, electricity is traded between four years and one month before delivery. Forward and futures are both financial products, that are settled against spot market prices for future delivery periods. Futures are standardised contracts that are traded on the ENDEX spot exchange, whereas forwards are traded bilaterally (over the counter, or OTC) and are not standardised (Energy Storage NL, 2016). Bilateral trade is trade directly between two parties, without the interference of a trader or exchange. The forward and futures market are particularly important for large producers and consumers that want to hedge the electricity prices for a certain amount of time, since this gives them financial certainty that they can sell/buy electricity for a definite price.

Day-Ahead Market

Trading on the day-ahead market takes place one day before the delivery of electricity. BRPs must submit their bids by 12:00 o'clock noon, and specify by hour how much the market participant intends to produce and/or consume the following day (Energy Storage NL, 2016). The EPEX auction system then determines the intersection of the electricity demand and supply. This intersection determines the electricity price and volume for each hour. More energy is generally traded on the EPEX day-ahead market than on the forward market because energy is generally cheaper on this market. The market clearing price per hour of the day-ahead market is often referred to as 'the electricity price', since it best reflects the value of electricity during different hours (Tennet, n.d.).

Intraday Markets

When the day-ahead market closes, the intraday market opens. The intraday market is used by BRPs to optimize their E-program. This is needed because electricity demand or renewables feed-in might have changed, leaving their portfolio in imbalance. The intraday market allows direct trading in electricity between market parties up to five minutes before delivery is due, in order to eliminate imbalance in their portfolios. In contrast to the market clearing principle on which the day-ahead market is based, the prices in intraday trading are set via the pay-as-bid principle, in which the trade deal is completed as soon as a sell bid is accepted by a buyer (Tennet, 2019). The minimum bid size in the day-ahead and intraday markets is 100 kW (TNO, 2021).

Balancing markets

The grid frequency must at all times be held at 50 hertz by the TSO. If a BRP does not adhere to its E-program, this can cause imbalance on the grid. The BRP is financially responsible for its own imbalance. The BRP has the opportunity to correct its own imbalance before the imbalance settlement period (ISP) ends. They can do that by making a trade on the intraday market, or by changing the load/production of their assets. At the same time, TenneT publishes the imbalance price. TenneT settles the BRP for its imbalance according to the imbalance price. If the BRP contributed to an imbalance in the system, the BRP is penalized the imbalance price of that moment by TenneT. If the imbalance of the BRP supported the system, then TenneT pays the BRP. This is called passive balancing.

Since the voltage of the grid must at all times be stable, TenneT procures three different kinds of balancing products: Frequency Containment Reserves (FCR), automatic Frequency Restoration Reserve (aFRR) and manual Frequency Restoration Reserve (mFRR). These ancillary reserves are provided by *balancing service providers* (BSPs). Each of these reserves has different technical requirements. If the frequency is different than 50Hz, after a few seconds first FCR is activated.

FCR

FCR, also known as primary reserve, is the reserve that is procured by TenneT via an auction on a weekly basis. The purpose of these primary reserves is to cancel out frequency disruptions throughout the whole European high-voltage grid. FCR reserve is automatically activated based on the frequency of the grid. FCR reserves need to have a power of at least 1 MW and capacity of at least 1MWh. It is possible to pool multiple energy assets in order to reach the capacity threshold of TenneT. Market parties that facilitate this are called *aggregators*.

aFRR

aFRR and mFRR are balancing services that are procured inside the Netherlands. Every half year TenneT calculates how much balancing reserves are needed. aFRR or secondary reserve is automatically activated in the area in which the imbalance takes place, just after FCR is activated. This capacity is purchased at a daily auction. BSPs are contracted by TenneT via ‘bid-obligations’, which means that TenneT contracts BSPs that have to provide balancing energy bids to TenneT at certain times (TenneT, 2022). In this way, ample aFRR is always available. aFRR also needs to have a capacity of at least 1 MWh and power of at least 1 MW.

mFRR

If there is a longer or larger imbalance on the grid and FCR and aFRR cannot deliver sufficient balancing, TenneT can activate mFRR. This happens manually. mFRR does not work with bid-obligation contracts but with capacity contracts. Market participants need to have the capacity available at all time and they are offered a standard remuneration by TenneT based on the offered capacity plus an additional fee if the reserve is activated. mFRR needs to have a power of at least 20 MW. Figure 30 shows the activation of the different balancing reserves in case of a frequency drop (Tennet, n.d.).

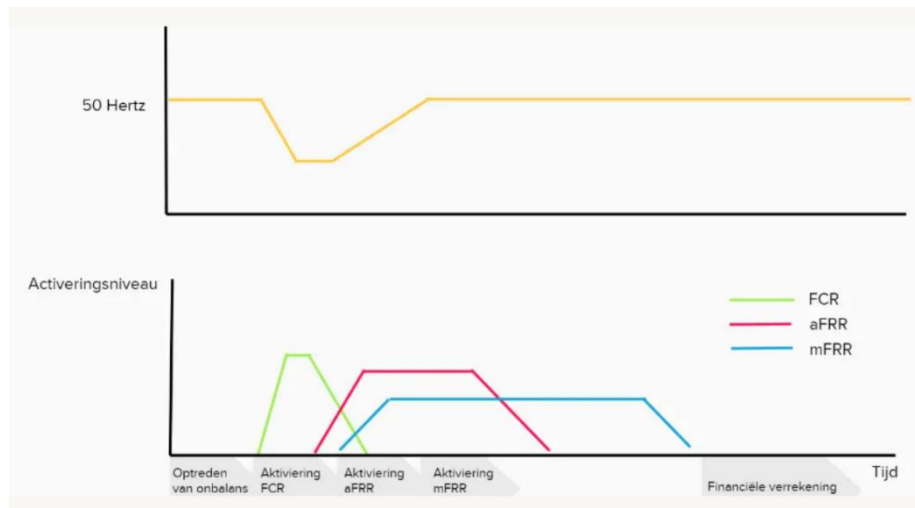


Figure 30: Activation of FCR, aFRR and mFRR after an imbalance event (Tennet, n.d.)

Congestion management

Next to these markets, FTM battery storage can create value in congestion management via the GOPACS platform. This is a relatively new market issued by TenneT and the regional DSOs in the Netherlands (GOPACS, n.d.; Tennet, 2022). On the platform operators of battery storage, recognized as Congestion Service Provider (CSP) can use their storage capacity for a fee to relieve congestion on the grid. An advantage of this platform is that its technical requirements are less stringent than the TenneT balancing markets and that assets with relatively low power output can also participate.

The business case for FTM battery storage

Given the high capital costs of battery systems, the business case for FTM battery storage is often complex. In order to make these systems profitable, different value streams and applications need to be combined. This is called value stacking (Englberger, Jossen & Hesse, 2020; Greenwood et al., 2015; Parra et al., 2017). FTM BESS can be deployed on various electricity markets, even within the same day. This section describes how batteries can create value on the different electricity markets.

Energy management plays a crucial role, because the battery must always be capable to (dis)charge to maximize financial revenue. EMS software therefore is needed (CE Delft, 2021). Batteries are not suited to take part in the futures and forward markets, since the deployment of batteries can vary in short periods of time and is only predictable in the short term. These are therefore not taken into account. Next to this, the fact that the minimum power of a battery storage system must be 20 MW to deliver mFRR, means that this ancillary service is out of the scope of this research.

Day-ahead and intraday markets

A battery storage system can be deployed on the day-ahead markets and intraday markets by charging when the electricity prices are low and discharging when the prices are high. This process is called energy arbitrage. An example of this process is pictured in Figure 31.

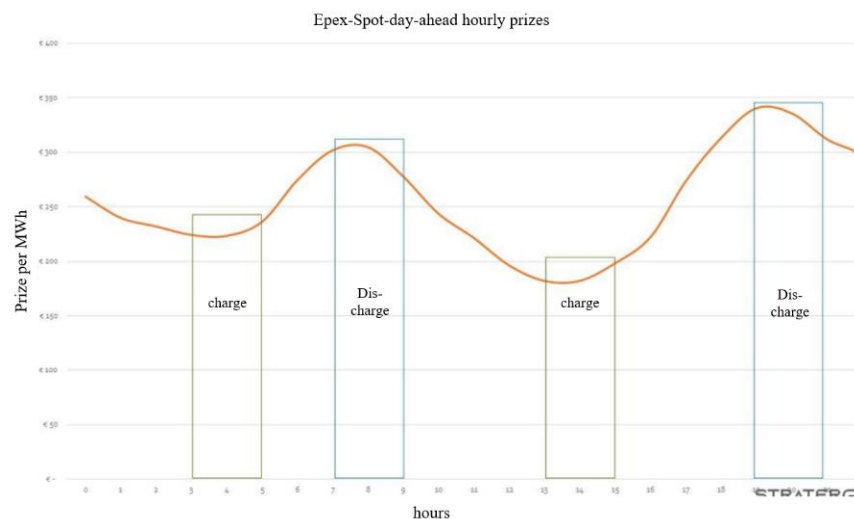


Figure 31: Energy arbitrage on the day-ahead market (Derived from Zwang (2022)).

The market size of the day-ahead market will approximately be 1,3 GW 2025 and 1,9 in 2030 (CE Delft, 2021). The market size of the intraday market is hard to estimate, since the volumes and prices traded on the intraday market are not publicly available. Recently these markets have become interesting for battery operators given the high energy prices and increased volatility on these markets due to uncertainty in the energy sector. Figure 32 shows the increased spot prices and price volatility in recent times (Göss, 2022). CE Delft (2021) expects that battery operators can make 27.000 euros per MW per year on the day-ahead market. The intraday markets normally have a slightly higher price volatility than the day-ahead market. The trading volumes on this market are increasing due to the increase in installed renewable, fluctuating generation capacity.

