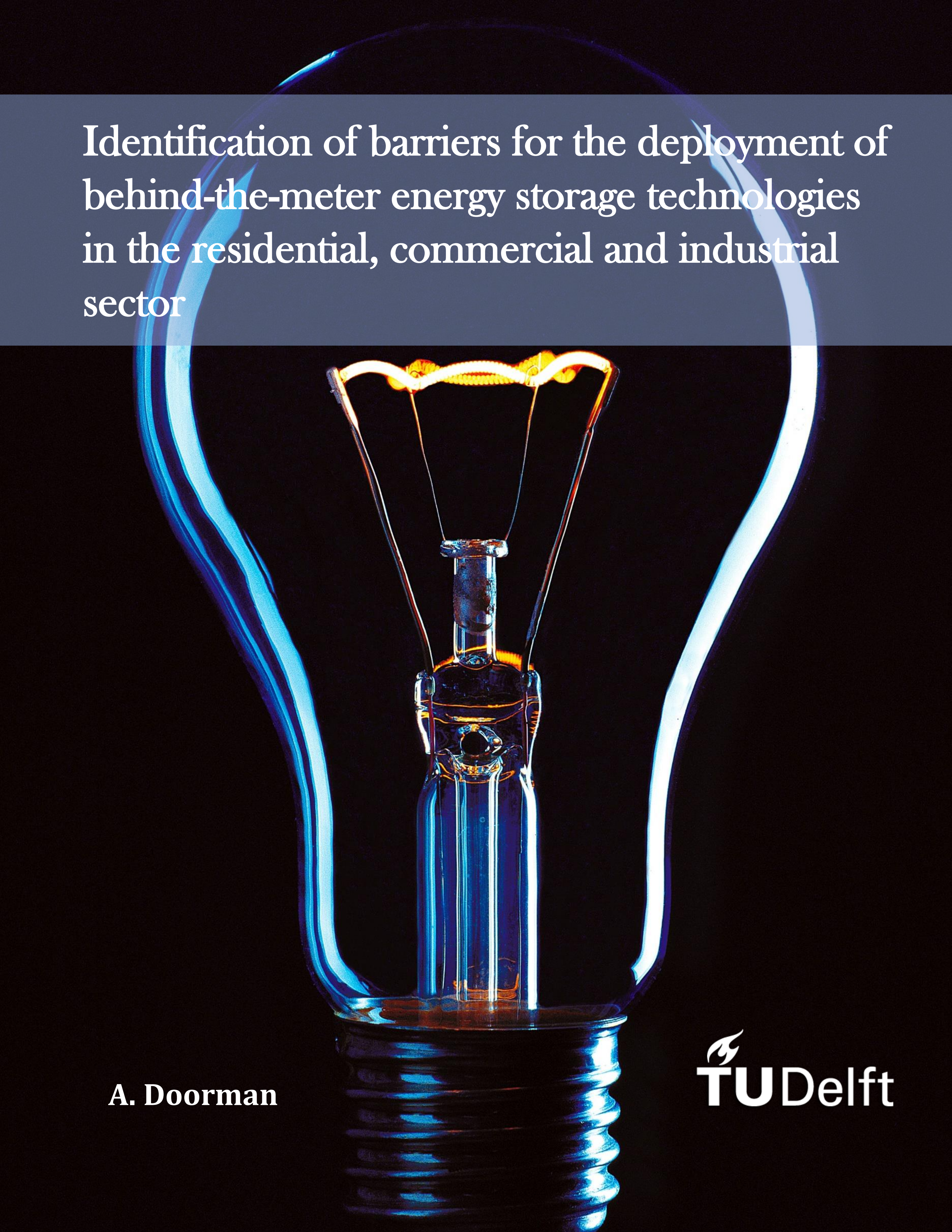
# Identification of barriers for the deployment of behind-the-meter energy storage technologies in the residential, commercial and industrial sector



**A. Doorman**

# The identification of barriers for behind-the-meter energy storage systems for the residential, commercial and industrial sector by using the Y-factor analysis.

Master thesis submitted to Delft University of Technology in partial fulfillment of the requirements for the degree of

**Master of Science** in

**Complex Systems Engineering and Management**

by

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# Preface

With this master thesis I finalize the master program of Complex Systems Engineering and Management at the faculty of Technology, Policy and Management of the TU Delft. It has been quite a journey, and I am very grateful for all the amazing friends I met during my studies, inspiring professors, study trips, committees and my Rwanda and Lisbon experience. The past six years, helped me gaining new knowledge on the complexity of the energy transition, and gave me multiple analytical skills and perspectives on approaching the challenges that lay ahead.

This thesis would not be possible without the help of others. First of all, I want to thank all the interviewees for their participation and interesting insights into the deployment of behind-the-meter storage systems. They provided extra knowledge to the – sometimes - 'dry' literature and made the overall research more tangible.

I want to thank Joao, my supervisor from Trinomics, for all the useful and constructive feedback moments. His in-depth knowledge on energy systems and patience in explaining the complexities of the electricity system helped me enormously on improving the content of this thesis. Moreover, I want to thank Emile, my first supervisor, for all the constructive, sometimes critical, and fun meetings. It never felt as an obligation to meet and his optimism and critical notes helped me obtaining the right direction of this thesis. Additionally, I want to thank Jan-Anne, my second supervisor, for his value added with regard to constructing the interviews and the useful comments on being able to see the overall picture of this research.

Unfortunately, my time as a student comes to an end, however, I am excited to start a new chapter. I am enthusiastic to contribute my future career to designing and accelerating the energy transition, with a focus on the electricity system for which this thesis forms the basis of that!

Enjoy the read!

Anniek

Delft, July 2022

# Executive Summary

The uptake of renewable energy sources in the energy system, due to pursuance of reducing greenhouse gases and the provision of energy security, leads to multiple challenges for the electricity grid in both the Netherlands and Germany. Intermittent renewable energy supply changes in time and is uncertain, and needs to be balanced (i.e. matched) with demand at all times, which requires system flexibility. Recent news articles on congested distribution and transmission grids in the Netherlands highlights the importance of providing system flexibility. Residential, commercial (small and medium enterprises) and industrial consumers can install their own renewable energy sources + energy storage to maximize self-consumption of renewable energy, to reduce electricity bills, reduce demand charges, to provide backup power and to provide grid balancing services (Bowen & Gokhale-Welch, 2021; Keiner et al, 2019; IRENA, 2019a; EnergySage, 2020).

Behind-the-meter storage technologies, such as stationary battery systems and electric vehicles enabled to bi-directional charge, allow active consumers to implicitly manage their consumption and demand in a way that reduces system flexibility needs (so-called implicit flexibility) and/or explicitly offer flexibility in electricity markets. However, the deployment of behind-the-meter storage systems comes with major barriers, which are the main focus of this study. The main research question is therefore defined as follows:

**What barriers affect the deployment of behind-the-meter storage technologies (such as, stationary battery systems and vehicle-to-grid)?**

The research consists of a literature study, an analysis of behind-the-meter storage systems in the Netherlands and Germany and 10 expert interviews. The main conclusion from the literature study is that 13 factors hamper the deployment of behind-the-meter storage systems, categorized in cost & financing barriers, technical barriers, market & regulatory barriers, multi-stakeholder complexity and behavioral barriers. To acquire knowledge on the significance of the barriers, the Y-factor method is used, a method initially designed by Chappin et al (2020) that allows to easily visualize, in once, which barriers are affecting what storage technologies. The Y-factor method can be explained by stating that "if you want to invest in this technology, in this sector and this county, then the following barriers play a crucial role". The scoring of the barriers is carried out by experts in the field of behind-the-meter storage technologies and quantifies the identified barriers from no barrier (0) to significant barrier (2). Each barrier is given a certain value, either 0, 1 or 2 and each value is specifically defined per barrier.

Each combination of technologies, sectors and countries is build up of all the 13 identified barriers. In figure 0.1, the Y-factor curve, a curve which displays an overview of barriers for the deployment of behind-the-meter storage technologies is shown. The combination of technologies, sectors and countries with the lowest scores and thus the lowest perceived barriers, are placed on the left. The technologies with the highest Y-factor score are placed on the right, hence, face several barriers in order to implement that technology in a certain sector.

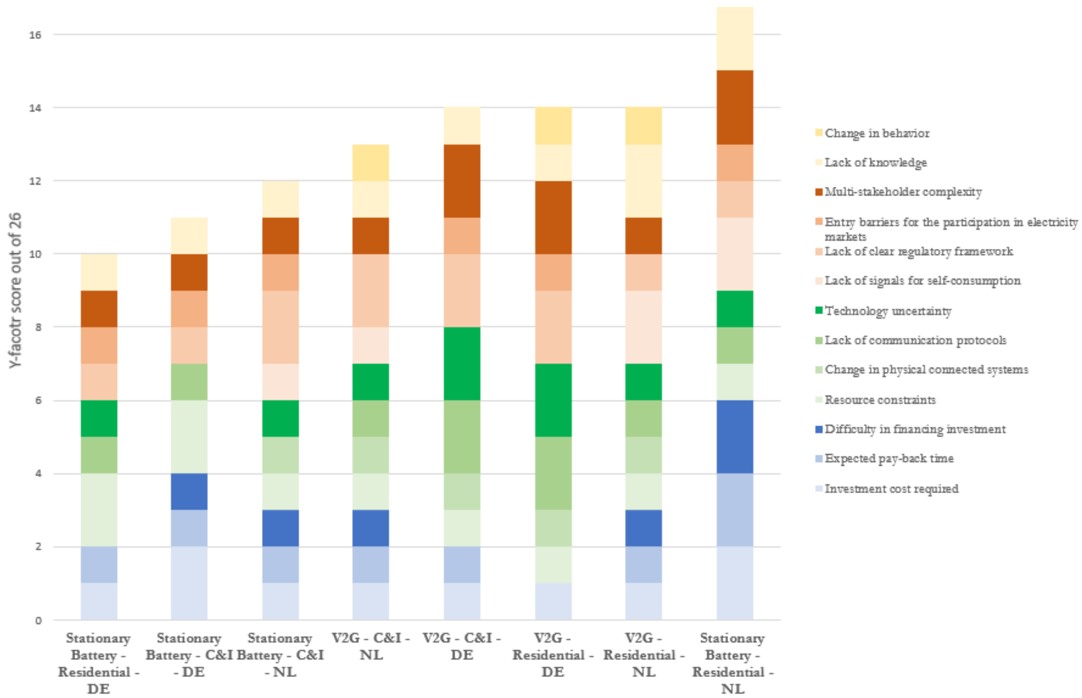


*Figure 0.1: Y-factor scores for behind-the-meter storage technologies in the Netherlands and Germany*

There can be concluded that:

- Whilst looking at the Y-factor curve, the main conclusion is that **all combinations of technologies and sectors face significant barriers for the deployment of behind-the-meter storage systems (equal to or above Y-factor score of 10 out of 26)**. In general, **financial barriers are hindering the deployment of stationary battery systems** to a larger extent compared to V2G technology, **whereas technical barriers as well as behavioral barriers play a larger role for the deployment of V2G technology**.
- **In the Netherlands, commercial and industrial consumers face less barriers with regard to stationary battery systems and V2G technology compared to residential consumers.** A lack of a clear regulatory framework is the most significant barrier for commercial and industrial consumers to invest in storage technology, whereas in the residential sector a lack of knowledge and of signals for self-consumption are found to be impeding the deployment. For residential storage in the Netherlands, costs & financing barriers, lack of signals for self-consumption, and dependency on other actors form the most significant barriers.
- In Germany, it can be noticed that **not the financial barriers, but technical barriers as well as market & regulatory barriers should be addressed when implementing V2G technology**. To be more precise, a lack of a clear regulatory framework, dependency on other actors, technology uncertainty and a lack of communication protocols form the major barriers with regard to the deployment of V2G technology. Moreover, in Germany, **commercial and industrial consumers face larger barriers compared to the residential sector with regard to stationary battery systems**, more precisely, the

required investment costs and acquiring funds/subsidies are more difficult for these consumers. Moreover, there can be noticed that **a change in behavior does not form a barrier for stationary battery systems in both the Netherlands and Germany.**

- **The main differences between the Netherlands and Germany** are that in the Netherlands, cost & financing barriers, lack of signals for self-consumption and a lack of knowledge play a crucial role contrary to Germany. In Germany, however, resource constraints, technology uncertainty, lack of communication protocols seem to form a major barrier, which is not as significant as in the Netherlands.

However, not all experts agreed on the significance of the barrier and therefore an uncertainty score is given to the final scores. Variances in scores resulted from including different fields of the experts (e.g. researchers, market operators or network operators), inaccurate interpretation (or formulation) of the barriers or the barriers being formulated on a too high, abstract level. Therefore, there can be concluded that the following barriers are found to be significant (2) and include high certainty, for a given combination of technologies and sectors.