Solar parks that get EPEX-spot day-ahead prizes for the electricity that they feed in, nowadays more often curtail their renewable generation because of negative spot prices. This is done because otherwise they have to pay the electricity price to feed in energy. FTM BESS can store the generated electricity during negative prices, so that the generation units don't have to be curtailed and no renewable energy is lost. The energy stored in the battery can be sold later that day when the electricity price is higher. This process is called load shifting.

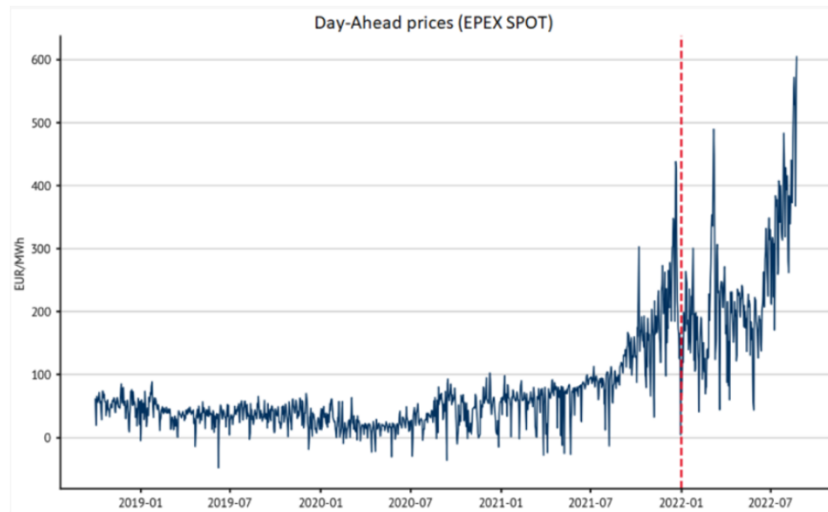


Figure 32: EPEX SPOT day-ahead prices (Göss, 2022)

Balancing reserves

BSPs receive a weekly capacity fee for offering FCR, depending on the amount of MW offered. BSPs can bid on blocks of four hours, whereafter the price is equal to the highest awarded bid. The current remuneration for FCR will approximately be 15 euros/MW/h on average in 2025, which comes down to a maximum of 122.000 per MW per year (CE Delft, 2021). It is expected that the remuneration for FCR services will decrease in the upcoming years, because the market will be saturated quickly with ample battery storage being available. The market size of FCR is 214 MW in the Netherlands and is expected to remain this size in the upcoming years.

TenneT organizes auctions to procure the amount of aFRR needed. The bids of the BSPs are ranked in a merit order list, which means they are ranked by price in ascending order (Next Kraftwerke, n.d.). An expensive order is thus less likely to be called by TenneT. BSPs that offer aFRR receive a capacity remuneration and an additional fee if their capacity is deployed. Combined these can amount to maximally 228.000 euros per MW per year (CE Delft, 2021). It is expected that the fees for aFRR remain merely constant in the upcoming years, since the amount of connected battery will keep pace with the growth in aFRR demand. The market size of aFRR is expected to be 530 MW in 2025 and 690 MW in 2030 (CE Delft, 2021).

Passive balancing

Due to increased installed capacity of renewables, capacity remunerations and imbalance prices are currently high. The imbalance price is based on the most expensive asset that is activated on the aFRR and mFRR together. The balancing market can be very lucrative, but the imbalance price is hard to predict. When there is imbalance, the EMS of a battery system decides whether to charge or discharge based on the expected imbalance price. This method requires a lot of upfront market information that needs to be incorporated into algorithms. A good algorithm is expected to yield 75% of the maximal benefits of passive balancing, which would amount to a maximum of 160.000 euros/MW/year (CE Delft, 2021). Because the remunerations of the balancing market are linked to aFRR, it is expected that these will also stay relatively constant over the upcoming years. The market size of the balancing market is expected to be 250 MW for batteries in 2025 and 500 MW in 2030 (CE Delft, 2021).

Congestion market

It is expected that because of the adjustments to the *Netcode*, GOPACS will drastically increase in size (Zwang, 2022). There is currently a big deficit of transport capacity in certain areas in the Netherlands and installed renewable generation will only increase. Next to that, GOPACS now only takes place on the intraday market, but it will be extended to the more liquid day-ahead market in the future. That is why GOPACS might become a viable value stream for FTM battery storage in the future. Currently, a battery operator can earn up to 42.000 euros/MW/year on the GOPACS platform.

Overview

An overview of the market sizes of the different possible value streams is given in Figure 33 (adapted from CE Delft, 2021). Given the non-transparency of the intraday market, no estimates can be made. Given the current institutional developments in the area of congestion management, the GOPACS market size is hard to predict and thus left out of the analysis. The maximum economic potential for batteries on the different markets is shown in Figure 34 (derived from CE Delft, 2021). This maximum economic potential is calculated by modelling the electricity markets in 2025 and 2030 using the Powerflex-model. All assumptions can be found in CE Delft (2021). The future market potential of GOPACS is also hard to predict. That is why the maximum economic potential is kept at the same threshold for 2030. Zwang (2020) claims that this market can grow to more than 3700 MW in the upcoming years, which could make GOPACS a vital value stream for the FTM battery business case.

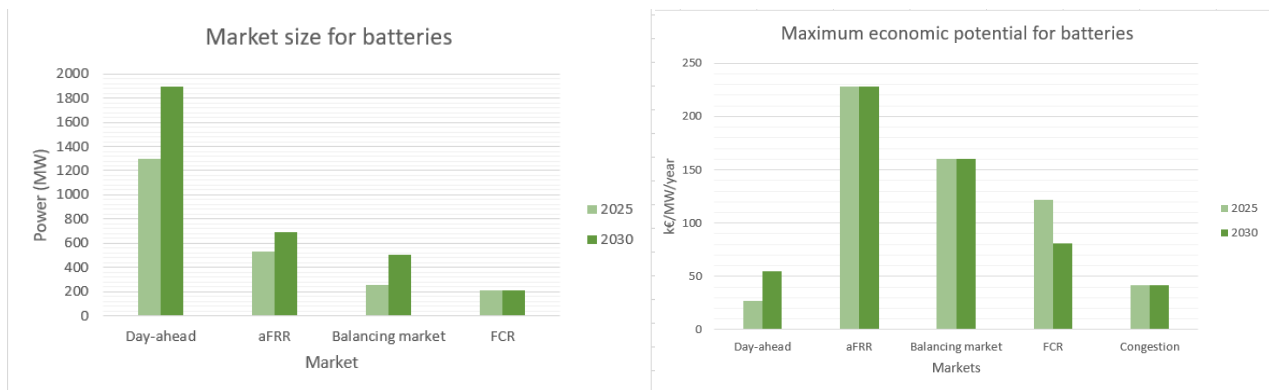


Figure 33: Market size for batteries (adapted from CE Delft (2021))

Figure 34: Economic potential for batteries (adapted from CE Delft (2021))

On the basis of the current price levels, most batteries are deployed on FCR, aFRR and passive imbalance market. Note that in the not too distant future, remuneration for the FCR market will dry up because the market probably will be saturated. Currently, day-ahead and spot market prices and volatility are getting more interesting and on some days batteries will also trade on these. But passive imbalance will most likely remain more viable than the day-ahead market, since it offers more opportunity to trade (trade windows of 15 minutes) than the day-ahead market (trade windows of an hour). Normally, prices go up when you come closer to the actual delivery time. Hence the prices on the passive imbalance market are usually the highest and the day-ahead prices the lowest.

It is very important to note that trading on some markets is mutually exclusive with other value streams. For instance, a battery operator cannot offer the same power on both the FCR and aFRR because the contracted FCR must be available at all times. Next to that, providing TenneT with ancillary services goes hand in hand with a lot of technical requirements. The battery must have significant power and must be able to deliver that power for a considerable amount of time. Passive imbalance is subject to less stringent technical requirements, but trading on this market is quite hard and requires a lot of market, technical and IT knowledge.

Given the complexity of combining value streams, only specialized parties with the help of an advanced EMS can bring this about with FTM battery systems. The way in which the battery system is used and on which markets is subject to a lot of factors. These factors include whether the battery storage system is enlisted as FCR, the kind of grid connection the battery has, the power and capacity of the battery, the type of battery and the goal of the operator of the battery (Zwang, 2022).

Appendix E Interview report

E1 Interview Questions

1. Mag ik dit gesprek opnemen en gebruiken voor mijn scriptie?
2. Wat is je functie bij [X] en hoeveel ervaring heb je in de de energie/batterijwereld?
 - a. Ervaringen hiervoor?
3. Welke rol vervullen jullie als [X] binnen de energiewereld?
 - a. Wat zijn jullie doelstellingen?
 - b. Waar hechten jullie waarde aan als bedrijf?
4. Wat zijn jullie belangrijkste doelen bij het plaatsen van een batterij?
 - a. Hoe ziet de businesscase eruit?
 - i. Hoe ziet die er momenteel uit?
 - ii. Welke waardestromen/energiemarkten combineren?
 - iii. Wat zijn de belangrijkste onzekerheden?
 - iv. Hoe zal deze er over 5 en over 10 jaar uitzien?
 - b. Hebben jullie andere, 'soft' doelstellingen als [X] zijnde?
 - i. Netcongestie tegengaan?
 - ii. Integratie van renewables?
 - iii. Stabiliteit netwerk?
5. Wat zijn voorbeelden van jullie batterijprojecten?
 - a. Wie zijn daarbij belangrijke stakeholders?
 - b. Partners voor aansluiting/hardware etcetera?
6. Zijn er nog bepaalde belangenverstengelingen tussen verschillende stakeholdergroepen? Fricities?
 - a. Hoe dealen jullie daar mee? Bijvoorbeeld als jullie BuCa in gevaar komt?
7. Wat zijn momenteel barrières voor voor de meter opslag in Nederland?
 - a. Waar loopt [X] nu tegenaan?
8. En waar liggen momenteel de kansen?
 - a. Bijvoorbeeld op welke markten? Binnen welke sectoren?
 - b. Wat is er nodig om die kansen te versterken/te houden?
9. Wat zou FTM storage in Nederland meer succesvol maken? Wat zou de integratie van deze systemen verbeteren?
 - a. Op technisch vlak
 - i. software, hardware, ems. Veiligheidsstandaarden?

- b. Op economisch/financieel vlak.
 - i. Subsidies/prijsprikkels?
 - c. Op sociaal vlak
 - i. Maatregelen die stakeholders dezelfde kant op krijgen?
 - d. Op institutioneel vlak
 - i. Wet- en regelgeving?
 - e. Organisatorisch
 - i. Bureaucratie verminderen? Samenwerken van instanties?
 - f. Bestaan er nog trade-offs tussen deze elementen?
 - i. Hebben jullie nog invloed op een van deze elementen?
10. Wat weegt voor jullie het zwaarst? Dus wat moet volgens jullie echt gebeuren om het batterijlandschap in Nederland succesvoller te maken?
11. Welke rol denk jij dat FTM batterijopslagsystemen gaan vervullen in het energiesysteem van de toekomst?
- a. Op welke energiemarkten?
 - b. Op welke manier en door wie geëxploiteerd?
 - c. Welke wet/regelgeving zorgt ervoor dat we deze situatie gaan bereiken?
12. Voorzie je nog additionele problemen in de toekomst met deze systemen? Zo ja, welke?
13. Kunnen wij lessen leren van andere landen?
- a. Bv de UK, Duitsland, Amerika?
14. Heb je nog andere comments over beleid, stakeholder complexiteit, technologieën, financiële prikkels, haalbaarheid & schaalbaarheid van voor de meter opslag of de impact die batterijen zullen hebben op ons toekomstige energiesysteem?

E2 Slide deck interviews

EQUANS **TU Delft**
30 december 2022
 Versie 1.1

De rol van voor de meter batterijopslag in het toekomstige energiesysteem van NL

1

Thesis in het kort

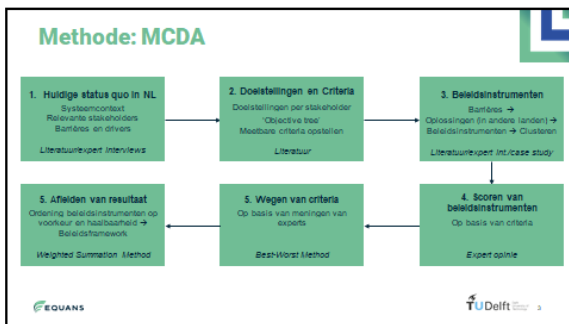
Onderzoeksvraag:
 Hoe kunnen verschillende beleidsinstrumenten de succesvolle integratie van voor-de-meter batterijopslag in Nederland bevorderen?

- Focus op medium-scale commerciële lithium-ion voor-de-meter batterijsystemen
- 'Aansluitingsoverstijgende/collectieve' batterijen

Welke rol zullen deze systemen vertolken in de energietransitie en het energiesysteem van de toekomst in NL?

EQUANS

2



Succesvolle toekomstige FTM storage

Vanuit het perspectief van [X]

- Wat zijn huidige kansen die jullie als [X] zien in de markt?
- Wat zijn de huidige barrières?

EQUANS

4

Succesvolle toekomstige FTM storage

Vanuit het perspectief van [X]
 Wat zou de huidige gang van zaken verbeteren? Beleidsinstrumenten op het gebied van:

- Techniek**
Aanpassingen aan software, hardware, standaarden?
- Financieel**
Financiële stimulansen, subsidies, lenen, meer zekerheid in BUC?
- Wet- en regelgeving**
Aansluitingen- en transportovereenkomsten, energieverdragen, wettelijke bepalingen?
- Sociaal**
Sociale incentives?
- Organisatorisch**
Incentives voor stakeholder partnerships, vermindering bureaucratie?

EQUANS

5

Succesvolle toekomstige FTM storage

Vanuit het perspectief van [X]

- Hoe ziet de ultieme voor de meter opslag eruit?
- Rol voor de meter batterijopslag in energietransitie en toekomstige systeem?
 - Op welke markten?
 - Op welke manier geëxploiteerd?
 - Door wie?
- Wet/regelgeving om deze situatie te berekenen?
- Beren op de weg?

EQUANS

6

EQUANS
 EMPOWERING TRANSITIONS

Bedankt!

7

- Hoofddoelstelling netbeheerder:
 - Aansluitplicht (geldt altijd, niet mogelijk te differentiëren op wat er achter de meter gebeurt. First come first serve!)
 - Momenteel ontstaan knelpunten! De scenario's blijken te dun geschat door meer dan verwachte duurzame opwek en elektrificatie.
 - Transportplicht (geldt niet altijd)
 - Dit vervalt in congestiegebied!
 - Nieuwe verplichting: onderzoek doen in congestiegebied. Daarna bouwen!
 - In principe geen doelstelling tot flexibiliteit/balancering
- Momenteel bezig met kijken hoe congestie 'slimmer' aangepakt kan worden:
 - 'Loze' ruimte op het net gebruiken. Het net wordt maar voor enkele tientallen procenten gebruikt, ook in rode congestiegebieden. Het net is gebouwd op de vermogenspiek die bijna nooit bereikt wordt. Er wordt gekeken naar theoretische i.p.v. fysieke belasting. Daarom: non-firm ATO's.
 - Drie oplossingen: Curtailment tegen een vergoeding. Flexibele bedrijfsprocessen. Flex (opslag/conversie).
 - De grote discussie: wat wordt de rol van de netbeheerder? Spagaat bij de netbeheerder. Gaan we zelf iets actief in de markt doen? Bijvoorbeeld batterijpartijen bepaalde plekken voor een batterij in congestiegebied aanbieden. Of laten we het volledig over aan de markt? Dit kan interessant worden!
 - Batterijen mogen dus niet 'rechtstreeks in het net' geplaatst worden. Hierom altijd een aansluiting voor de meter. Batterij staat dan eigenlijk achter de meter, maar toepassingen is voor de meter.
 - Doordat de netbeheerder dit niet mag, wordt er zeer prijzig uitgebreid voor maar congestie van een paar uur per jaar. Als zij een batterijasset mogen hebben, dan is dat zo opgelost.
 - Zelfs als er een batterij geplaatst worden, moet het net verzwaaard worden.
- Barrières:
 - Huidige vergoedingen GOPACS vaak te laag. Partijen kiezen voor andere oplossingen.
 - Spagaat Netbeheerder (zie boven).
 - Voor de meter mag er eigenlijk nog niks in Nederland. Stricte regels voor netbeheerders: netcode, elektriciteitswet, tarievencode elektriciteit. Dus ze mogen geen actieve deelnemer zijn in het net. Hoe plaats je dan een batterij voor de meter zonder dat de netbeheerder hier een rol in speelt?
 - Biedingen voor flexibiliteit van marktpartijen vaak te hoog (7-10x de elektriciteitsprijs). Limiet van uitgaves netbeheerder in congestiegebied (prijs/MW/jaar), dus er komt niet veel van terecht.
 - Batterijen worden momenteel niet meer aangesloten door de netbeheerders. Redenen:
 - Er moet invoer- en afnamecapaciteit reserveren. Dit helpt congestie in de hand!
 - Ook door de enorme aanvraag van batterijen. Die is groter dan het gehele vermogen van ons elektriciteitsnetwerk.
 - Discrepancie tussen de intenties van marktpartijen en de intenties van de netbeheerder. Verdienen op de EPEX SPOT staat bijvoorbeeld vaak haaks met congestie.

- Foute prikkels: bv Eneco wil overdag zijn wind op zee opslaan met een batterij in Amsterdam, terwijl er daar momenteel een tekort aan aanbod is. Precies wat je niet wil!
 - Er zijn afspraken nodig! Non-firm ATO's. Dit kan natuurlijk de businesscase drukken.
 - Wie gaat de batterij plaatsen, van wie is hij en hoe zorgen we ervoor dat hij ook echt de netten ondersteund?
- Het energiesysteem van de toekomst:
 - De toekomst is flex. Het gasnet is 15x zo groot als ons elektriciteitsnet en we moeten om! Flex enorm belangrijk in elektrificatie. Want wij kunnen nooit in 30 jaar het systeem 15x verzwaren.
 - Batterijopslag gaat een grote rol krijgen! In de rol van netondersteuning.
 - Lastig: gaat dit om een aantal grote batterijen, of om heel veel kleintjes. En voor of achter de meter?
 - Het net moet ook slimmer!
- Eisen/criteria batterijen:
 - Niet discrimineren achter de aansluiting!
 - RFG eisen! Kortsluitvermogen/reactietijd/afschakeling bij problemen etc.
 - Bij grote batterijen zijn deze eisen best wel fors.
 - Gemeentelijke eisen voor omgevingsvergunningen. Inpassen in het milieu, bijvoorbeeld in een gebouw.