- Required investment costs, expected pay-back time and a difficulty in financing investment for stationary Li-ion batteries in the residential sector in the Netherlands.
- Lack of signals for self-consumption in the residential sector in the Netherlands.
- Investment costs required for commercial and industrial consumers in Germany.
- Resource constraints for stationary battery systems in both the residential as the C&I sector in Germany.
- Technology uncertainty, lack of communication protocols, dependency on other actors and lack of clear regulatory framework with regard to V2G technology in both sectors in Germany.

Policy recommendations are formulized in order to address the significant barriers, such as the removal of net-metering to address the lack of signals for self-consumption in the Netherlands. Moreover, the provision of subsidies or loan schemes for stationary battery systems in the Netherlands could address cost & financing barriers, and, the removal of double taxation and/or double grid charging in national regulatory frameworks in both the Netherlands and Germany is recommended. Moreover, the definition of the independent aggregator should be formulated to provide more flexibility to the system. In addition, the lack of knowledge for both stationary battery systems, but mostly for V2G technology should be addressed in order to increase the deployment of these two storage systems. Additionally, the Netherlands should consider partially energy-based network tariffs, in stead of capacity-based tariffs to incentivize self-consumption and Germany should accelerate the provision of smart-metering systems, so that explicit demand side flexibility, hence grid balancing services, can be offered.

This was the first research that applied the Y-factor in interviews to a specific set of technologies. The Y-factor method provides a quick overview on barriers regarding the deployment of behind-the-meter storage systems for different countries. Future research could be focused on the addition of multiple countries and technologies to the current framework, or to apply the Y-factor method to other specific technologies, for example, in-front-of-the meter energy storage.

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# 1. Introduction

In 2015, 196 parties signed the Paris Agreement, a legally binding international treaty to fight climate change (UN, n.d.). The aim of the agreement is to limit global warming well below 2 degrees Celsius, nonetheless, to achieve this long-term temperature goal, countries should limit the amount of greenhouse gases (GHG) immediately. The coming years are crucial to address the challenges in order to fight climate according to the IPCC report (2022). Addressing intermittency due to an increasing amount of renewable energy is one of these key challenges and therefore energy storage is crucial in the next phase of the energy transition (IRENA, 2017).

## 1.1 Problem introduction

The electricity system has to deal with a wide range of challenges according to the IEA (2019a,b). Variable renewable sources, like wind power and solar energy, are increasing in the total share of electricity supply and therefore requires an increasing amount of flexibility in the system (Koltsaklis et al., 2017). Additionally, local network congestion problems occur due to an increasing amount of distributed variable renewable energy sources. According to the capacity map of NetbeheerNL (2022), numerous parts of Netherlands' grid locations reached the limits of its capacity for injecting electricity, meaning that generated renewable electricity can not be injected into the grid. For example, in some parts of the Netherlands, new commercial parties can not acquire grid connections to distribution and transmission grids since the electricity grid is congested (NOS, 2022) and this therefore highlights the importance of providing system flexibility.

The main sources that provide flexibility are networks, demand response, dispatchable and flexible power generation and *energy storage*. Energy storage will become an important building block of the EU energy system and enables consumers and users to store energy for later use and among other uses, to reduce imbalances between energy demand and energy generation (EC, 2020). While the traditional focus has focused on supply-side solutions, the value of demand side solutions to address balancing issues becomes increasingly clear. According to the study of PNNL (2022) there is a need for "a solution that integrates the coordination of demand flexibility into everyday grid operation, ensures it is automated, puts the customer in control of how much or little they participate and fairly compensates them for the level of flexibility they provide to the grid". Behind-the-meter storage technologies can play a key role in providing flexibility according to Golden et al (2019) and could therefore provide grid stability. Small scale behind-the-meter energy systems are mostly installed at customers' premises, up to 5kW/13,5 kWh for residential consumers and up to 5MW/10MWh for commercial and industrial units (IRENA, 2019a). Energy storage technologies, such as stationary battery systems and vehicle-to grid (V2G) technologies provide the ability to use the storage capacity for grid balancing services and peak shaving (i.e. to store energy from the grid during off peak hours and use the stored energy later during peak hours).

The main benefits of behind-the-meter storage systems for consumers is to maximize self-consumption of renewable energy, more specifically, to store generated excess energy and use the stored energy to cover demand when solar energy is not available. Other benefits for consumers of behind-the-meter energy storage are: reduction in electricity bills, reducing demand charges and providing backup power and resiliency for the consumer ((Bowen & Gokhale-Welch, 2021); Keiner et al, 2019; IRENA, 2019a,; EnergySage, 2020). Additionally, non-energy benefits, although their impacts are more difficult to quantify, are increased property values, the potential to create job opportunities, better land use and fewer emissions (Rezaeimozafar et al, 2022). Moreover, during a power outage, a behind-the-meter energy storage system can provide load for a certain period, depending on the installed capacity and thereby increasing resiliency (Rezaeimozafar et al, 2022).

However, the deployment of behind-the-meter energy storage systems to offer flexibility to both consumers as the energy system comes with major barrier. As behind-the-meter storage technologies are a relatively new energy asset, the adoption is not yet widely initiated. The study of Bowen & Gokwale-Elch (2021) identified technical, regulatory, and financial barriers to behind-the-meter battery energy storage in the US, which is partially applicable to European countries. Regarding utilizing behind-the-meter storage systems for self-consumption, the study of Hennings et al (2017) identified multiple factors hampering self-consumption, such as the prices for electricity injected into and withdrawn from the grid, governmental support programs, aspects of taxation and the behavior of consumers. The focus of this study is to research the barriers of behind-the-meter storage technologies for the residential, commercial and industrial sector and to provide policy recommendations on how to reduce these barriers.

#### 1.1.1 *Case demarcation*

This study focuses on barriers of the deployment of behind-the-meter storage systems in two countries, the Netherlands and Germany. Germany is chosen, since it has the largest market share regarding residential storage systems (< 30kWh) with about 750 MWh newly installed energy storage capacity in 2020 (EES, 2022). The reason of this market share is largely due to support programs for home storage systems, which was in place between 2013 and 2018, followed by state-specific support schemes afterwards (Krokowski, 2021). In contrast, only 27MW/57MWh of industrial storage (30kWh – 1MWh) was installed in Germany whereas storage capacities larger than 1MWh was even smaller, namely 36MW/32MWh of new installations (Energy-storage news, 2021).

Moreover, in 2020, 340.000 battery electric vehicles and 341.000 plug-in hybrid EVs were registered in Germany, meaning that the total amount of combined batteries is around 40GWh. This accumulated total brings major flexibility potential to the overall system and gives opportunities of utilizing vehicle-to-grid or vehicle-to-home applications (Energy-storage news, 2021). This is further discussed in section 3.4 on V2G technology.

In the Netherlands, the behind-the-meter storage market is significantly smaller in size, in 2021 around 2000 residential batteries for different purposes were installed (DNE, 2021). This study gives a clear overview which barriers play a role for the deployment of such systems and thereafter, country-specific policy recommendations are given.

### 1.2 Knowledge gap and main research question

Currently, there are numerous barrier related studies focused on energy storage systems, however, a clear overview of barriers related to research on behind-the-meter storage is unrepresented. During the literature review, numerous articles are identified with common ground on behind-the-meter storage systems, nonetheless, existing research on energy storage mainly focuses on economic issues (for example, Rotella et al, 2021; Nguyen et al, 2017, Keiner et al, 2019), or technical characteristics (Nair et al, 2010) of behind-the-meter storage systems. Or, for example, Baran (2017) provides an overview of barriers related to storage systems, however focused on utility-scale storage systems and thus does not take residential storage systems into account.

This study aims to focus on the broader perspective of behind-the-meter storage technologies and therefore, besides economic and technical barriers, includes market & regulatory barriers, stakeholder complexities and behavior. The aim of this study is to oversee, in once, the existent barriers that should be addressed in order to incentive the deployment of behind-the-meter storage technologies. Moreover, the goal is to give policymakers handles to discuss these identified barriers and can result in developing or adjusting policies to incentivize the deployment of these storage systems. The master thesis is combined with an internship at Trinomics and could contribute to research on policy & regulation on energy storage for the Netherlands and Germany.

The found knowledge gap leads to the following main research question:

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**What barriers affect the deployment of behind-the-meter storage technologies (e.g. stationary battery systems and vehicle-to-grid)?**

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Dissecting the main research question results in the following sub-questions:

1. What factors may contribute to barriers for the deployment of behind-the-meter energy storage technologies (e.g. stationary battery systems and vehicle-to-grid) in the Netherlands and Germany?
2. How can we modify the Y-factor method to capture barriers for the deployment of behind-the-meter storage systems?
3. What barriers may significantly hamper the deployment of specific behind-the-meter storage technologies (e.g. stationary battery systems and vehicle-to-grid) in the Netherlands and Germany?

### 1.3 Societal and scientific relevance

This study contributes to the lack of scientific knowledge by providing a clear, and technology and sector specific, overview of barriers of behind-the-meter storage systems. Moreover, this study intends to contribute to the application of the Y-factor method, a method initially designed to provide more insights into barriers that may hinder the materialization of $CO_2$ abatement options. In this study the Y-factor method, explained more in depth in 2.1.1, is applied to specific behind-the-meter storage technologies and not yet earlier applied to specific technologies. The addition of a clear overview of technology and sector specific barriers as well as the application of the Y-factor method can be seen as scientific relevance.

In terms of societal relevance, this thesis aims to bring new insights for policy makers with regard to barriers for behind-the-meter storage systems. System flexibility, that among other things can be offered by behind-the-meter storage systems, is crucial to reach the goals of the Paris Climate Agreement and to increase the amount of variable renewable energy sources in the system. The understanding of the barriers of behind-the-meter storage systems is essential to take adequate action to reduce the barriers. Therefore, this study contributes to enriching the understanding of barriers of these systems and may help in facilitating additional constructive dialogues whilst considering implementing storage technologies.

Moreover, the societal relevance is directly linked to the projections of the growth of the annual European energy storage market, as shown in figure 1. The European energy storage market is divided into the residential and commercial & industrial (C&I) behind-the-meter energy storage and front-of-the-meter sector. As shown, all market segments are expected to grow according to the projections of the European Association of Energy Storage (EASE) (2021) and therefore this thesis on the barriers for the deployment of these storage systems can be found relevant.

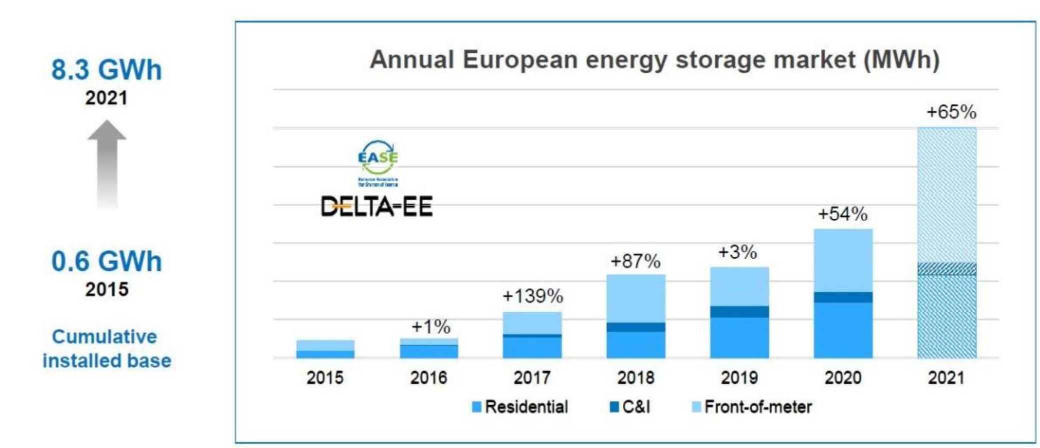


*Figure 1: Annual European energy storage market (EASE, 2021)*

### 1.4 Alignment to Complex Systems Engineering and Management

The Complex Systems Engineering and Management (CoSEM) master program of the TU Delft addresses multiple complex socio-technical systems and therefore matches the subject of behind-the-meter energy storage perfectly. The deployment of behind-the-meter storage technologies covers a broad range of complexities, such as technical requirements, economic aspects, stakeholder involvement and market & regulatory frameworks and therefore is in alignment with the CoSEM master program.

### 1.5 Outline of the research

The study consists of 8 chapters. Chapter 2 focuses on the methodology and the research approach of this study whereas chapter 3 provides more information on the background concepts of behind-the-meter storage technologies. Chapter 4 identifies factors regarding behind-the-meter energy storage systems for the Netherlands and Germany. In chapter 5 the Y-factor curve and the results are presented and analyzed per significant barrier. Finally, chapter 6 provides the conclusion, discussion, policy recommendations and a personal reflection.

# 2. Methodology & research approach

This chapter describes the methodology and research approach in order to answer the main research question. The objective of this chapter is to provide understanding on how the research is conducted, the possible methodologies, what the Y-factor method entails, and a research approach per sub question. This chapter ends with a research flow diagram in which is shown how the different chapters relate to on another and how the main research question is answered.