Functie: Board member at battery operating company
08/12/22

Date:

- Huidige functie: board member bij Bedrijf X. Hiervoor: Verduurzaming van vastgoed. In 2018 met drie man Bedrijf X begonnen, dus 5 jaar in de batterijwereld.
- Waarom zijn jullie in de batterijwereld ingestapt?
 - Gat gezien in de energietransitie. Zon/wind niet regelbaar, dus een business case voor batterijen. Dat kon toen nog niet, maar er moest een businesscase komen. Als eerste bijzijn!
- Huidige verdienmodel:
 - Snelle, ondiepe batterij (2C). Ook snel leeg, in 37 minuten. Deze zijn dus goed voor korte pieken.
 - Onbalansmarkt is een kwartiermarkt en passief. Per 3 minuten wordt er door TenneT een signaal gestuurd, maar dat kan nog veranderen. Eindwaarde wordt betaald, dus hier kunnen grote verliezen op gemaakt worden. Oplossen door team van 4 IT'ers. Deze verliezen moet je dag daarop wegraden: andere partijen pakken jouw onbalans.
 - Batterijen worden nu vaak beheerd door bv Eneco om onbalans te hedgen van eigen portfolio.
- Doelstellingen bedrijf X:
 - Gas- en kolencentrales vervangen op lange termijn
 - Congestie verhelpen.
- Barrières FTM batterijopslag:
 - Belangrijkste: Transportkosten. kWmax en kW kosten. 80.000 per MW per jaar kan dit kosten, dat doet het meeste pijn.
 - Stikstof
 - Wet- en regelgeving private netten. MLOEA, GDS, allemaal administratieve rompslomp!
 - Financieren. Investeringsrisico's. Geen subsidies ook. Banken zijn huiverig omdat non-firm ATO's en CBC contracten de businesscase kunnen beïnvloeden.
 - Netbeheerders zijn bang voor gebruik van batterij dat congestieproblematiek alleen maar verergert. 'heen en weer pingelen'.
 - Lastige plaatselijke samenwerking
 - Nederlandse markt wordt overspoeld door 'cowboys', batterijpartijen die overal maar een aansluiting aanvragen zonder verstand van zaken en de daadwerkelijke wil om een batterijsysteem te implementeren. Dit is dus een soort 'handoekje leggen'. Dit geeft een vertekend beeld van de daadwerkelijke interesse in het operatoren van batterijsystemen. Dit zorgt ervoor dat de netbeheerder niet meehelpt, want die zeggen dat de transporttarieven niet naar beneden hoeven, kijk maar naar de aanvragen van batterijcapaciteit! Dus deze aanvragen werken averechts. Wordt niet gerealiseerd, omdat de Nederlandse markt heel anders werkt dan in het buitenland.
 - De markt wordt dus niet echt overspoeld. Neerzetten en ontwikkelen van batterijen kost heel veel tijd. ATO's, stikstof, vergunningen, wet- en regelgeving. Dus waarschijnlijk wordt wat in de pijplijn zit lang niet allemaal gerealiseerd.
- Kansen FTM batterijopslag:
 - Kleinere batterijen en die dan collectief gebruiken. Dit is echter complex en weinig partijen doen dit. Wij focussen op zo groot mogelijk; dit geeft schaalvoordelen!
 - Batterijen bij zon- en windparken
 - Batterijopslag binnen GDS'en vanwege gedeelde transportkosten.
- Beleid tot betere integratie van FTM batterijopslag:

- Hordes wegnemen: MLOEA's, wet- en regelgeving, gemeentevergunningen (bijvoorbeeld kruimelvergunningen). Het proces wordt onnodig ingewikkeld terwijl er op veel plekken hele acute vraag is. Dit wordt nu vaak ingelost met bijvoorbeeld dieselaggregaten. Dus belang dat de batterij er snel komt!
- Vergoeding voor congestie! Dit zou veel onzekerheid wegnemen! Maar helaas, transportkosten zijn het verdienmodel van netbeheerders. Er moeten afspraken komen. Bijvoorbeeld; tegen een gereduceerd transporttarief helpen wij de netbeheerder met congestie! Dit zou perfect zijn.
- De rol van FTM batterijen in het toekomstige energiesysteem:
 - Tegen congestie
 - Balanceren net
 - Vervanging gas- en kolencentrales
 - Pieken van zon en wind opvangen
 - Allemaal wel op dagbasis. Seizoensopslag is te duur met batterijen! Batterijen bieden dus 'échte flex'.

Functie: Energy Flexibility Manager at a Technical service provider
and board member at industry Association Energy Storage NL

Datum: 22/12/2022

- Huidige kansen vanuit perspectief technische dienstverlener
 - Meerdere partijen zien een businesscase (door onbalans en intermittency van renewables, waarde van energie omhoog. Verwachting is dat deze prijzen niet meer naar het niveau van voor de energiecrisis zullen gaan)
 - Dus veel grootschalige batterijaanvraag! BuCa zit in het inzetten, maar barrière ligt in het realiseren. Heel complex!
 - Technische dienstverlener kan een belangrijke rol in aansluiten spelen. Betrouwbare partner! Succesvolle, betrouwbare, tijdige oplevering van projecten. EPC partners!
- Barrières:
 - Verhoging transporttarieven. Verhoging kostprijs.
 - Beschikbaarheid netcapaciteit
 - Restricties voor batterijen van de netbeheerder in bepaalde gebieden
 - Netbeheerders proberen batterijpartijen te ‘duwen’ naar regio’s waar geen problemen zijn.
 - Onbalansmarkt levert het meeste geld op, dus wordt het meeste gedaan. Maar dan kan je het gedrag van de batterij niet voorspellen. Gaat tegen alle normale patronen in door de handelspositie!
 - Non-Firm ATO’s. Mes snijdt aan twee kanten (positief en negatief voor operateanten):
 - Hoe groter de onzekerheid over of en wanneer je beschikbare netcapaciteit hebt, wordt de BuCa onzekerder.
 - Aan de andere kant kunnen ze ervoor zorgen dat je een aansluiting krijgt waar je die normaal niet zou krijgen.
 - Capaciteitsprobleem: netbeheerder discrimineert toch achter de meter, want sluit opportunistische batterijpartijen uit. Prioritering, mag dat? Overheden mogen prioriteren in aansluitvolgorde (Netcodewijziging).
 - Helaas zit de grootste businesscase op de nationale onbalansmarkt. Hierom creëren batterijen eigenlijk problemen. Batterij wordt eerder hierop ingezet dan om congestie tegen te gaan, omdat dit meer geld oplevert. Hier om moeten er afspraken komen en moeten CSP meer vergoeding krijgen. Je lost namelijk het probleem op op TSO niveau, maar creëert een probleem op het DSO vlak. Daar wordt het ingekocht namelijk!
 - Batterij plaatsen alleen voor congestiemanagement kan nog niet uit qua businesscase.
- Er speelt enorm veel momenteel: rechten/plichten van een aangeslotene op het energienet
 - Kosten aansluiting en transport, non-firm ATO’s
 - Of voor de meter met eigen aansluiting, of meerdere achter de meter en dan in de collectiviteit gebruiken (virtual power plants etc.)
- Beleidsinstrumenten die integratie van FTM batterijopslag zouden kunnen verbeteren:
 - *Technisch:*
 - Geen aanpassingen van software nodig.
 - Hardware ook niet.
 - Er moet wel bij de omgevingsdiensten helderheid komen over de veiligheidseisen. Brandveiligheid, geluidsnormen etc. Standaarden/meetmethoden zijn nog niet helemaal duidelijk.
 - *Institutioneel:*
 - Aansluiting- en transportovereenkomsten worden hard aan gewerkt.

- Capaciteitsbeperkingscontract (CBC): IV2 ziet dit nog niet zitten. Eerst geef je volledige capaciteit, daarna koop je capaciteit deels terug. Omslachtig! Vergoeding voor gedeerde inkomsten. Voorkeur voor non-firm ATO.
 - Wel belangrijk: hoe gebruik je die contracten om het optimale gebruik van het net te faciliteren.
 - Organisatorisch:
 - Voor de technische dienstverlener. Stroomlijnen van het implementatieproces. Partnerships met batterijleverancier voor grote projecten zeer belangrijk gezien de kosten. Zo gaan de faalkosten en risico's naar beneden. Intergaal management!
 - Positie van de technische dienstverlener. Zet jezelf sterker neer als volledige technische ontzorgder in combinatie met een sterke partnership met een batterijpartij.
 - Financieel:
 - Subsidies niet echt nodig.
 - Lastig in de BuCa momenteel: onzekerheid over congestievergoeding. GOPACS geef veel onzekerheid. Je moet intekenen en dan moet je maar zien waar het schip strandt.
 - Duidelijkheid en goede vergoeding moet er komen! Wat levert het op en wat moet je ervoor leveren. Neem de onzekerheid weg!
 - Hoge vergoeding zonder te weten of en wanneer hij komt, is nog steeds te onzeker voor een solide businesscase
 - Sociaal
 - Ideale situatie: batterijprojecten brengen vanuit ruimtelijke ordening naar plekken waar ze makkelijker gerealiseerd kunnen worden
 - Bv op bedrijventerreinen of in de buurt van een zonnepark, liggen al kabels en is genoeg ruimte!
 - Evt. met de vluchtstrookaansluiting
 - Zo kan je sturen op waar batterijen komen! Dit zorgt voor prettigere vergunningsprocedures
- Situatie in the UK
 - Eiland (klein grid!)
 - Balansproducten in Nederland kunnen ook elders in Europa ingekocht worden.
 - Marktomvang in de UK groter, want daar moet alles binnenlands ingekocht worden: grote markt voor balanceringsproducten.
 - Markten werken heel anders
- Duitsland
 - Ander soort congestieprobleem. Zij hebben een transportcongestieprobleem, wij een distributieprobleem.
 - Frankrijk en Duitsland hebben al eerder zwaardere netten aangesloten. Plek van congestie ligt aan hoe het net is ontwikkeld. Andere invulling aan plek van batterijen in het net!
- NL is gasland, ontzettend goed gasnetwerk. Daarom relatief netten met weinig capaciteit. Gelijktijdigheid van 1,1-1,2 kW per huishouden. Dat is te weinig natuurlijk tegenwoordig! 44
 - Te laat geïnvesteerd, pas als het probleem er is! Benchmark is voor netbeheerders de efficiëntie van de investeringen.
 - Heel efficiënt om alleen te investeren daar waar het nodig is. Maar daar waar het over vijf jaar nodig is, wordt niet gedaan. De benchmark werkt dus eigenlijk onder investeren in de hand!
 - Elektrificatie is een enorm probleem! Dit sijpelt enorm door in elk deel van het net. Te weinig focus geweest op bedrijventerreinen.

- **Ervaring:**
 - Veel ervaring energiewereld. Onder andere in WKK, Waterstof, Klimaatakkoord., Batterijen. Vooral de afgelopen paar jaren veel met batterijen.
- **Functie:**
 - Ik doe geen legal werk over wet- en regelgeving die al bestaat. Wel advies geven aan de ‘voorkant’, dus feedback geven bij nieuwe wetsvoorstellen bij het ministerie en codewijzigingen bij de ACM. Hier ook aangeven wat anders moet volgens *bedrijf*.
 - Ik word ingeschakeld wanneer er verschillende knelpunten zijn. Bijvoorbeeld congestie, verduurzaming, CO₂-reductie en het betaalbaar en robuust houden van ons energiesysteem.
 - Voorbeeld: met de nieuwe Netcode zorgt de ACM ervoor dat het ‘tweede, reserve’ transmissienetwerk in tijden van hoge congestie ook gebruikt kan worden als soort spitsstrook. Dit zorgt voor meer uitval. Wie draait daar voor op? Dit is een ellenlange durende discussie over schadevergoedingen. Ik lobby hierbij.
- **Doelstellingen met batterijen:**
 - Vooral geld verdienen. Daarnaast natuurlijk kunnen verduurzamen en investeren in de energietransitie.
 - Doelstellingen van de beleidsadviseur bij *bedrijf*:
 - We moeten financieel gezien uit de huidige investeringen komen met de wet- en regelgeving die van kracht is.
 - Safeguards toekomstige investeringen in energietransitie
 - Competitiviteit waarborgen binnen de markt
 - Want beleid heeft invloed op de markt. Bepaalde randvoorwaarden (bv competitiviteit) mogen nooit geschonden worden door beleid.
- **Kansen FTM batterijopslag:**
 - Zon wil iedereen. Wind op land wil niemand. Zon en batterijen zijn perfect compatible qua energieprofiel.
 - Congestie ook een kans! Aan de afnemerskant zijn de kansen het grootst! Een fabriek wil koekjes maken. Stel je voor, ze willen er meer maken. Als ze geen transportcapaciteit hebben, moeten ze uitbreiden adhv een batterij. De kosten van die batterij drukken niet heel erg op hun BuCa, het belangrijkste is dat ze kunnen uitbreiden. Door nood ontstaat er een BuCa!
 - Congestie management. Maar wel lastig: Energie is Europees. Congestie is lokaal. Hoe kan je dat rijmen?
 - Betrouwbaarheid en leveringszekerheid van het energiesysteem. Dit zal voor een deel op het conto van batterijen komen in de toekomst.
 - Balanceringsmarkten niet zo kansrijk in de toekomst. Deze zullen snel verzadigd zijn.
- **Barrières:**
 - Energiebelastingen waren dubbel, maar dit is gecorrigeerd.
 - Transporttarieven zijn te hoog. Hier over onderhandelen is verschrikkelijk complex. Kostenverdeling tussen industrie, consumenten, producenten etc. Wie gaat betalen? Dit is een publieke discussie! Dus ligt zeer gevoelig.
 - Moeilijk om een grid connectie te krijgen.
 - Soft component: markt mist sturing van overheid. Wat gaan we straks nou doen met batterijen? Waar komt de flexibiliteit en leveringszekerheid vandaan? Batterijen hebben een beperkt volume. Evenwicht tussen batterijen en regelbaar vermogen moet er komen

- o om betrouwbaarheid te houden in het toekomstige energiesysteem. Het huidige marktmodel is hierin niet meer houdbaar.
 - o Sector technologisch nog in ontwikkeling. Dit zorgt voor technologierisico!
 - o Investeringsonzekerheid. Risico doordat hoogte waardestromen niet zeker zijn in de toekomst. Nu bestaat er wel een goeie BuCa door energiecrisis, maar blijft dit zo? Door de huidige prijzen stappen veel operateurs in, maar blijven de prijzen zo? Als de prijs omslaat, is de BuCa voor al deze batterijen onzeker. Dit is een varkenscyclus!
- Beleid tot betere integratie van FTM batterijopslag:
 - o Positief uit de netcode: meer mogelijk voor langetermijncontracten. Ontwikkelaar/producent neemt hierbij het investeringsrisico! De nieuwe Netcode zegt dat in congestiegebied de netbeheerder geld moet uitgeven aan flexibiliteit en dan op de beste manier om het te voorkomen. Dit geld maakt langetermijncontracten mogelijk, omdat het zekerheid biedt.
 - o Veiligheidsnormen en standaardisering begint te komen.
 - o Subsidies kunnen verstrend zijn. Kans op oversubsidieren! Dan kost het later meer om voor leveringszekerheid te zorgen. Dus niet aan te raden!
 - o Nodig: Beleidsverandering. Nieuwe regelingen, marktmodellen. Nieuwe langetermijncontracten.
 - o Er zijn serieuze initiatieven vanuit sectoren. Er moet meer flexibiliteit ontsloten worden. Hiervoor moet het moment van verbruik steeds waardevoller worden. Dit gebeurt al, maar moet nog meer gebeuren.
 - o Batterijen maken 100% groene stroom mogelijk. Deze marketing rond de origine van energie kan gunstig zijn voor batterijen.
 - o Partners zijn nodig! Dit moet geïnitieerd worden. Er moet vertrouwen binnen de keten zijn omdat alles lang termijn gebeurt en steeds complexer wordt.
 - o Afwachten wat de nieuwe Netcode gaat doen voor leveringszekerheid en langetermijncontracten!
 - o Ander capacity remuneration mechanisms zijn nodig (CRM's). De huidige voldoet niet omdat er niet wordt voldaan aan voorwaardes van de theorie. Dit energy only model werkt dus eigenlijk niet. Het kan namelijk eigenlijk niet technologieneutraal, omdat een batterij en een zonnepark intrinsiek te veel verschillen. Dus beleidskeuzes om hier mee om te gaan.
- Hoe moet dit beleid geprioriteerd worden:
 - o Succesvolle integratie van deze systemen moet omhoog:
 - o Congestie management is de eerste stap. De financiële vergoeding moet echter hoger. Daarnaast moet er een andere tariefssystematiek komen, bijvoorbeeld een verlaagd tarief voor batterijen. Transportkosten idem.
 - o Bovendien kunnen sociale incentives wel degelijk helpen, zoals lokale energiecorporaties met buurtbatterijen waarbij iedereen mee profiteert. Hetzelfde idee als bij de postcoderoos bij zonnepanelen!
- De rol van FTM batterijen in het toekomstige energiesysteem:
 - o Batterijen zullen een grote rol spelen! Ze zijn bronnen voor leveringszekerheid zonder wind en zon. Voldoende elektriciteit moet in de toekomst geleverd worden door Import/vraagreductie/renewables/opslag, dus zonder conventionele opwek. Waar komt de rest van de zekerheid vandaan? Dit is waar nieuw beleid op gebouwd moet zijn. Deze onzekerheid tegengaan. Want een gascentrale die bv 1000 uur per jaar draait, daar wordt niet meer in geïnvesteerd. Er moeten nieuwe mechanismes/garanties vanuit de overheid komen. Want anders gaat het fout!

Functie: Battery project developer and consultant at battery project development company

Date: 20/12/22

- Hoe ziet het implementatieproces van begin tot eind eruit?
 - Je begint met de BuCa.
 - Tweedelig: CAPEX en OPEX.
 - CAPEX drukt zwaar. Dus technische optimalisatie belangrijk
 - Invloedsfactoren:
 - Euro/dollar koers
 - Prijs batterijen. Cellenleverancier belangrijk, is duurste component.
 - Yen heeft invloed, want chinese partijen (Catl)
 - OPEX
 - Vooral te maken met de aansluiting
 - Energie/transportkosten onder 2mva
 - 1,6 cent per kWh transportkosten
 - Energiebelasting
 - Netbeheerkosten
 - Komt uit op ongeveer 6 cent per kWh achter de meter al!
 - Daarom technische inpassing zeer belangrijk. Bij windpark ideaal (zelfconsumptie, minder transportkosten etc.)
 - Stap 2: hoe ga je de batterij inzetten?
 - Onbalans? FCR? EPEX? Peak shaving?
 - Dit kan behoorlijk complex worden
 - Bv bij klanten als agrariërs. Die heeft wkk/zon/eboiler/batterij/licht. Allerlei assets op andere markten. Je kan bv niet lampen aFRR en dan batterij iets anders, want batterij moet dan 24/7 beschikbaar zijn. Dit bemoeilijkt de businesscase!
 - Stap 3: inkooptraject van batterij. Parallel hieraan:
 - Omgevingsvergunning bij gemeente
 - Verzekeraar (PGS 37-1, brandveiligheid)
 - Civiel traject
 - En dan integratie. Dit is ook pittig:
 - EMS partij. Hoe koppel je batterij op portal?
 - BSP/BRP'er die batterij aanstuurt
 - Bv Greenchoice/Engie gebruikt batterij als asset om eigen onbalans te hedgen.
 - Vooral nu, omdat onbalansboetes enorm hoog zijn. Gaan ze bijna aan onderdoor! Ze hebben langetermijncontracten voor zon/wind. Als je miszit, dan kan dit flink in de kosten lopen
 - Dit is het verdienmodel van Giga! Bv Eneco bij Rhino!
 - Eneco biedt zekerheid, dus dan krijg je de volledige investering.
 - Je kan ook Merchant financieren. Maar dat is risicovoller. Waardestromen zijn onzeker, dus je krijgt geen volledige investering van de bank.
 - i. BSP/BRP moet kijken hoe en waar ze de batterij in gaan zetten. Dit staat in verband met energiecontract (nodig: uurcontract, contract moet toegang geven tot markt, kennis moet er zijn), aansluiting, combinatie van waardestromen (mffr en onbalans bv kan niet samen met één asset). Voor optimalisatie van stromen is een EMS nodig.