## 2.1 Methodology considerations

Multiple methodologies could be possible for the analysis of the identified barriers. Researchers developed multiple multi-criteria analysis tools in order to support decision-making among policy makers. One of the methods to analyze barriers and to support decision-making is the Analytic Hierarchy Process (AHP), a decision-making tool which can include qualitative and quantitative aspects of a decision and uses pairwise comparisons. There are multiple researches that used the AHP theory for prioritizing barriers, for example the research of Kagazyo et al (1997) in which energy projects are divided into technological and societal aspects. Although the AHP method could possibly suit the aim of this study, the use of absolute judgements on scaling factors is time-consuming and therefore not suitable due to time constraints. Similar arguments are in place for the Decision-making and Trial Evaluation Laboratory (DEMATEL) tool, a multi-criteria decision making tool which utilizes experts decisions to validate and scoring different barriers and measures the relationship between barriers. For both the AHP and DEMATEL methods, the focus lies on the interrelation of barriers which is not the main focus of this study.

The majority of barrier-related studies are on the basis of qualitative research whereas this study focuses on the quantification of barriers. Hence, for the quantification of (societal) barriers and prioritizing barriers in a clear overview other methods are found to be more relevant.

### 2.1.1 *The Y-factor method*

The Y-factor method was introduced by Chappin et al (2020), a method to provide more insight into barriers that may hinder the materialization of $CO_2$ abatement options. In this study, thirteen factors as shown in table 1, divided into the categories of cost & financing, multi-actor complexity, physical interdependencies, and behavior, are constructed on the fifty cheapest climate abatement options to complement the Marginal Abatement Cost Curve (MACC). This curve published by McKinsey shows the overview of the potential range of abatement options ordered per Mton reduced $CO_2$ emissions (Nauclér & Enkvist, 2009), however the MACC curve gives the impression that the financial aspect is the main barrier of implementing the abatement option. The results of Chappin et al (2020) showed that the Y-factor curve is found to be useful for complementing the MACC curve since the solely financial aspect is replaced by the Y-factor barriers. Moreover, the method aims to solve the 'why' questions of climate abatement barriers. The Y-factor analysis is a relatively new method, but already improved or applied by other master thesis students, such as Cheung (2018), Arensman (2018), Soana (2018) & Arriaga (2020), who for example applied the Y-factor analysis for reducing GHG emissions in Mexico.

The Y-factor method suits the aim of this study since it allows to easily visualize, in once, which barriers are affecting what storage technologies. Although the Y-factor method is originally designed to formulate barriers regarding $CO_2$ abatement options, it does consist overlapping barriers with regard to behind-the-meter storage systems. More specifically, the deployment of storage technologies can also be hampered by non-quantitative characteristics, such as: change in behavior of end-consumers and stakeholder complexity.

Each technology could be build up of all the identified barriers, meaning that the deployment of the technology is majorly hampered. The Y-factor method includes expert interviews to score and thus quantify the identified barriers from no barrier (0) to significant barrier (2). Each factor is given a certain value, either 0, 1 or 2 and each value is specifically defined per factor. The scoring of 0 suggest that there is no barrier, the score of 1 suggest a possible barrier and the score of 2 suggest a significant barrier. For example, the factor '*expected pay-back time*' is found to be no barrier if it is lower than 5 years, a medium barriers if the expected pay-back time is between 5-12 years and a high barriers if its larger than 12 years. How the interviews are carried out with regard to this study, is explained in 2.2.4 'the interview protocol'.

**Table 1: List of factors research to cover fifty abatement technologies Chappin et al (2020)**

| **Category** | **Factor** | **Value 0** | **Value 1** | **Value 2** |
|---|---|---|---|---|
| Cost and financing | Investment cost required | Absent | Medium | Large |
| | Expected pay-back time | < 5 years | 5-12 years | >12 years |
| | Difficulty in financing investment | Low | Medium | Large |
| Multi-actor complexity | Dependence on other actors | None | Few | Many |
| | Diversity of actors involved | Low | Medium | Large |
| | Division of roles and responsibilities | Clear | Somewhat unclear | Unclear |
| Physical interdependences | Physical embeddedness | No | Medium | Strongly |
| | Disturbs regular operation | No | Slightly | Strongly |
| | Technology uncertainty | Fully proven | Small | Large |
| Behavior | Knowledge of actor | High | Low | Lacking |
| | Frequency of opportunity | Often | Medium | Rarely |
| | Change in behavior | No | Slight | Severe |

The identified factors of table 1 are used as a basis for this study on behind-the-meter storage systems. However, to be able to cover all fifty abatement options, the factors identified in the study of Chappin et al (2020) are formulated at a high, more abstract level. Since this study entails a more technology-specific approach, some factors of table 1 could be overlapping or redundant, while new ones may need to be added.

## 2.2 Research approach

This section describes the research approach in order to answer the main research question and helps to provide understanding on how the research is conducted. The answers of the first three sub questions leads to the answer to the main research question, namely: *what barriers affect the deployment of behind-the-meter storage systems?* In figure 2 the Research Flow Diagram (RFD) is shown, which gives a clear overview on how chapters and sub questions are related in order to answer the main research question.

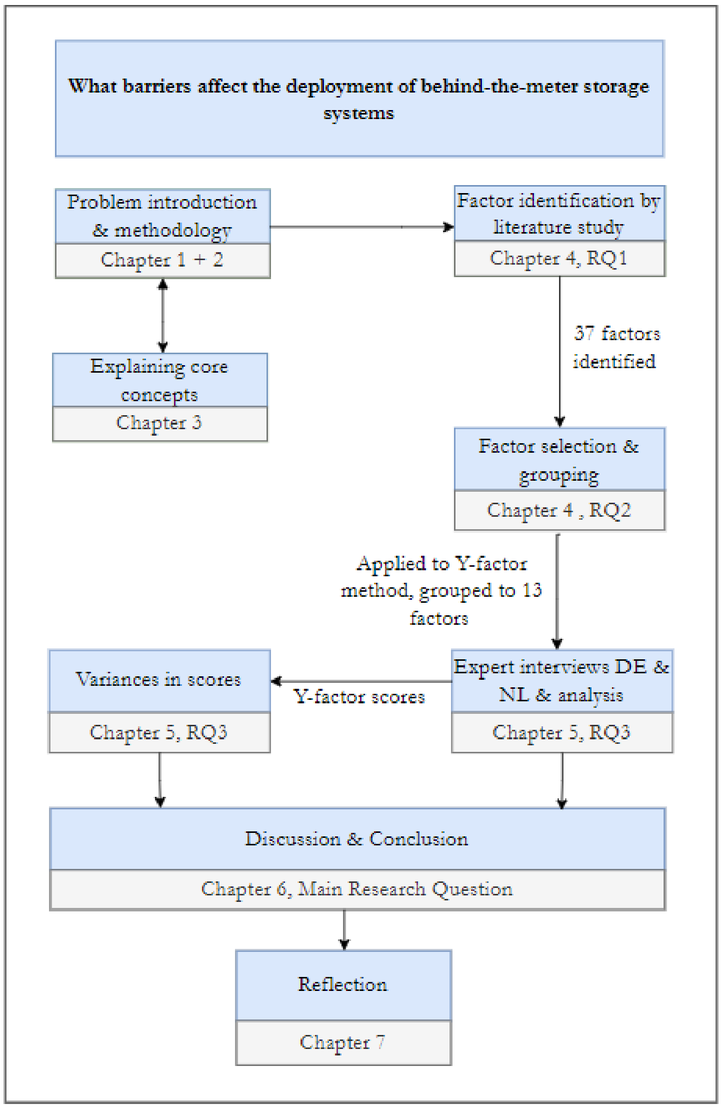


*Figure 2: Research Flow Diagram*

### 2.2.1 *Research approach sub-question 1*

First, a literature review is carried out to identify possible factors influencing the deployment of behind-the-meter energy storage.

- o What factors may represent barriers for the deployment of behind-the-meter energy storage technologies (such as, stationary battery systems and vehicle-to-grid) in the Netherlands and Germany?

The aim of the first sub question is to collect factors that may hamper the deployment of behind-the-meter storage systems by executing qualitative research. An extensive literature study is caried out by analyzing scientific papers, recent news articles and governmental papers whilst using the definition of a barrier defined in chapter 3. Found literature related to behind the meter storage technologies and more specifically, to stationary Li-ion battery systems and V2G technologies is used to structure the direction of the research. The literature databases used are Google Scholar and Scopus using the following keywords: "barriers," "behind-the-meter battery energy storage", "vehicle-to-grid", "bi-directional charging electric vehicles", "regulatory barriers energy storage", "technical barriers storage systems". The output of the first sub question is an overview of barriers related to stationary battery systems and EVs enabled for bi-directional charging and is displayed per affected sector.

### 2.2.2 *Research approach sub-question 2*

The second research question that is answered in this study is:

- o How can we modify the Y-factor method to capture barriers for the deployment of behind-the-meter storage systems?

As mentioned above, this study intends to contribute to the application of the Y-factor method, a method initially designed to provide more insight into barriers that may hinder the materialization of $CO_2$ (Chappin et al, 2020). The approach for answering this sub question is as follows: the identified factors acquired from the first research question are compared to the research of Chappin et al (2020) to match overlapping factors. Subsequently, the identified factors are grouped to a higher level and categorized to provide a clear overview.

The research is focused on multiple abatement options and therefore the factors identified could potentially not suit and cover all the barriers relating to - the more specific - behind-the-meter storage technologies. The barriers identified in the research of Chappin (2020) is used as a basis, however, could be modified accordingly. The output of this sub question is an overview of high-level barriers, their definitions, values, and related concepts, relating to behind-the-meter energy storage technologies. The overall output is used as input for the third sub-question.

### 2.2.3 *Reseach approach sub-question 3*

The third research question answered in this study is:

- o Which barriers may significantly hamper the deployment of specific behind-the-meter storage technologies (such as, stationary battery systems and vehicle-to-grid) in the Netherlands and Germany?

All the identified barriers display a broad variety of problems that occur around behind-the-meter storage systems. Hence, the output of the second sub question is used as input to determine which barriers significantly hamper the deployment of stationary battery systems and EVs enabled to bi-directional charge. To determine the significance of the barriers, experts in the field of behind-the-meter energy storage are asked to score the barriers.

The aim of the interviews is to both let experts score the identified factors on behind-the-meter storage technologies and to understand the issues of implementing behind-the-meter storage systems by discussing the barriers one per one. Two approaches are possible for the scoring of barriers, the first one being, to score the barriers by using the literature study and let experts validate the scores as done in the thesis of Escobar (2020). More specifically, the experts then revise the scores on behind-the-meter storage and the understanding of the revision is analyzed. The second approach is to let the experts score the barrier themselves, and to go one-per-one through the scored factors and understand the scoring. According to the research of Arensman (2018) it is advised to choose for the second approach, since less subjectivity is then included.

### 2.2.4 *Interview protocol*

To increase certainty to the Y-factor analysis, experts in the field of behind-the-meter energy storage technologies are asked to score the identified barriers in a one-on-one semi-structured interview as well as provide details on their answers. The experts in the fields are selected given their knowledge on behind-the-meter energy storage technologies and are chosen from different perspectives in the field of these storage technologies, more specifically, the experts interviewed are network operators, knowledge institutions, a storage operator, battery manufacturers and an energy supplier. In table 2 an overview of the participants interviewed, and the type of organization is shown.

**Table 2: Overview interview participants**

| **Anonymized participants** | **Type of organization** |
|---|---|
| Participant 1 - Netherlands | Research institution |
| Participant 2 - Netherlands | Research institution |
| Participant 3 - Netherlands | Storage operator / consultant |
| Participant 4 - Netherlands | Energy supplier / aggregator |
| Participant 5 - Netherlands | Battery manufacturer |
| Participant 6 - Netherlands | Network operator |
| Participant 7 – Netherlands | Network operator |
| Participant 8 – Germany | Research institution |
| Participant 9 – Germany | Research institution |
| Participant 10 – Germany | Battery manufacturer |

To all the participants the overview of the barriers are sent three days before the interview was held in order to get familiar with the identified barriers. All the interviews started with a summary of the purpose of the interview and an example to demonstrate the scoring of the barrier. The preparation of the interview is based on the research of Arensman (2018) who conducted interviews herself whilst using the Y-factor analysis.

During the one-on-one interview, an overview of the identified factors is shown, the definitions and relating concepts are shared and per factor the scores are given for the different sectors and technologies. Additionally, there is emphasized that the to-be-scored factors should be scored from the perspective of the one investing in the technology. All the barriers are scored (0/1/2) for the following technologies:

- Stationary battery systems for the residential sector
- Stationary battery systems for the commercial and industrial consumers
- EVs enabled for bi-directional charging in the residential sector
- EVs enabled for bi-directional charging for commercial and industrial consumers

During the interview questions are asked to clarify motivations behind the scores. The interviews with Dutch participants are held in Dutch whereas the interviews with German participants are held in English and have a duration of approximately 60 minutes. The responses of the participants are recorded and transcribed. The transcripts are sent to the participants for approval. In appendix B, an overview of the interview protocol, questions and answers are provided. Moreover, all scores per participants and their motivations are depicted.