- De rol van *bedrijf* in de batterijwereld
 - Technisch adviseur voor batterijen vanaf 1 MWh. Projectmanager bij een kleine batterij. Grote batterij dan worden we meer een ‘gedelegeerd projectontwikkelaar’. Voor of wel een succesfee of uurtarief of ‘sweat equity’
- Relevante stakeholders:
 - Je krijgt gewoon een container geleverd. Maar je moet ze kunnen aansturen, dus technische partners zijn zeer belangrijk.
 - Financiers zijn ook heel belangrijk. Ze hebben geen kennis van zaken maar gaan uit van gevalideerde partners, zoals Tesla en Rolls Royce. Dit valideren doet bijvoorbeeld een DNV GL. Dus daar moet je ook aan denken: de bank legt de basis voor met welke partijen je kan samenwerken.
 - Veel partijen. Complex projectmanagement! Een greep uit de partijen:
 - AC partij (Laag/middenspanningspartij. Draden leggen!)
 - Batterijleverancier.
 - EMS partij (Scholten/Spectral)
 - Technische partners
 - Financiers
 - Funderingspartner
 - Omwonenden
 - Brandveiligheidsadviseur
 - BSP/BRP
- Barrières FTM battery storage
 - Het is lastig projectmanagement. Heel veel interfaces koppelen. Het is echt integraal projectmanagement.
 - Faalkosten als je het niet goed doet zijn hoog. Waardestromen goed in kaart brengen is lastig. Schematisch overzicht zou zeer helpen. Zoals in deze studie over warmtepompen van Accenture (2021). Dit zou ook zeer helpen ook voor batterijen
 - Waarde van congestiemanagement zit bij de netbeheeder. Maar die mag er niks voor geven. Dat is lastig!
 - Transportcapaciteit!
 - Toch nog steeds de businesscase is moeilijk!
 - Onder de 1MWh sowieso geen businesscase.
 - Ideale situatie: CAPEX zeer laag, makkelijke technische integratie, midden/laagspanning met korte kabel, lage OPEX, kW contract en kWmax (netkosten) laag. Daarnaast moet er vrije ruimte zijn op de aansluiting om te kunnen traden. Trade-off: netkosten versus vrije ruimte op de aansluiting. Bv supermarkt alleen s nachts ruimte om te traden.
 - CAPEX wordt momenteel lichtelijk hoger (batterijen duurder)
 - OPEX wordt hoger (transportkosten gaan omhoog met 60 procent)
 - Dus BuCa wordt dunner!
 - Stel je voor. 60mwh batterij, alles perfect. Goedkope grond en omgevingsvergunning. Niet binnen 10 jaar terugbetaald onder huidige marktomstandigheden.
 - Daarom financieren partijen als Giga/Eneco voor 10 jaar. Over 10 jaar afbetaald en dan geen contract meer met Eneco. Dan nog 5 jaar een kosteloze asset. Dan ga je echt geld verdienen!
 - Last van cowboys in de markt.
- Kansen van FTM batterijopslag:

- Op plekken waar geen businesscase is, maar door nood wel. Bijvoorbeeld bouwers/woningbouw die behoefte aan elektrificatie hebben maar dat niet kunnen door stikstofwetgeving of netcongestie.
- Voor de meter energieoplossingen op laagspanningsnet in combinatie met zonnepanelen/EV laadinfrastructuur door je eigen 'energiehubje' te creëren met één aansluiting om zo het net te ontzorgen.
- Beleidsinstrumenten die integratie van FTM batterijopslag zouden kunnen verbeteren:
 - Netbeheerder mag investeren.
 - Wet- en regelgeving:
 - Salderen energiebelasting mag alleen op MLOEA. Dit moet veranderen!
 - Congestie beter in kaart brengen. Waar zit de congestie? Hoe kunnen we die oplossen? Waar ontstaat het en wanneer?
 - Dit is een kernpunt. Er is transparantie nodig. Dan kan je bv zeggen: in de 300 uur dat net congestie op deze transformatorstation is, helpen wij de netbeheerder. Daarbuiten laat je ons vrij handelen. Dit zorgt voor meer marktkoppeling en vermindering van congestie. Komt dus op afspraken neer tussen netbeheerder en marktpartijen! Dus ook opties voor capaciteitsbeperkende contracten.
 - Juridische barrières wegnemen. Ondernemers worden aan hun lot overgelaten.
 - Meer kans geven aan energie-initiatieven, zoals energie communities en energie delen..
 - Meer actie ondernemen om flexibiliteit te ontsluiten bij marktpartijen, bijvoorbeeld fabrieken die demand response doen.

- Rol Edmij
 - Deels BSP, deels BRP. Stroomhandelaren!
 - Edmij stuurt op een slimme manier assets aan (zoals batterijen).
 - Alleen de daadwerkelijke aansturing, niet de technische integratie
 - Dit doet de EMS partij
 - Edmij krijgt toegang tot deze portal om uiteindelijk de batterij optimaal in te zetten op de verschillende energiemarkten
 - Dit gaat via API's.
 - Edmij doet dit al redelijk lang voor verschillende partijen
 - Bijvoorbeeld GIGA, Faraday.
 - Vaak klanten die echt investeren in een batterij om geld te verdienen, niet uit noodzaak.
- Huidige businesscase
 - Vooral onbalansmarkt. Hierbij de individuele onbalans afrekenen van grote partijen
 - FCR ook nog wel.
 - Deze gaat misschien opdrogen, maar dat kan je nog niet met zekerheid zeggen. Het blijft dus toch nog wel even
- Barrières
 - Allergrootste: geen netaansluiting krijgen
 - Daarnaast hoge transporttarieven.
 - Niet discrimineren achter de aansluiting. Geen 'voorrang' voor batterijen. Dit is zeer schadelijk voor succesvolle integratie.
- Kansen
 - Onbalansmarkt!
 - En in de nabije toekomst: batterijen voor regelvermogen.
 - Diepere batterijen nodig met diepere vermogens. Deze moeten langer kunnen laden en ontladen.
 - Momenteel is de verhouding kWh/kW bij veel Li-ion batterijen niet goed. Minimaal een c-factor van 0,25C om een bepaalde periode door te komen.
 - Standaard Li-ion batterijen voldoen vaak nog niet door de technologie
 - Congestiemanagement! Dit moet je meer zien als 'slagroom op de taart'. Er wordt momenteel jaarlijks nog maar 144 GWh verhandeld, dat is te weinig. Dit kan wel groeien.
- Beleidsmaatregelen
 - Geen subsidies! Kans op oversubsidiëren
 - Financiering makkelijker maken. Financiers meer aan boord krijgen zodat het makkelijker is om te investeren!
 - Technische mensen. Zo'n enorm personeelstekort. Ongelofelijke stop op de ontwikkeling daardoor.

- *Bedrijf*
 - Veel doen met lokale energieinitiatieven en lokale energiehubbs met batterijen in congestiegebied
 - Marktleider in Nederland als system integrator als het gaat over batterijsystemen tussen 1 en 15 MW. Alleen software door *bedrijf* geleverd!
 - Veel projecten met veel stakeholders in congestiegebied, waarbij collectieve oplossingen efficiënter en goedkoper zijn dan individuele.
- Voorbeelden projecten: Schiphol Trade Park.
 - Beste voorbeeld is Schiphol Trade Park. Draait nu bijna een jaar. Vooral theoretische congestie, geen fysieke congestie. Verschillende bedrijven delen gecontracteerd vermogen, waarbij constant gemonitord wordt of er niet overheen gegaan wordt.
 - Sommige partijen hadden al gecontracteerd vermogen toegezegd gekregen, anderen hadden ‘pech’ en moesten op de wachtrij. In plaats van individuele oplossingen, koppelt het EMS platform van *bedrijf* alle assets op het terrein van de verschillende partijen (batterijsystemen, generatoren, opwekunits, laadinfra) aan elkaar. Door gelijktijdigheid kan de groeps-ATO efficiënt gebruikt worden en ontstaat er opeens ruimte op de aansluiting.
 - Al het gecontracteerd vermogen wordt bij elkaar opgeteld en het platform van *bedrijf* houdt in de gaten of men ergens richting de limiet van de ATO gaat en schakelt zo nodig assets af. Dit is nog niet nodig geweest. Zo hoeft de generator nog niet aan, terwijl dit wel al had gemoeten als deze waren geplaatst bij individuele partijen.
 - Verrekenmethodiek opgesteld voor het delen van assets/energie. Dit zit in de software verwerkt!
 - Systeem:
 - Achter de meter bij de partijen omdat veel partijen al veel assets hadden. Bij één partij een generator, back-up generator, noodstroom, batterij en meer dan 6 MW zonnepanelen. Kan in ijland modus! Nog een partij met een batterij. Andere partij heeft nog een batterij besteld. Assets worden virtueel bij elkaar gebracht. Dit gaat over het publieke net van Liander heen. Één partij levert terug aan het net, verderop op de kabel van Liander kan dit afgenomen worden door een andere partij. Hierbij blijft men als collectief onder de groeps-ATO. Dit is een ‘virtueel net’.
 - Collectieve oplossingen extra moeilijk. Dit gebeurt nog niet/nauwelijks in NL.
- Stakeholdermanagement
 - Veel verschillende partijen. Batterijleverancier/operateur, energiebedrijven, systeemintegrator, netbeheerder, gemeente, vastgoedontwikkelaar, projectontwikkelaar, huurders. Allemaal verschillende belangen. Dit duurt zo meer dan een halfjaar om de hoofden de juiste kant op de krijgen. Gebruiker/netbeheerder overtuigen van de oplossing.
 - Pilot is nodig voor een groeps-ATO oplossing. Raad van bestuur van Liander was zelfs betrokken.
 - Partijen hebben ook wensen met hun batterij. Ze willen hem bijvoorbeeld op een bepaalde markt inzetten.
- Andere voorbeelden pilot projecten: Schieoevers, Hessepoort Zwolle.

- *Wat zijn de huidige belemmeringen die u in deze projecten bent tegengekomen? Bijv. lokale samenwerking of procedures rond de netaansluiting?*
 - a. Eigendom niet echt spannend via ESCo's. Wie investeert? Dit wordt gewoon aangeboden door een partij als Joulz. Kosten eerlijk verdelen ligt hier in het verlengde en is ook goed aan te pakken.
 - b. Pieken afvlakken. Dit geeft voordeel collectief en netbeheerder. Eigenlijk moet netbeheerder hiervoor betalen. Dit gebeurt bij de nieuwe 40MWh/10MW batterij van GIGASTorage. Deze batterij zal diensten leveren voor Liander Dit is verplicht! Als er geen krapte is, mogen ze andere zaken doen. Hierbij komt het geld bij GIGA binnen, terwijl dit eigenlijk bij het collectief binnen zou moeten komen.
 - c. Collectief: iedereen vindt het spannend. Er zijn geen templates. Partijen hebben vaak de expertise niet. Vinden een aandeel in een batterij vaak eng, liever dan een persoonlijke generator bijvoorbeeld.
 - d. Voor collectieve inkoop van energie op lokaal niveau moet iedereen bij dezelfde energieleverancier zitten. Als partijen langetermijncontracten hebben bij andere partijen, kan dit een probleem zijn. Afspraken zijn nodig! Er is wel beweging.
 - e. Maar ook nog steeds angst bij de Netbeheerder. Boven de 10MW moet naar TenneT volgens de netbeheerder. Of tijdsgebonden contracten. Netbeheerders zijn aan het stoeien.
- *Hoe beïnvloeden deze beleidsopties de kans op succes voor een succesvolle integratie van collectieve batterijopslag bij een project als Schiphol Trade Park?*
 - a. *Toolkit voor collectieve initiatieven:* Hele goeie. Blueprints zouden enorm helpen. Bij Trade Park heeft het vier ton aan advocaaturen gekost om het allemaal rond te krijgen. Er zijn initiatieven, maar nog niks concreets. Juist zo breder, met organisatievormen etc. Heel goed zou dat zijn! Met een blueprint, zou denk ik tot 80% van de transactiekosten weggenomen kunnen worden.
 - b. *Betere procesondersteuning:* Niet heel realistisch om aan de overheid te vragen omdat het zo nieuw is. Wat vooral zou helpen zou ondersteuning zijn in de onderzoeksfase, de eerste fase. Hierdoor zou het makkelijker van de grond kunnen komen. Één portal maken, waarin alles op te vragen is. Ook alle meetdata van de verschillende meetbedrijven.
 - c. *Minder bureaucratie:* Dit kan zeker helpen. In de lijn met a en b, maar actieve participatieondersteuning van gemeentes en netbeheerders helpt zeker mee.
 - d. *Pilot projecten:* Liander heeft zes pilots uitgeroepen, die zijn goed bezig. Stedin en Enexis een stuk minder. Bij Liander meer de mentaliteit we gaan het maar gewoon doen, en dan zien we het wel. Bij Stedin en Enexis is het allemaal heel klein, afwachtend en voorzichtig. Experimenteerruimte vanuit de netbeheerder en ACM mag groter. Dan kunnen we stappen maken en eindelijk kansen gaan pakken. Hierbij moet de netbeheerder over het huidige risico-averse stramien heen.
 - e. *Welke heeft jouw voorkeur?*
 - i. Toolkit! Zonder deze standaardizeringsdocumenten is het zeer ingewikkeld om iets op te tuigen. Dit moet zo snel mogelijk geïmplementeerd worden.
- *Hoe beïnvloeden deze beleidsopties de kans op succes voor een succesvolle integratie van collectieve batterijopslag bij een project als Schiphol Trade Park?*
 - a. *Voorspellen en real-time bekendmaken van fysieke congestie om nieuwe contractvormen te faciliteren:* Netbeheerder heeft verplichting om rekening te houden met 150% van het totaal gecontracteerd vermogen. Netbeheerder heeft alleen een beperkt inzicht in gecontracteerd vermogen en gebruik (in de toekomst). De netbeheerder heeft geen goed zicht op 'handdoekje leggen': het voor de zekerheid aanvragen van huidige netcapaciteit dat pas in de toekomst

- gebruikt gaat worden. Gecontracteerd vermogen is misschien wel te goedkoop. Voorbeeld: eerste inventarisatie bij Schiphol tradepark bij de partijen kwam neer op 14 MW, ze hebben nu maar 3,5 MW nodig. **Real time inzicht op het net** zou heel erg helpen. Hierdoor kunnen marktpartijen als *bedrijf* inspringen en is het minder koffiedik kijken. CBC contract zou ook een optie zijn. Dit geeft ook zekerheid.
- b. *Herziening van netaansluiting procedures*: omgekeerde van wat er nu gebeurd. Wat heel belangrijk is om de ruimte die de batterij krijgt, nooit congestie in de hand werkt. Bijvoorbeeld dag van te voren te weten krijgen. Alleen onder die voorwaarden een batterij voorrang geven. Maar dan is de vraag, wat doe je met andere flex partijen? Krijgen die ook voorrang? Bv een vrieshuis met mogelijkheden tot op- en afschakelen, of een partij met elektrische mobiliteit die ook veel flex kunnen bieden.
 - c. *Verandering van private netten regelgeving*: Allemaal zeer duur. Qua infrastructuur. Je kan al een boel virtueel oplossen en het net aan de netbeheerder te laten. Afspraken mogelijk maken voor energiedelen tussen burenen/bedrijven bij elkaar in de buurt met één kabel ertussen. Hierbij wordt het onderstation niet meer belast en dit kan je aantonen. Hiervoor afspraken maken tussen partijen en de netbeheerder! Alleen een meet/regelkastje nodig ipv een kabel. Daar moet wel meer ruimte voor komen! **Groepscontracten (Groeps-ATO's)**: heel interessant. Binnen energiehubs met flexibiliteit en gelijktijdigheid kunnen namelijk de ATO's veel kleiner gehouden worden. Hierbij betaalt men voor minder contractvermogen door middel van zijn eigen systeem met flexaansturing. Maar weegt dit op tegen de ontlopen kosten van de Netbeheerder? Dat is de vraag! Dit houdt de netinfrastructuur betaalbaarder en er zou dus extra vergoeding vanuit de netbeheerder hiervoor moeten komen.
 - d. *Contractuele vergoeding voor congestie/korting op transporttarieven*: Lastig, congestievergoeding is nog nieuw. En rekening komt bij alle gebruikers terecht. Ongeremde vergoeding lijkt mij geen goed idee. Wat wel kan is in de vorm van CBC contracten. Bijvoorbeeld: van de 3 MW die je krijgt, is er 1 beperkend. Van deze kan de netbeheerder bijvoorbeeld de dag van te voren zeggen dat er geen ruimte op het net is voor de batterij.
 - e. *Welke heeft jouw voorkeur?* Real time inzicht op het net, daarna netaansluiting procedures. Private netten zie ik niet zo zitten. Gecombineerd met nieuwe contractvormen voor energiehubs en meer ruimte voor collectieve zaken. Dan zijn we al een heel eind!