The output of the interviews is an overview of significant barriers ordered per technology, per country and per sector. Thereafter, the significant barriers are analyzed and variances in scores are addressed by using an uncertainty score.

# 3. Background and core concepts

This chapter offers the context of behind-the-meter storage systems, the core concepts of the electricity system, and an explanation of the energy storage technologies analyzed in this research. Understanding the core concepts of the electricity system is of key importance to understand barriers for the deployment of behind-the-meter storage systems.

## 3.1 Definition of flexibility

In order to ensure a reliable energy system, the frequency of the electricity system needs to be controlled and maintained at the frequency of 50 Hz. System imbalances, due to an increasing amount of variable renewable resources can result in small frequency deviations and thereby threatening the security of supply.

In the traditional energy system, households, companies, and industries are final customers and thus the end-users of energy. The suppliers, program responsible parties and the DSO’s and TSO’s ensure that the produced electricity reaches the end customers. In a new energy system, in which locally generated sustainable energy will play an increasingly important role, households and companies will also be given new roles in addition to their roles as final consumer. Consumers can become electricity producers, also known as active consumers, and provide flexibility to the system. The definition of flexibility used across this research is the following:

*“The modification of generation injection and/or consumption patterns, on an individual or aggregated level, in reaction to an external signal (price signal / network tariff / activation / congestion) in order to provide a service within the energy system or maintain stable grid operation. The parameters used to characterize flexibility can include: the amount of (active) power modulation, the duration, the rate of change, the response time, and the location. The delivered service should be reliable and contribute to the security of the system.”* (CEER, 2018).

Moreover, behind-the-meter storage systems can provide implicit and explicit demand-side flexibility. Explicit demand-side flexibility is “dispatchable flexibility that can be traded on the different energy markets (wholesale, balancing, ancillary services, and reserve markets)” and implicit demand-side flexibility is the adaptation of consumers behavior due to price signals. (SmartEN, 2017). Both use-cases are analyzed in this study.

## 3.2 Behind-the-meter storage systems

All grid-tied energy systems can be differentiated between in front-of-the-meter or behind-the-meter systems. Behind-the-meter storage refers to a “customer-sited stationary storage system that is connected to the distribution system on the customers’ side (i.e. residential, commercial or industrial) of the utility’s service meter” (Bowen & Gokhale-Welch, 2021) whereas front-of-the-meter storage systems refer to utility-scale systems connected to transmission systems and are designed for grid balancing purposes and meeting power system needs (Energysage, 2019).

In figure 3 a schematic diagram of behind-the-meter storage systems and its electricity flows is shown.

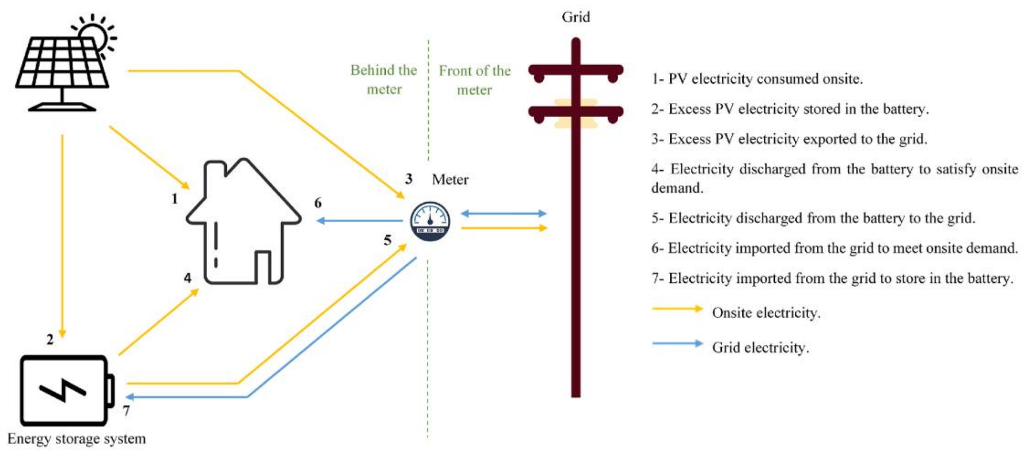


*Figure 3: Schematic diagram of PV + Behind the meter storage system (Source: Rezaeimozafar et al, 2022)*

In general, a behind-the-meter energy storage system stores electricity that either comes from self-generated solar PV systems or is drawn from the distribution grid. The electricity discharged from the battery can be used to satisfy onsite demand or can be discharged to the grid (Rezaeimozafar, 2022).

### 3.3 Stationary battery storage systems

There are currently various manners to store energy: mechanical, electrochemical, electrical, chemical, and thermal energy storage. Each of these technologies bring technological aspects, such as energy and power capacity, round-trip efficiency, conversion efficiency and storage duration.

An battery energy storage system, an electro-chemical storage technology, is being deployed at transmission, distribution, and consumer levels. The costs of battery energy storage systems are decreasing and thus the amount of these systems have tripled in less than three years. The battery storage industry is to a large amount – more than 80% of all battery capacity - driven by Lithium-ion (Li-ion) batteries, what provides mostly short-term energy storage (IEAb, 2019) and are thus applicable for behind-the-meter storage systems.

Several types of battery storage technologies are available, including Li-ion, lead-acid, nickel-based, sodium-based and redox flow (Zinaman et al., 2020). Li-ion batteries have a relatively high energy density, low self-discharge, long cycle life and high energy efficiency (Crabtree et al., 2015). Several cells can be connected to greatly increase the power rating and energy storage capacity. Since Li-ion batteries are currently the number one market leader and can provide short-term energy storage due to their technological characteristics, this technology is the main focus of this research. The Li-ion battery technology is both used in the V2G technology as in the stationary battery storage systems.

### 3.4 Vehicle-to-grid technology

The second technology included in this research is vehicle-to-grid (V2G) technology and is defined as: "the delivery of electricity from vehicles to the electricity grid as a service for electric utilities" (Ghotge et al., 2019). EVs with V2G capabilities carry Li-ion batteries which can be used as a form of grid energy storage when plugged-in in the electricity grid (Tarroja et al., 2016). This technology allows the battery to charge and discharge electricity back into the grid and therefore can provide peak demand support when required (Becky, 2015).

Since EVs are already being deployed in the transportation sector due to decarbonization reasons, the use of these vehicles to support grid services can be seen as an opportunity (Tarroja et al., 2016). The average duration over which electric vehicles are used for transportation is about 5%, which is based on work-home rides during the weekdays and travelling in the weekend. Meaning that, the remaining 95% electric vehicles could be used for other purposes, which is the basis of the V2G concept (Wolbertus et al, 2018).

Additionally, V2G can provide multiple grid services and ancillary services, for example voltage and frequency control and therefore improve the performance of the electricity grid, such as stability and reliability (Yilmaz & Krein, 2013;EASE, 2021). Moreover, EVs enabled to bi-directional charge, could lower investments in the distribution grids due to preventing congestion in regional grids due to the spread of EVs over the system and allows for absorbing local imbalances (Wolbertus et al, 2018). Moreover, an EV enabled to discharge electricity could also supply energy to households or businesses and is in the literature referred to as vehicle-to-home (V2H) or vehicle-to-business (V2B). The combination of providing self-optimizing for the residential, commercial, and industrial sector and the provision of grid balancing services are both included in this study.

It is important to mention that V2G technology is still largely in a development phase. Currently, limited numbers of EVs are enabled to provide bi-directional power flows and thus able to provide grid or self-consumption services. One of the main objectives of this study is to identify barriers for enabling current EVs to EVs providing bi-directional power flows.

*Differences V2G and smart charging*

The main difference between smart charging (V1G) and V2G is the major addition of flexibility and the ability to balance the grid that V2G can offer. When the battery of an EV is full, smart charging can no longer offer flexibility. When using V2G technology, continuous services of using the battery can be provided when connected to the electricity grid. This provides a significant increase in the flexibility and better integration into the grid, according to ELaad (2022).

There are multiple differences between stationary storage systems and the use of V2G charging and discharging of EV. Firstly, stationary storage systems can be charged and discharged according to their energy capacity whereas the charging and discharging of EVs is constrained by the available capacity. The available capacity differs over time since the overall number of EVs differ and the state of charge of each vehicle is differenced when plugged in. Therefore, the flexibility offered from stationary storage systems can benefit the electricity grid more then V2G integrated EVs can (Tarroja et al., 2016). However, one of the advantages for V2G technology over stationary battery systems is that EVs provide multiple functions, namely transportation and energy storage whereas stationary battery systems are only used for storage purposes.

### 3.5 Customer benefits versus system benefits

In the literature multiple studies are conducted to investigate the benefits of energy storage systems. Behind-the-meter storage technologies can be divided into two purposes, firstly, to provide benefits for electricity consumers and secondly the possibility to provide benefits from a system perspective. An overview of the benefits for consumers versus system benefits is shown in figure 4.

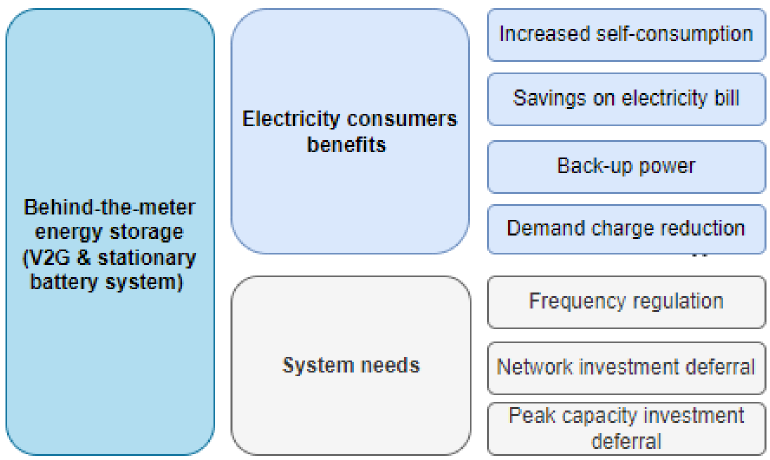


*Figure 4: Grid side vs customer side benefits (Source: based on IRENA, 2019a)*

Benefits for electricity consumers are the increased self-consumption from stored self-generated solar energy, possible savings on the electricity bill, back-up power in case of black outs and demand charge reduction. Behind-the-meter storage systems can furthermore provide benefits for the overall electricity system by maintaining the frequency of the grid and decreasing network investment since expanding grid infrastructure due to congestion is less necessary (IRENA, 2019a).

*Residential, commercial, and industrial consumers*

The focus of this study is the residential, commercial and industrial sector. Residential, commercial and industrial consumers can play a role in maintaining the grid balance by providing flexibility and helping to avoid grid congestion by using locally generated energy when available and storing the energy when needed (Donker et al., 2015).

Residential storage could enable the optimization of production and consumption by making locally use of generated electricity. As seen in figure 5, installing a behind-the-meter battery system could increase the amount of self-consumption from 30% up to 70% for households (EC SWD, 2015). Additionally, residential storage can create value by using flexible electricity prices when exposed to dynamic price tariffs which is explained more in depth in section 4.4.1. The increased self-consumption and response to price signals leads to a decrease in electricity bills, could provide back up power and demand charge reduction (IRENA, 2019a). In this study, the residential sector is defined as small-scale consumers with a grid connection smaller than 3x80A and a storage capacity between 3-10 kW.

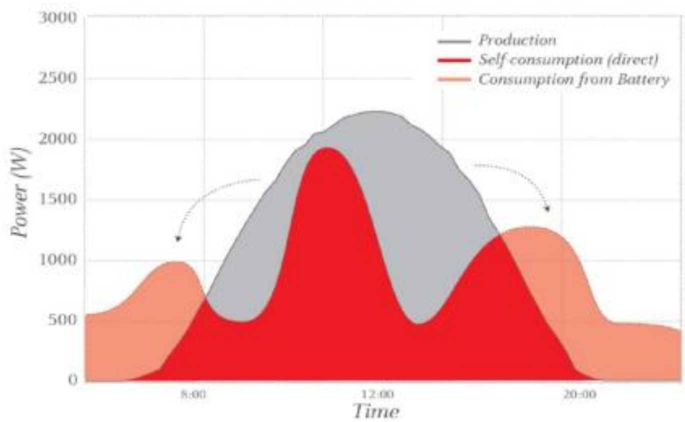


*Figure 5: Effect of local electricity storage on self-consumption household (EC SWD, 2015).*

Commercial and industrial consumers are defined in this study as consumers with a grid connection size > 3x80A and are for example, supermarkets, enterprises and industries for which storage capacities can range from 10 kW - 5MW. Commercial and industrial consumers storage systems could play a role in optimizing self-consumption, their network costs and taking advantage of low and negative electricity prices on balancing markets (ESNL, 2016). The Energy Storage World Forum (n.d.) identified four key benefits for energy storage in the C&I segment:

- Energy bill management - Flattening the daily load profile by cutting peak demand charges. A stationary battery system combined with on-site renewable energy can prevent exposure to volatile prices.
- Increased grid independence - Provision of back-up power during outages
- Ancillary services - Additional revenue streams by providing ancillary services, such as frequency response or voltage control.
- Arbitrage and energy market billing - Commercial and industrial consumers could benefit from additional revenues from participation in energy, ancillary and capacity markets by using optimized control and software systems.

*Aggregation of (small-scale) storage systems*

According to Mckinsey (2019) aggregated (small-scale) batteries could support grid stability by linking the batteries together to deliver grid support services also known as 'a virtual power plant'. Energy storage systems from multiple (small-scale) consumers can be bundled by an aggregator and as a result, participate in energy markets and generate additional revenue streams. There are already some examples (Crowdnett (Middelkoop, n.d.), Lichtblick, Sonnengroup, Next Kraftwerke, Jedlix) where aggregated storage systems work together as a virtual power plant and provide grid balancing services. According to Murray (2022) the annual deployment of virtual power plants is expected to reach 3GW by 2030. In figure 6 an example of a virtual power plant is shown. In figure 7 the differences in battery capacity used for self-consumption and battery capacity used for self-consumption and grid balancing services from the pilot study of Crowdnett (2018) is shown.

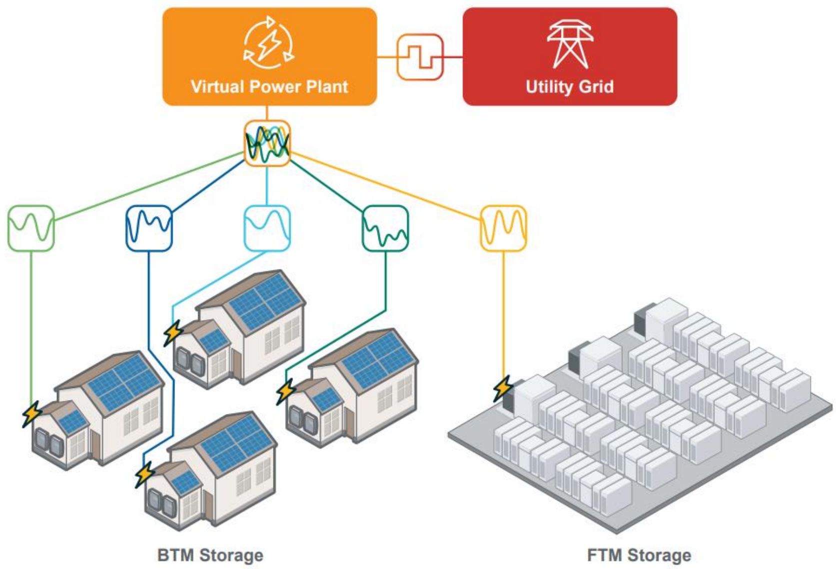


*Figure 6: Virtual power plant (Source: Bowen & Gokhale-Welch, 2021)*

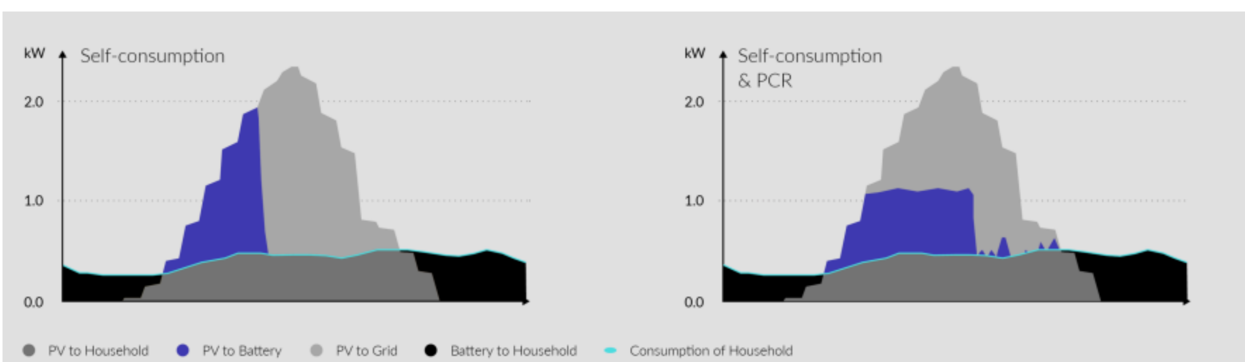


*Figure 7: Self-consumption vs self-consumption + PCR. Source: Crowdnett (2018)*

### 3.6 Stakeholders

As popularity of energy storage systems grows within the residential as in the C&I sector, so does the opportunity for broader market participation. In table 3, the involved stakeholders and their role and applicability to stationary batteries or V2G technology is given.

**Table 3: Overview involved actors behind-the-meter storage systems**

| | | Stationary battery systems | V2G technology |
|---|---|---|---|
| **Active Consumers** | The role of active consumers is to consume, generate or store electricity. In this report active consumers are referred to all residential, commercial and industrial users. | X | X |
| **Energy supplier** | The role of the supplier to source, supply, and invoice energy to its consumers. The energy supplier is program responsible. | X | X |
| **(Independent) aggregator** | The role of the aggregator is to aggregate flexibility from active consumers and their flexible assets and sell it to balancing responsible parties (BRP), the distribution system operator (DSO) or transmission system operator (TSO). The aggregator can be seen as a third party who empowers flexibility owners to use the capacity of the battery for grid balancing purposes. The aggregator aggregates multiple batteries in order to provide flexibility to the system and trades on several electricity markets.<br><br>However, multiple stakeholders (such as energy suppliers or independent aggregators (i.e. no energy suppliers) can fulfill the role of an aggregator. | X | X |
| **DSO** | The DSO is responsible for operating, maintaining and if necessary, developing the distribution system. Including, the installation of grid connections. | X | X |
| **TSO** | The role of the Transmission System Operator (TSO) is to transport energy from centralized producers to active consumers and DSOs via its high-voltage grid. The TSO safeguards the system's long-term and short-term ability to meet electricity transmission standards. The TSO is responsible for balancing the system by deploying regulating capacity, reserve capacity and emergency capacity. The TSO can purchase flexibility via the BSP or Aggregator. | X | X |

| | | | |
|---|---|---|---|
| **Producer** | The role of the producer is to inject energy into the electricity grid. | X | X |
| **Car manufacturers** | Responsible for manufacturing EVs and provision of guarantees on EVs' battery. Moreover, car manufacturers could choose to implement bi-directional charging components. | | X |
| **Charge Point Operators** | Charge Point Operators (CPO) operates the charging infrastructure for EVs and thereby monitors, controls and maintains the infrastructure. | | X |
| **E-Mobility Service Providers** | Responsible for providing different charging points to end-user and ensure payments are handled. MSPs are the link between CPOs and EV drivers. | | X |

# 4. Factor identification & analysis

The question this chapter answers is: "What factors may represent barriers for the deployment of behind-the-meter energy storage technologies (e.g. stationary battery systems and vehicle-to-grid) in the Netherlands and Germany?". This question is answered by first selecting the most important factors that influence the development, secondly the categorization of the factors and finally analyzing behind-the-meter storage systems on the selected factors.

## 4.1 Overview of the selected factors

The factors impacting behind-the-meter energy storage are derived by thoroughly analyzing the current literature on behind-the-meter energy storage systems and its barriers. In this thesis, factor and barrier are used interchangeably.

### 4.1.1 *Factors that represent barriers for the deployment of behind-the-meter storage systems*

The current indicators are selected for being a barrier:

1. A barrier is "*anything that prevents or obstructs or hinder the progress, movement or development of something*" (Gupta et al., 2017). With reference to the deployment of behind-the-meter energy storage in this thesis, this means that a barrier is anything that *hinders* the progress, movement or development of stationary Li-ion battery systems or electric vehicles with V2G capabilities.

2. The barriers identified concern the residential *or* commercial & industrial sector, focused on *behind-the-meter storage systems who are connected to distribution networks or transmission networks (the latter possible for the C&I sector)*.

3. The barriers identified concern *technological, economical, and behavioral or regulatory aspects of behind-the-meter storage systems.*

In table 4 an overview is given what barriers affect the deployment of behind-the-meter storage systems. Moreover, in the table is shown which barriers affect what technologies and sector and from which sources the factor is derived from.

**Table 4: Identification factors literature study**

| Identified factors in the literature | Affected technology | Affected sector | Sources |
|---|---|---|---|
| High upfront investment costs | Battery / V2G | Residential/ C&I | • Bowen & Gokhale-Welch, 2021<br>• HIS Markit, 2020<br>• IRENA, 2017<br>• DNE Research, 2022 |

| | | | |
|---|---|---|---|
| Lack of remuneration schemes | Battery / V2G | Residential / C&I | • Zonneveld, 2019<br>• Kubli et al, 2019<br>• Carradore & Turri, 2010 |
| Lack of value stacking | Battery / V2G | Residential / C&I | • Sioshansi, 2020<br>• IRENA, 2017<br>• USEF, 2021a |
| Price arbitrage | Battery / V2G | Residential/ C&I | • Donker et al, 2015<br>• Tsai et al, 2020 |
| Difficulties acquiring loans | Battery | Residential / C&I | • DNV, 2021 |
| Lack of subsidies | Battery / V2G | Residential / C&I | • Energy Storage World Forum, 2021<br>• NBD, 2021) |
| Lithium constraints | Battery / V2G | Residential / C&I | • IEA, 2021<br>• Greim et al, n.d. |
| Lack of technicians | Battery / V2G | Residential / C&I | • NOS, 2021<br>• Garsten, 2022<br>• Czako, 2020 |
| Lack of chips | V2G | Residential / C&I | • Hjar, 2021<br>• E-drivers, 2021<br>• Hiar, 2021<br>• Cuff, 2022 |
| Lack of availability smart-meter | Battery / V2G | Residential / C&I | • SmartEN, 2019<br>• BNE, 2020 |
| Lack of grid connection | Battery / V2G | Residential / C&I | • Liander. (n.d.) |
| Lack of bi-directional charging points | V2G | Residential / C&I | • Svarc, 2022<br>• Elaad, 2022 |
| Lack of physical space to implement technology | Battery / V2G | Residential / C&I | • Clean Energy Councel, n.d. |
| System integration complexity (converters/inverters) | Battery | Residential / C&I | • Rezaeimozafar et al (2022).<br>• Sandelic, (2019). |
| Lifetime decrease due to battery degradation | Battery / V2G | Residential / C&I | • Heymans et al, 2014<br>• Dubarry et al, 2017<br>• Elaad, 2022<br>• Uddin et al, 2017 |
| Low reliability of the system | Battery / V2G | Residential / C&I | • Hajeforosh et al, 2020<br>• Sandelic, 2019<br>• JouwEnergieMoment, 2020 |

| | | | |
|---|---|---|---|
| Safety issues | Battery / V2G | Residential / C&I | • CFPA Europe (n.d.) |
| Privacy issues (cyber security) | Battery / V2G | Residential / C&I | • Bayram & Ustun, 2017<br>• Schweiger al, 2020<br>• Annala et al, 2013 |
| Low willingness to insure | Battery / V2G | C&I | • DNV, 2021 |
| Lack of communication protocols | Battery / V2G | Residential / C&I | • Greenflux, n.d.<br>• Hivepower, 2021 |
| Lack of energy management systems | Battery / V2G | Residential / C&I | • Bayram & Ustun, 2017<br>• Nair & Garimella, 2010 |
| Interoperability and compatibility challenges | Battery / V2G | Residential / C&I | • Zonneveld, 2019<br>• Elaad, 2021 |
| Net-metering | Battery / V2G | Residential | • Rijksoverheid, n.d. |
| Double taxation issues | Battery / V2G | C&I | • PWC, 2017<br>• RVO, n.d. |
| Lack of dynamic pricing (ToU, real-time pricing) | Battery / V2G | Residential / C&I | • Donker et al, 2015<br>• USEF, 2021a<br>• Bowen et al, 2021 |
| The height of retail electricity prices | Battery / V2G | Residential / C&I | • Keiner et al, 2019<br>• Ugarte, 2015<br>• ACER, 2021a |
| Influence network tariffs on self-consumption | Battery / V2G | Residential / C&I | • SmartEN, 2019<br>• USEF, 2021a<br>• ACER, 2021b |
| Lack of definition storage | Battery / V2G | Residential / C&I | • ACM, 2021 |
| Lack of definition aggregator | Battery / V2G | Residential / C&I | • PWC, 2017<br>• ACM, 2019 |
| Entry barriers for the participation in multiple electricity markets (DA, ID, balancing markets) | Battery / V2G | Residential / C&I | • Malmgren, 2016<br>• TenneT, 2018<br>• Donker et al, 2015<br>• DNV, 2021<br>• USEF, 2021a<br>• ACER, 2021a |
| Entry barriers in capacity mechanisms | Battery / V2G | Residential / C&I | • ACER, 2021a |
| Absence of local flexibility markets | Battery / V2G | Residential / C&I | • Radecke et al, 2019<br>• ACER, 2021a<br>• GOPACS, n.d. |
| Dependency home-owner - tenant | Battery / V2G | Residential | • Held et al, 2021 |

| | | | |
|---|---|---|---|
| | | | • Ministry for Economic Affairs and Climate Action, n.d.). |
| Dependency on aggregator | Battery / V2G | Residential / C&I | • Immonen et al, 2020<br>• ACM, 2019 |
| Interaction supplier / aggregator | Battery / V2G | Residential / C&I | • Baker, 2016<br>• Schittekatte et al (2021) |
| Lack of knowledge storage opportunities | Battery / V2G | Residential / C&I | • ESNL, 2019<br>• Energy Storage World Forum, n.d. |
| Necessity of changing behavior for implementing technology | Battery / V2G | Residential / C&I | • Lazzeroni et al, 2019<br>• Zonneveld, 2019<br>• Parson et al, 2014 |

The found 37 factors of table 3 can be broadly referred to as factors that represent barriers for the deployment of behind-the-meter energy storage systems. However, the factors derived from the literature should be categorized and grouped for two reasons: to make the study more compact due to time-constraints of interviews, and to present a clear overview of the identified factors, which should facilitate their understanding by policy makers and other stakeholders.