- Batterijproject ervaring
 - Smartgrid Flevoland (GIGA storage battery)
 - Aantal batterijprojecten binnen GDS'en
 - Universiteit Utrecht batterijproject
- Validatie barrières:
 - Kritieke barrière 1
 - Zeker een grote barrière voor kleinere batterijen omdat je de batterij vaak combineert met allerlei andere assets. Grid-scale batterijen hebben hier minder last van omdat ze al een beetje kunnen voorsorteren op non-firm ATO's en dus afspraken kunnen maken over transporttarieven (Zie PI2,3) maar buiten de scope van de thesis.
 - Kritieke barrière 2
 - Zeker, veel onduidelijkheid. Maar het belangrijkste wat je ziet is dat financiers het eng vinden als er alle bijzondere ATO constructies bedacht worden. Omdat het geen standaard netaansluiting is en een aparte overeenkomst tussen twee partijen is geworden, vinden investeerders het risicovol. De financier stelt eisen, dit mondt uit in de creatie van eindeloos veel ATO's totdat de financier akkoord gaat. Dit is lastig. Complexiteit, daar kan de financier zich niet in vinden.
 - Kritieke barrière 3
 - Hier kan ik me in vinden. De lokale inpassing van de batterij is gewoon heel complex. Ook met eisen vanuit de brandweer/gemeente voor de vergunningen en veiligheidseisen. Daarnaast met lokaal energie delen: netbeheerder mag hier niets mee doen door regelgeving. Wie wordt vervolgens de eigenaar? Hoe deel je energie en de winsten? Dit is complex en vormt zeker een implementatiebarrière.
- Validatie en evaluatie beleidsinstrumenten:
 - Kritieke barrière 1
 - PI1 – paar jaar geleden was de lening niet het probleem met de lage rentes. Toen was meer de businesscase het probleem. Met de huidige volatiliteit op de energiemarkten en de hogere rentes van leningen is dit omgedraaid. Nu kunnen overheidsleningen zeker helpen.
 - PI2 – Momenteel betaal je dubbele transportkosten (bij laden én ontladen). Dit zou aangepakt moeten worden, dat men alleen nog enkele transportkosten betaalt voor de dienst die men levert. Als een batterij ten gunste van het net wordt ingezet, zou daar niet voor belast moeten worden. Dit is dus een interessant voorstel
 - PI3 – Hier minder voorstander voor. De marktwerking in de energiesector rondom congestiemanagement staat nog in de kinderschoenen. Dit lijkt me geen goed moment om vaste, contractuele vergoedingen uit te geven, dit zou de ontwikkeling van marktwerking tegen kunnen zitten.
 - **Voorkeur:** duidelijk PI2. De tariefsystematiek is nog niet op batterijen aangepast en hierom nog 'stuk' voor batterijen. PI2 is een goede manier om dit aan te pakken. Dubbele transporttarieven eruit en niet belasten voor momenten dat batterijen ten gunste van het net werken. Punt 1 zou een goeie kunnen zijn, mochten de rentes verder oplopen.

- Kritieke barrière 2
 - PI4 – Inderdaad, momenteel alleen nog rekening gehouden door de netbeheerder met congestie op papier (optellen van alle ATO's), maar nog niet kijken naar de daadwerkelijke ruimte op het net. Daarom moet de netbeheerder kijken naar non-firm vormen waar nog wel fysieke ruimte is, maar geen theoretische ruimte. Kijken naar het daadwerkelijke gebruik van een lijn t.o.v. hoeveel rechten er zijn verkocht. Dit is echt super waardevol. Onderscheid maken tussen contractueel en daadwerkelijke congestie. Dan komt de discussie los! Dit geeft mogelijkheden.
 - PI5 – Geen groot voorstander van. Dit zou een tijdelijke oplossing kunnen zijn. Dit is wel heel ingewikkeld. Op lange termijn moeten we dit niet willen, we moeten gewoon het probleem oplossen. In combinatie met PI4 kan het zo zijn dat het duidelijk wordt in een gebied dat er nog ruimte is. Dan kunnen we evt. met PI5 zorgen dat hier wat flex partijen met non-firm ATO's naar voren in de rij getrokken worden. PI5 is dus afhankelijk van PI4, en zou een tijdelijke oplossing moeten zijn.
 - PI6 – Onder bepaalde omstandigheden kan het delen van een aansluiting bijvoorbeeld al. Dit is wel heel complex. Dit zou makkelijker gemaakt kunnen worden, maar PI4 en PI5 zouden meer invloed hebben om CB2 te overkomen.
 - Voorkeur: PI4 zou enorm helpen. PI5 zou hierna als additionele, tijdelijke maatregel geïmplementeerd kunnen worden. Echter heeft PI5 minder zin zonder PI4. PI6 is minder nodig, en zou ook minder helpen in het overkomen van CB2.
- Kritieke barrière 3
 - PI7- Heel enthousiast over de standaardcontracten. Dit moet zeker in samenspraak gebeuren met Netbeheer Nederland als het gaat over groeps-ATO's, energie delen etc. Intern ook nuttig om te standaardiseren. Dit is ook goed voor het aantrekken van investeerders zoals Triodos Bank. Dit zal zeker helpen. Zo kan men nagaan hoe een project aangepakt kan worden.
 - PI8 – Zit in het verlengde van PI7, maar echt de standaardcontracten zijn doorslaggevend. Daarnaast is het handig als de gemeente enthousiast is, dan komen de vergunningen makkelijker binnen. Echter heb ik nog niet veel projecten gezien waarin de gemeente een doorslaggevende rol speelt. Dit zijn vaak andere factoren, zoals de businesscase. Hier dus minder enthousiast over.
 - PI9 – Pilotprojecten: kunnen geen kwaad, echter denk ik dat PI7 en PI8 waardevoller zijn, en dan met name PI7.
 - Voorkeur: PI7. PI8 is hier een aanvulling op. PI9 zou kunnen helpen, maar de echte meters worden gemaakt met een pakket met standaardisaties.

Appendix F – MCDA criteria weighting

Criteria	ID	Expert 1 Flex consultant at DSO	Expert 2 Battery operator	Expert 3 Regulatory affairs advisor	Expert 4 Battery project advisor	Average rank	Weight
Effectiveness	C1	7	7	7	6	7	0,250
Efficiency	C2	6	6	6	7	6	0,214
Equity	C3	4	2	1	1	2	0,071
Liberty	C4	1	3	2	2	2	0,071
Political feasibility	C5	5	4	4	4	4	0,143
Technical feasibility	C6	2	5	5	3	4	0,143
Administrative feasibility	C7	3	1	3	5	3	0,107

Table 22: MCDA criteria weighting

Appendix G – Objective tree

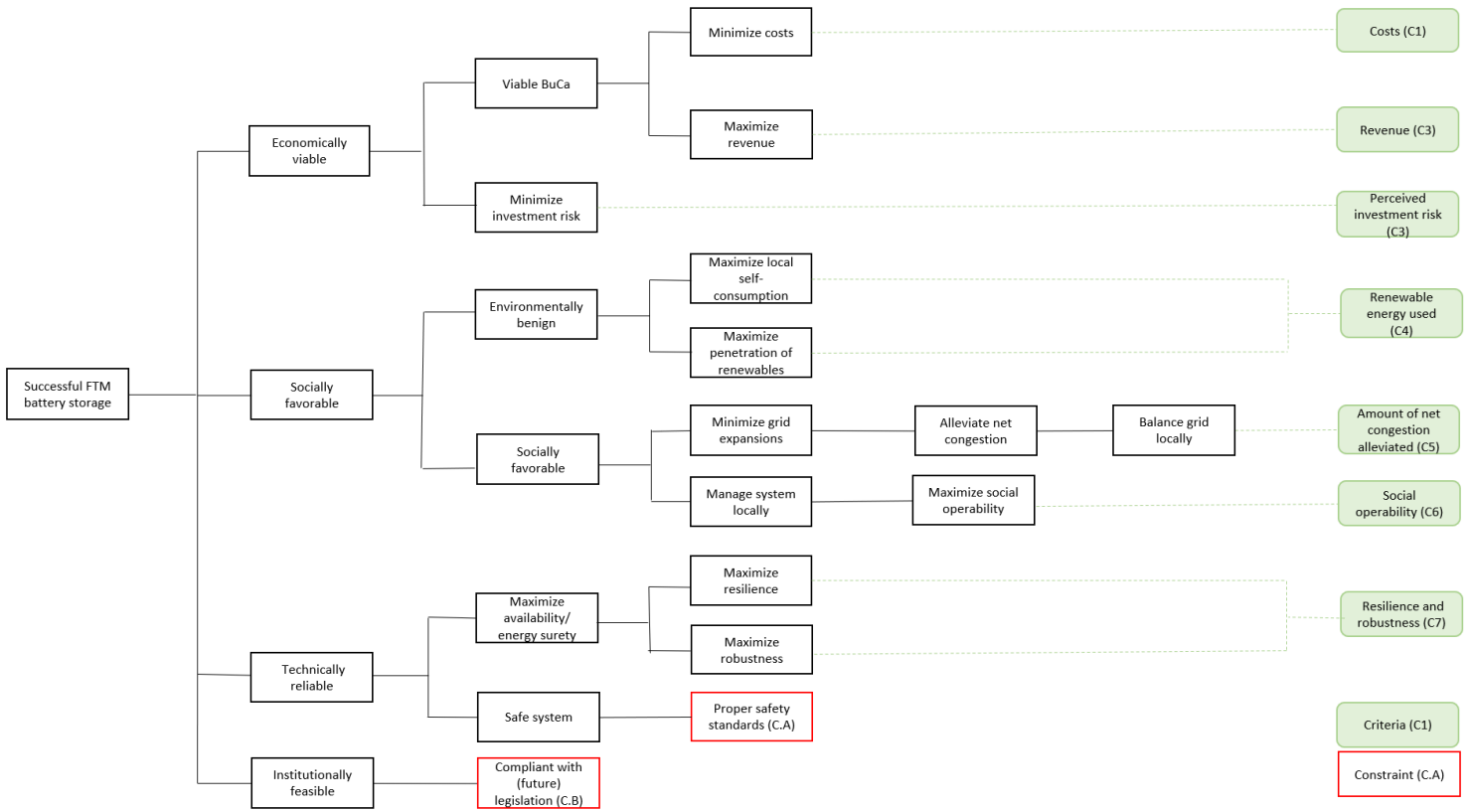


Figure 35: Example of an objective tree with criteria for collective battery storage