### 4.1.2 *Modifcation of the Y-factor method*

The second sub question is: How can we modify the Y-factor method to capture barriers for the deployment of behind-the-meter storage systems? To answer this question, the found barriers of table 3 are held against the Y-factor framework of Chappin (2020). As explained in the methodology, the barriers identified in the Y-factor framework gives an overview of the found factors and values that apply to multiple abatement technologies and are formulized on a high level to capture all the abatement technologies. However, the suitability of the Y-factor method to this technology-specific research could be limited as the Y-factor method is not covering all the barriers relating to behind-the-meter storage systems.

In figure 8 an overview is shown of the selection and categorization procedure of the factors. On the left side all 37 factors identified in the literature are mentioned, thereafter the factors are connected to the factors identified for the Y-factor method. For multiple factors, however, such as *entry barriers for the participation in electricity markets*, *lack of a storage definition* and an existing *net-metering* mechanism no factor from the research of Chappin et al (2020) could be linked towards these factors and therefore new factors are added.

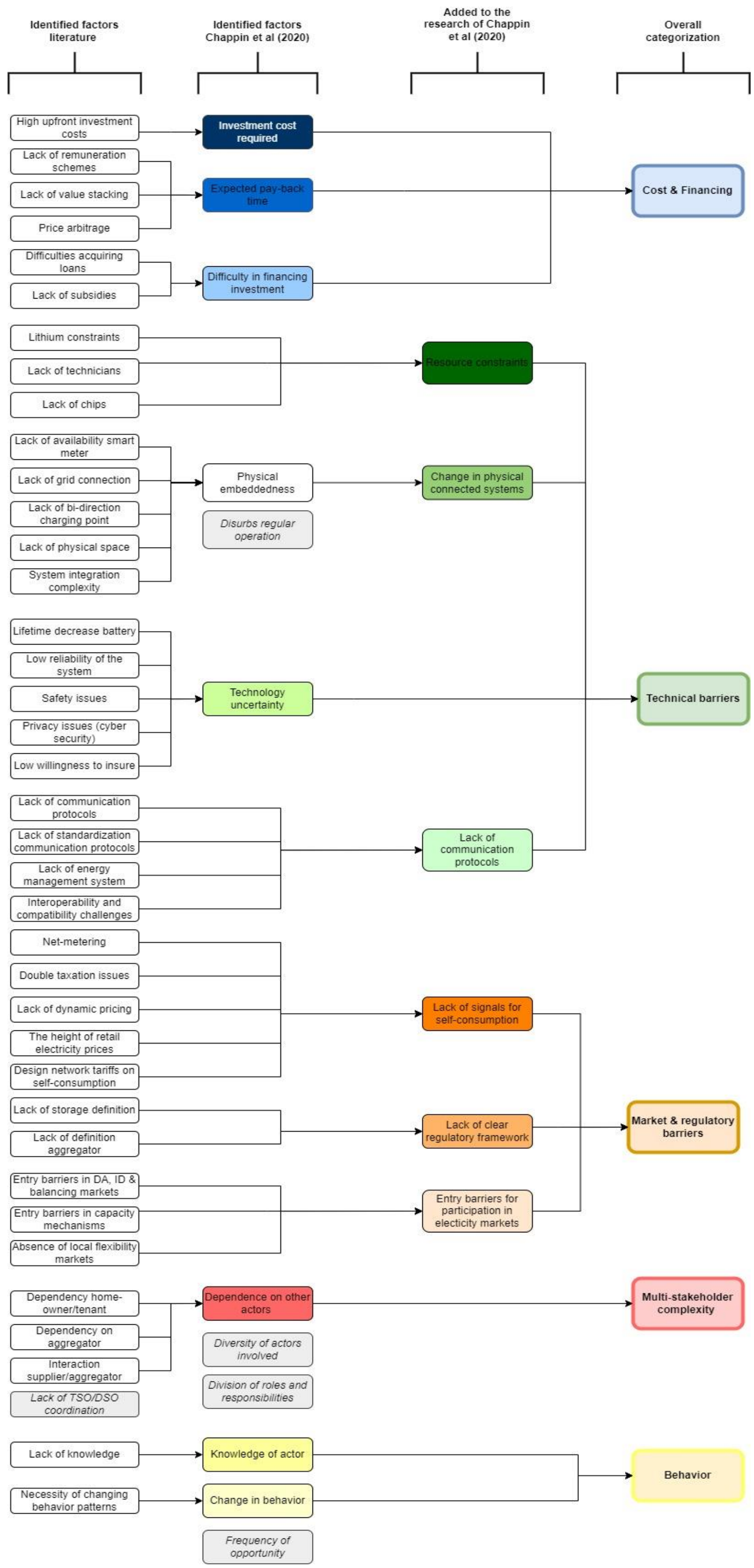


*Figure 8: Overview grouping and selecting factors behind-the-meter storage technologies*

The factors that are excluded (factors in grey) from the research of Chappin et al (2020) are:

- Diversity of actors involved
- Division of roles and responsibilities
- Frequency of opportunity
- Disturbs regular operation

The reason for the exclusion of the factors '*diversity of actors*' and '*division of roles and responsibilities*' is that it has not been identified as a major issue in the literature on behind-the-meter energy systems, since the number of stakeholders and the corresponding roles and responsibilities are less diverse in comparison to multiple abatement measures. Moreover, '*frequency of opportunity'* and the *'disturbance of regular operation'* is not identified as an issue either.

Regarding the coupling of multiple factors, the following categorization is chosen:

I. The deployment of stationary battery systems and EVs enabled for bi-directional charging require investments (Rotella Junior et al., 2021) and therefore leads to barriers regarding **costs and financing**. The costs and financing factors are related to the significance of the investment, the payback time and the difficulty to obtain financial means. The '*required investment cost*' factor does not entail the absolute value, yet, the factor is scored to the degree for which the investment costs are significant in size for the one investing in the storage technology.

II. Stationary battery systems and EVs enabled for bi-directional charging are still in development and therefore results in **technical barriers** for the deployment of the storage technologies**.** This study is focused on only two technologies and therefore, the more technology-specific barriers such as resource constraints, change in physical connected systems, lack of communication protocols and technology uncertainty should be incorporated to cover the technical challenges which were not covered in the initial Y-factor framework.

III. The two storage technologies can participate in different electricity markets, however face **market & regulatory barriers**, such as entry barriers or the presence or absence of policies. Market & regulatory barriers are added to the initial Y-factor framework to cover all the barriers with regard to the deployment of the two storage technologies.

IV. The deployment of behind-the-meter energy storage systems comes with challenges regarding stakeholders, such as **stakeholder complexity**, for example the dependency on other actors. Stakeholder complexity is difficult to quantify, however the dependency on other actors could impact the investment choice of consumers willing to invest in storage technologies and is therefore included in this study.

V. The deployment of stationary battery systems and EVs enabled to bi-directional charge could require a change in **behavior,** which can be seen as a barrier and is therefore included in this study. The necessity of adjusting behavior towards storage technologies can play a part in the investment decision. Additionally, a lack of knowledge on these storage systems can play a role in the investment decision as well and therefore both factors are included and analyzed.

Overall, technical barriers as well as market & regulatory barriers are added to the initial Y-factor framework of Chappin et al (2020) and are needed to cover all the barriers with regard to the deployment of stationary battery systems and EVs enabled to bi-directional charge.

Table 5 represents the overview of the identified factors, values and definitions and relating concepts. The overall definition of the factor is generic since it has to be applicable to residential and commercial and industrial consumers, to both stationary battery systems as EVs enabled to bi-directional charge and to both the Netherlands and Germany. Therefore, generic definitions are formulated, however, explicit and operational enough so they can be scored by experts. Moreover, values are defined per barrier. For example, regarding the factor '*investment costs required*', no barrier (0) exist if the investment costs are low in size for the investor, and a significant barrier exist (2) when the investment costs are large in size for the one investing in the technology.

In the next sections, the factors are explained and analyzed per sector, per technology and per country.

**Table 5: Overview factors and definitions**

| Category | Factor | 0- No barrier | 1- Possible barrier | 2- Significant barrier | Definitions | Relating concepts |
|---|---|---|---|---|---|---|
| **Costs and financing** | Investment cost required | Low | Medium | Large | The degree to which the investment costs are significant in size for the investor | |
| | Expected pay-back time | <5 years | 5-12 years | >12 years | The degree to which the expected pay-back time is significant | *Renumeration providing balancing services* |
| | Difficulty in financing investment | Low | Medium | Large | The degree to which attracting appropriate financial means is difficult | *Subsidies, loans* |
| **Technical barriers** | Resource constraints | No constraints | Medium constraints | High constraints | The degree to which the resources and/or the technology is constraint | *Availability of lithium; Lack of technicians to install technology* |
| | Change in physical connected systems | No | Medium | High | The degree to which physical change is required in connected or related technical systems or physical change is not possible in time | *Smart meter; Availability of charging point; Availability of grid connection; Bidirectional charging system; Permitting procedure issues* |
| | Lack of communication protocols | Little | Medium | Major | The degree to which the access to, or management of real-time data between storage unit and smart meter is not possible | *Smart management system services in place; Availability of communication* |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | *protocols V2G technology; Lack of permission to access technology; Interoperability standards; Data management systems* |
| | Technology uncertainty | Certain | Somewhat certain | Uncertain | The degree to which technological reliability, safety, privacy and performance are uncertain | *Reliability of the system; Cyber security; Safety, Privacy* |
| **Market & regulatory barriers** | Lack of signals for self-consumption | Little | Medium | Major | The degree to which existent incentives for injecting electricity into the grid instead of storing self-generated energy is significant | *Existence of net-metering policies; Feed-in tariffs; Lack of dynamic pricing; Design grid tariffs; Height of wholesale electricity prices* |
| | Lack of clear regulatory framework | Clear | Somewhat clear | Unclear | The degree to which the regulatory framework is unclear | *Lack of definition for self-consumption; Lack of definition of (independent) aggregator in current legislation* |
| | Entry barriers for the participation in electricity markets | Low | Medium | High | The degree to which entry barriers for participation in electricity markets (i.e. DA, ID, balancing) are existent | *Entry barriers to participate as small-scale consumer in electricity markets; Absence of aggregators' rules for accessing wholesale markets; Value-stacking* |
| **Multi-stakeholder complexity** | Dependency on other actors | Low | Medium | High | The degree of dependency on other actors to successfully implement the technology | *Dependency on aggregator to decrease energy bills; dependency aggregator – supplier; Dependency tenant-home owner; Complex interaction stakeholders in different electricity markets* |
| **Behavior** | Lack of knowledge | No | Medium | High | The degree to which the investor does not know about possible opportunities to install technology | *Information gaps* |
| | Change in behavior | No | Slight | Severe | The degree to which the investor needs to change their behavioral patterns | |

## 4.2 Cost & Financing

Behind-the-meter storage systems provide the ability for residential and C&I consumers to manage their (self-)consumption, as well as to participate in electricity markets, which results in possible benefits for consumers. However, cost & financing aspects, such as required investment costs, pay-back time and the difficulty of financing investment are considered as important barriers for implementing new technologies (Chappin, 2020). In this section, the required investment costs, pay-back time and the difficulty of financing investment are explained and analyzed.

### 4.2.1 *Investment costs required*

High investment costs are seen in the literature as an important barrier for the deployment of behind-the-meter storage energy systems and are therefore included in this study (Bowen & Gokhale-Welch, 2021). The investment costs of both stationary batteries and EVs enabled for bi-directional charging are dependent on the price development of Li-ion battery packs. According to IHS Markit (2020), the average cost of a Li-ion battery has fallen from 2012-2020 by 82% and is expected to decline even further due to economies of scale and technology advancements (i.e. improvements of battery energy density and efficiency) (Nguyen & Byrne, 2017) as shown in figure 9. The investment costs required for stationary battery systems is dependent on the capacity of the battery, more specifically a stationary Li-ion battery ranging from 4 to 8 kWh cost around 5000-8000 euro's (without VAT).

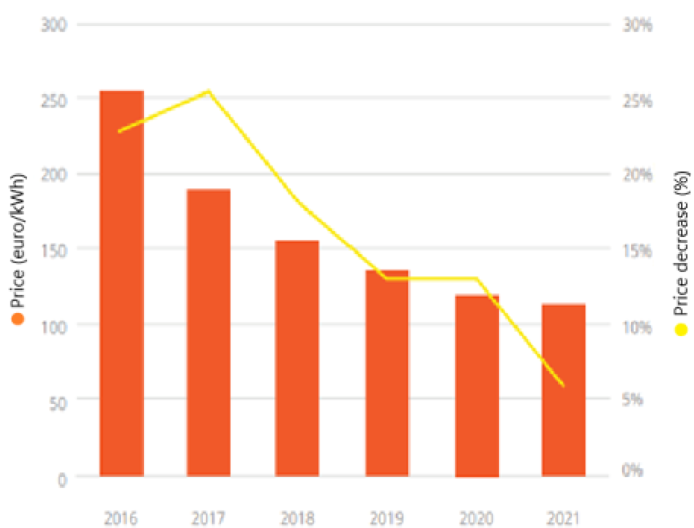


*Figure 9: Price decrease of lithium-ion battery packs worldwide. Source: Smart Storage Trend report (2022)*

The required investment costs of enabling EVs to bi-directional charge is dependent on the cost of integrating charging hardware and a bi-directional charging point in the current infrastructure. According to a case study of Nissan & Enel, the investment costs are approximately €1300 - €1400 higher for a direct current (DC) charging point and €400 higher for an alternative current (AC) charging point compared to a mono-directional charging point. The additional costs of an EV enabled for bi-directional charging compared to a 'conventional' EV is negligible (PWC, 2021). However, due to the higher upfront costs of bi-directional charging compared to mono-directional charging the possibility exists that only wealthy or well-informed EV owners would adopt to V2G technology.

The differences in the investment costs for stationary battery systems and EVs enabled for bi-directional charging lies in the dual application of V2G technology. The investment in an EV is made for mobility purposes and therefore the storage capacity of the battery can be seen as 'free' whereas the investment in stationary battery systems is only used for self-optimization or provision of grid balancing services. However, for both technologies investment costs could play a crucial role and is therefore included as barrier in this study.

### 4.2.2 *Pay-back time*

Pay-back time is considered as an important indicator for investing in behind-the-meter storage technologies and is dependent on multiple factors, namely: reduced energy bills due to peak shaving or demand response and/or offering flexibility that can be traded on different electricity markets. Value stacking (i.e. combining multiple value streams by the aggregator which can improve the business case of investing in storage systems) is included since it could differ in the Netherlands and Germany if value stacking is allowed. An overview of these three subfactors impacting the pay-back time of behind-the-meter energy storage technologies are shown in table 6. The factors *'investment costs required'* and *'difficulty of financing investment'* influences the pay-back time as well, but are analyzed individual.

**Table 6: Overview factors pay-back time generating revenues**

<table>
<tr><th></th><th>Residential – li-ion battery systems</th><th>C&I sector – Li-ion battery systems</th><th>Residential - V2G</th><th>C&I – V2G</th></tr>
<tr><td>Implicit demand-side flexibility</td><td colspan="4">NL/DE: Enabling consumers to opt for implicit demand-side flexibility could provide significant energy savings for the residential and the C&I sector (smartEN, 2017). Industrial or large consumers could adopt their production or operation schedule to times when electricity prices are lower, also known as peak shifting or demand-response.</td></tr>
<tr><td>Explicit demand-side flexibility</td><td colspan="2">NL: Consumers could receive financial compensation (fixed availability fee + variable fee for calling the capacity) by providing capacity or energy to aggregator (pilot JouwEnergieMoment, 2019, Crowdnett, 2018)<br><br>DE: There are multiple parties (Sonnen, Next Kraftwerke, Lichtblick) who build virtual power plants of decentralized</td><td colspan="2">NL/DE: Remuneration for participating in V2G contracts (i.e. contracts used for rewarding or penalizing when failing to comply) for supplying electricity to the grid (Zonneveld, 2019)</td></tr>
</table>

| | | |
|---|---|---|
| | batteries into revenue-generating grid assets for consumer | |
| Value stacking | **NL:** Value stacking in different electricity markets currently only possible via aggregator for the residential sector. There are possibilities for behind-the-meter storage assets above certain capacities to stack value in different markets. Distributed resources can participate in FCR, aFRR and mFRR markets (USEF, 2021a). Moreover, pooling is allowed in the Netherlands.<br><br>**DE:** Value stacking in different electricity markets currently only possible via aggregator for the residential sector. There are possibilities for behind-the-meter storage assets above certain capacities to stack value in different markets. Distributed resources can participate in FCR, aFRR and mFRR markets (USEF, 2021a). | |

*Implicit demand-side flexibility*

Implicit demand-side flexibility is the adaptation of consumers' behavior due to price signals. Both residential as C&I consumers are able to manage and optimize their own energy demand, whilst utilizing behind-the-meter storage systems, based on variable hourly market price signals and as a result save on energy expenses. Nonetheless, implicit demand-side flexibility is only possible when consumers are equipped with smart metering devices (SmartEN, 2017).

*Explicit demand-side flexibility*

Explicit demand-side flexibility is "dispatchable flexibility that can be traded on the different energy markets (wholesale, balancing, ancillary services and reserve markets)" (SmartEN, 2017). When utilizing behind-the-meter storage technologies for grid balancing purposes, revenues for proving flexibility could be in place which in general, except for large commercial or industrial consumers, is facilitated and managed by an aggregator. Explicit demand-side flexibility can provide dispatchable and reliable services to network operators and is measured in terms of available capacity whereas implicit demand-side flexibility is only focused on self-optimization (SmartEN, 2017). In the Netherlands, a pilot study was conducted, in which aggregated home batteries functioned as a virtual power plant to balance overall supply and demand. Consumers participating in the pilot received an extra substantial revenue per year by the aggregator (CrowdNett, 2017) and thereby decreasing the overall pay-back time.

Both types implicit and explicit demand-side flexibility are complementary and according to SmartEN (2017) should co-exist to "allow for consumer choices and enable an efficient energy system".

With regard to EVs enabled for bi-directional charging, similar arguments account for implicit demand-side flexibility. However, with regard to explicit demand-side flexibility, discomfort can arise when providing grid services, since the battery may not be fully charged when the owner of the EV wants to use the car (Zonneveld, 2019). Therefore, the EV owner could be compensated for the discomfort that can be experienced Kubli et al (2018), Possible remuneration for participation in V2G could be a free charging station or annual or monthly remuneration of providing battery capacity to the aggregator. To give an example, the first project implementing V2G in the market consisted of a remuneration of 2,00 euro/10-hour plug-in duration, guaranteed energy at 90 kilometers and a contract duration for 12 months (OVO energy, n.d.). According to Carradore & Turri (2010) it is expected that a higher remuneration leads to higher participation in V2G programs.

*Value stacking*

Behind-the-meter energy storage can be used to deliver multiple services at the same time, from providing on-site services to fast response services for balancing purposes (Sioshansi, 2020). Value stacking refers to the pooling of revenue streams from multiple services to build up the business case for investing in flexibility (Renewable Energy Agency, 2017). However, in the Netherlands and Germany, value stacking for the residential sector is only possible and realistic opportunity via the aggregator due to value stacking being highly complex and requires complex algorithms. Financial benefits are shared between consumers and aggregators.

Transparent and objective rules by network operators on which services can be combined by storage can provide the certainty necessary for value stacking. The markets in which storage operators (or operators of aggregated storage assets) are able to participate include balancing markets, as well as congestion management and other flexibility services.

Value stacking is important for increasing the business case of battery energy storage, however, it has its limitations since providing two services in the same time window with opposite directions (i.e. upward and downward generation) might counteract the overall net-effect (USEF, 2021b). Value stacking could be necessary to improve the business case for the aggregator, however, value stacking is complex and should therefore be thoroughly analyzed before implementation.

### 4.2.3 *Difficulty in financing investments*

The difficulty of financing investments for behind-the-meter storage technologies lies in the complexity of acquiring direct subsidies (e.g. grants) and the availability of financing schemes (i.e. non-subsidized finance such as loan schemes which have to be repaid). This factor is directly related to *'the expected pay-back time'* and *'the required investment costs'*, however, this factor is purely focused on the difficulty of acquiring the necessary cash for the purchase of the necessary equipment and services.

In the Netherlands, there are currently no direct subsidies available for stationary battery systems and bi-directional charging points. In Germany, solar + storage systems < 30 kW receive subsidies that cover a third of the battery systems' cost (Energy Storage World Forum, 2021). In table 7 an overview of current subsidy and loan schemes for stationary batteries and V2G can be found (Krokowski, 2021).

Next to subsidies, acquiring (non-subsidized) loan schemes could be one of the possibilities to finance behind-the-meter storage technologies. In Germany, environmentally friendly energy is viewed positively in multiple municipalities and therefore loans can be promoted to consumers (Krokowski, 2021). Nonetheless, acquiring a loan from financing entities could require a strong business case, the provision of collateral as well as the need to pass credit checks, could therefore be hard to obtain for consumers.

**Table 7: Overview possible subsidies/loans (Information based on (Krokowski, 2021))**

| | **Stationary Li-ion batteries** | **V2G** |
|---|---|---|
| Netherlands | No subsidy available. However, the C&I sector could apply for Energie-Investeringsaftrek (i.e. incentive to motivate entrepreneurs to invest in sustainable, energy efficient assets) to reduce 45,5 % of the investment costs. (Belastingdienst, n.d.) | There are currently no subsidies on charging points. However, there are some possibilities in multiple municipalities, however depending on business/private EV owner. However no information identified on enabling charging points for V2G services. C&I sector could apply for innovation funds. |
| Germany – Federal level | *"kfW Promotion Program 270"* a low interest loan.; up to 100% of investment costs for an electricity storage system can be covered, however, have to be repaid. | The residential sector is eligible for a grant of 900 euro's for purchasing and installing private charging stations, including grid connection. Charging power > 11kW and should be 'intelligent' in order to enable V2G services (BMVI, 2021). |
| Germany - Bavaria | *"Energy storage Photovoltaic Program"* Solar PV systems + storage capacity > 3 kWh. Subsidy starts at 500 euros for a 3 kWh storage system and each additional kWh of storage capacity adds 100 euro's. (Maximum of 30 kWh) | |
| Baden – Württemberg | *"Grid Service Photovoltaic Battery Energy Storage"* - funding program | |
| Berlin | *"EnergiespeicherPLUS"* program; Newly installed solar PV systems + storage 300 euro's/kWh of storage capacity funded when meeting initiatives' requirements. | |
| Lower Saxony | Promotes PV systems + storage; Grants covering 40% of battery storage system costs; output at least 4kWp | |

| | | |
|---|---|---|
| Municipality level | There are diverse subsidy programs in federal German states; opportunities differ per municipality | |

## 4.3 Technical barriers

In addition to the cost & financial barriers, technical barriers should be overcome in order to increase the deployment of behind the meter storage technologies (Bowen & Gokhale-Welch (2021). Technical barriers include resource constraints, required changes in physical related systems, the uncertainty of the technology and a lack of communication protocols. In this section, these barriers and sub-barriers are discussed.

### 4.3.1 *Resource constraints*

Resource constraints could influence the availability of the storage technologies and is therefore seen as a barrier. Three subfactors within the resource constraints are: lithium and other critical minerals constraints, lack of human resources, and chip shortages affecting the car manufacturing sector. The subfactors are explained one per one.

*Lithium and other mineral constraints*

In the past thirty years, there is significant growth in Li-ion battery market for both stationary, mobile, and portable applications, and therefore led to an enormous increase in the raw material demand, especially lithium (IEA, 2021). The study of (Greim et al., n.d.) addresses the long-term availability of lithium and thus possible shortcomings for the acceleration of the energy transition. The study concludes that supply and demand of lithium are well balanced for the short-term, however problems with the availability of lithium could arise in the long-term due to an increase in demand in the transportation and power sector. However, the extraction of lithium is not without environmental damages nor greenhouse gas emissions throughout the supply chain. In Germany, a project is established with the aim to extract carbon neutral lithium and thereby contributing to the European Battery Alliance's mission to establish competitive and sustainable lithium-ion battery production (Energy Storage News, 2020).

Next to lithium, other minerals such as graphite, cobalt and nickel are critical in order to develop EVs and stationary battery systems. According to the IEA (2021) EVs use approximately six times more minerals compared to conventional vehicles. The necessary minerals for Li-ion batteries are based on the chemistry of the cathodes, and different cathode technologies give rise to different battery characteristics. The (future) availability of lithium and other critical minerals is considered as barrier in multiple studies and therefore included as a sub-factor.

*Lack of human resources*

According to NOS (2021) the acceleration of the energy transition could be slowed down due to a lack of technicians. The shortage of technicians is affecting all sectors, including the automotive sector (Garsten, 2022), as well as the power sector, ranging from the installation of solar panels to expanding grid infrastructure (Czako, 2020). The lack of technical human resources is currently affecting the daily operations of DSOs by increasing waiting times for developing grid connections. Since problems occur in both the automotive sector as well as the power sector, the problem could be translated to manufacturing and installation of storage technologies throughout the whole supply chain of the technology, and thereby ultimately affecting the availability of the technology for behind-the-meter applications.

*Chip shortage in transportation sector*

Due to the shortage of chips, caused by the COVID-19 pandemic, car manufacturers could not deliver (electric) vehicles as usual (Hiar, 2021; E-drivers, 2021). A global shortage of chips is slowing down the roll-out of EVs according to Hiar (2021), and, the chip shortage affects the manufacturing of charging stations as well (Cuff, 2022). Besides the transportation sector, there are some noises indicating chip shortage affecting the manufacturing of (smart) meters (TDworld, 2021). Overall, the shortage of chips impacts the availability of EVs and other technical equipment within the storage technology and therefore this sub-factor is included.

### 4.3.2 *Change in physical related systems*

Change in physical related systems is required in order to integrate behind-the-meter storage technologies effectively (Clean Energy Council, n.d.). Physical space, a grid connection, smart metering systems, bi-directional charging points and/or power converters are required when installing behind-the-meter storage technologies and are therefore explained in this section.

*Lack of smart metering system*

Without a smart meter, dynamic pricing (i.e. adjusting consumption towards real-time price signals; *explained in lack of dynamic pricing section*) to provide signals to (active) consumers to optimize self-consumption and participate in electricity markets is not possible. A smart meter is a measuring device which is essential for monitoring real-time consumers' energy consumption and carrying out balancing responsibility and records this data at pre-determined intervals (TNO, 2021).

In the Netherlands, increasing numbers of small-scale consumers have a smart meter (80-90% coverage), which have a measurement granularity of 15 minutes and can be read-out remotely. In 2017, Germany initiated in the Act on the Digitization of the Energy Transition, a process on mass distribution of smart meters. In principle, the law requires meter operators to equip customers above 6000 kWh/year and prosumers with 7kW installations with a smart meter (BNE, 2020). However, in Germany, in 2020, the smart meter roll-out of 23% penetration. The possible reason for the delay of the smart-metering roll-out is the stringent certification process for smart meter gateways (SmartEN, 2019; BNE, 2020). The lack of smart-metering systems leads to less exposure to dynamic pricing and no opportunities for offering explicit demand-side flexibility and thus influences the opportunities for consumers to generate extra revenues.

*Technical complexity*

Technical complexity, such as the integration of power electronics, is part of implementing behind-the-meter storage technologies and could influence the choice for consumers whether to invest in the technology. Power electronics are an important part of integrating behind-the-meter storage systems and are primarily used to convert electric power from alternating current (AC) to direct current (DC) or the other way around (Rezaeimozafar et al, 2022). Examples of such converting processes are AC-to-AC (wind energy to grid conversion), AC-to-DC (grid to battery), DC-to-DC (PV system to battery) and DC-to-AC (battery/PV system to grid) and therefore converters are required in residential & C&I systems.

In figure 10 two possibilities for such systems are shown, a DC coupled energy storage system and an AC coupled energy storage system. In the DC coupled energy system solar energy is sent to the DC-DC PV converter to match the DC link voltage level. Dependent on the decision of the energy management system, power is either converted to AC and used on-site or injected into the grid or sent towards the battery (Rezaeimozafar et al, 2022). In this system the battery and the solar system share the same DC link and thereafter the same DC-AC PV inverter, however the usage of three different converters/inverters affects the overall energy efficiency (Sandelic et al, 2019). Next to a DC coupled energy storage system, is the possibility for an AC storage system. The benefits of such a system are that the capacity of the storage system is no longer limited to the capacity of the single inverter and therefore can provide more power to the grid or on-site applications. The downside is that AC coupled systems are more expensive since an extra inverter is required. Hence, technical complexity affects design choices for investors and should be carefully considered before investing in behind-the-meter storage technologies.

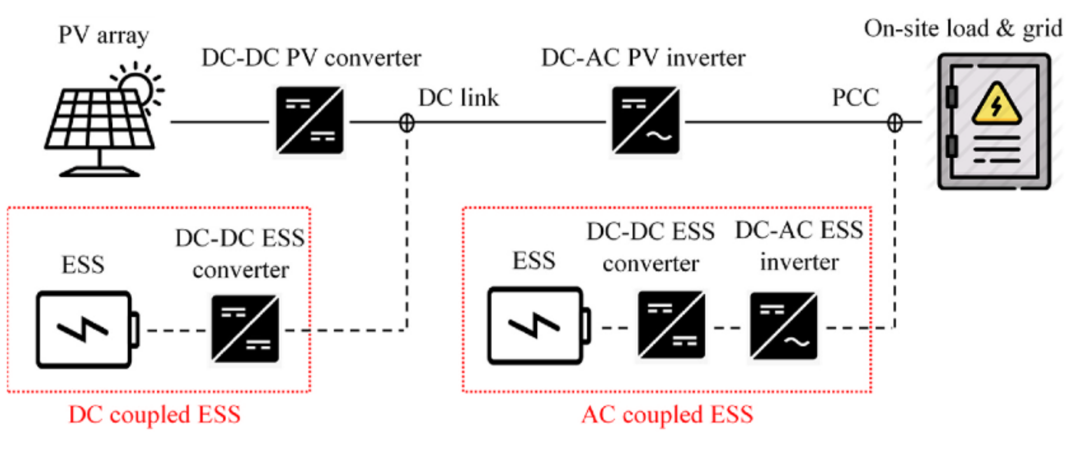


*Figure 10: Schematic overview AC and DC coupled energy storage systems (Source: Rezaeimozafar et al, 2022)*

*Required bi-directional charger*

A bi-directional charger is an advanced EV charger that is capable of charging and discharging the battery of the EV and should be integrated in the physical system to allow EVs to provide energy flows for self-consumption and/or grid services. Most EV owners installed an AC charging point, meaning that the electricity coming from the charging point is converted to DC in the car. When implementing V2G services two possibilities are there: AC V2G and DC V2G. The difference between AC and DC V2G is mainly the place where bi-directional power happens, from the battery (DC) to the electricity grid (AC) and back. With regard to AC V2G the converter is located in the car (Elaad, 2022), which means that for an EV owner willing to provide V2G services an onboard bi-directional inverter should be installed to be able to discharge energy to the charging point. The EV is able to charge and discharge after the adjustment of the EV and current installed AC charging points received a software update. The other possibility is DC V2G for which conversion takes place in the charging station and means that the EVs should only require a software update to be able to discharge. Nonetheless, bi-directional charging points should be integrated in order to provide grid balancing services. In figure 11 the differences between AC and DC V2G charging are shown.

Additionally to the barrier of required bi-directional points is the lack of standardization of EV charging stations, which can be seen as barrier for the large roll-out of EVs enabled for providing V2G services. Some vehicle manufacturers develop bi-directional chargers which are only compatible with EVs from the same manufacturer and thus thereby limiting the large roll-out of these EVs (Svarc, 2022).

In the Netherlands, 70% of all households are not equipped with their own driveway. Problems could arise for this group who are driving electric, but can not find compatible charging points (PWC, 2021). However, there must be noted that one option does not exclude the other option, meaning that a combination of AC and DC V2G is seen as part of the solution for the large roll out of the provision of V2G services.

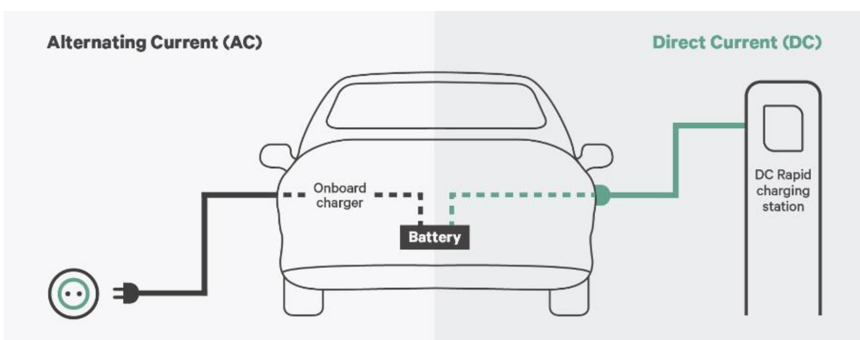


*Figure 11: Differences AC/DC charging (Source: Wallbox, n.d.).*

### 4.3.3 *Technology uncertainty*

Technology uncertainty influences the investment choice (Kauffman, 2015) and is therefore addressed as barrier in this study. The investment choice for the residential and C&I sector on behind-the-meter storage technologies is related to multiple uncertainties, the focus of this barriers is on battery degradation, reliability of the system, safety issues, as well as privacy issues.

*Battery degradation*

One of the important technical uncertainties regarding the implementation of technologies delivering grid services is the battery degradation caused by an increasing number of charge and discharge cycles (Heymans et al., 2014). According to Dubarry et al (2017) the impact of bi-directional charging of the Li-ion battery is detrimental to cell performance. According to the study the additional use of the battery could shorten the lifetime by five years. However, according to Elaad (2022) there can be an advantage of regulated discharging compared to 'normal' discharging: rules can be set for minimum and maximum energy that must remain within the battery during the discharge process, so that there is a safe margin for the State of Charge (SoC). The research of University of Warwick showed that smart charging can even extend the battery life (Uddin et al., 2017). According to the research of Uddin et al (2017) the number of charging cycles is an important indicator, yet temperature, the charging current and the depth of discharging determine the lifespan of batteries as well. According to this study a smart bi-directional charging station combines all the complexities and hence is able to extend the lifetime of the battery.

Car manufacturers are responsible for the manufacturing of EVs and are obliged to provide guarantees on the battery pack. Since the effect of bi-directional charging on the battery is not yet proven, most car manufacturers did not yet implement EVs enabled to bi-directional charge (Alvarex, 2018). According to Malmgren (2016) most EVs come with a 10-year battery warranty, however, integrating bi-directional charging could void the warranty on the battery under current manufacturer's rules and thereby increases the uncertainty of the technology. However, developments are ongoing as Nissan announced to remain the same warranty condition when V2X functionality is implemented (Elaad, 2021). Overall, the possibility exists that providing grid services affects the lifetime of the technology and thus, battery degradation is included as sub-factor.

*Reliability of the system*

The assumption of battery energy systems is that energy storage is continuously available and could be utilized at any time of the day, however, in practice, energy storage systems are not fully reliable and are subject to failures when components fail (Hajeforosh et al., 2020). According to Sandelic et al (2019) the reliability of a battery energy system combined with solar PV is mostly dependent on the number of components and their electrical loading. The study assessed a comparison between DC and AC coupled configurations, including DC/DC and DC/AC converter units and concluded that DC-coupled configuration achieved higher reliability. Moreover, according to JouwEnergieMoment (2018), a pilot study on aggregating stationary home batteries, multiple reliability issues were found: the central energy management server was offline, communication issues between the battery and energy management system, the interfaces between multiple control layers did not work and an unreliable data connection so that inverters did not respond. The (un)reliability of the overall functioning of the system could affect consumers' choices to invest in storage technologies and is therefore included as subfactor.

*Safety issues*

According to CFPA Europe (n.d.) battery systems can bring along fire risks and other safety issues hence increasing the uncertainty of the technology. Li-ion batteries could experience "thermal run-away," meaning that the electrolyte within the battery vaporizes causing problems for maintaining pressure within the cell and toxic gases could be released causing major safety issues. However, the majority of battery systems contain a safety mechanism in the form of ventilation when the pressure increases and therefore prevents an explosion. Additionally, safety issues can also relate to fire breaks in residential buildings or industrial plants in which power packs are installed. Currently, in the Netherlands PGS 37, a norm with the aim to guarantee the safety of storing electricity in Li-ion batteries by meeting certain safety requirements, is under development (Publicatiereeks Gevaarlijke Stoffen, 2021).

Fire risks related to the usage of Li-ion batteries and possible thermal run-aways could affect consumers willingness to invest in the technology. Moreover, safety issues could affect insurers' willingness to provide an energy storage insurance cover (Marsh Commercial, 2021). The difficulty of acquiring insurance could especially apply for the C&I sector since higher costs are involved.

*Privacy*

When data about consumers' energy consumption is collected, data privacy should be guaranteed and could influence the investment choice of the consumer. For example, Beckel et al (2014) found that data on electricity consumption can lead to gathering information on residential socio-economic status, such as household activities and dwelling. Moreover, these privacy concerns are related to security risks since criminals could be able to access the data and use it accordingly (Bayram & Ustun, 2017). Behind-the-meter storage systems could require smart-metering systems which gathers granular information and therefore brings privacy issues.

The European Union established the General Data Protection Regulation (GDPR), a number of rules to protect (automatic) processing of personal data (European Commission, 2016) which is implemented in the Netherlands and Germany. For example, transparency, consent, data minimization, right to restrict the use of data and the right to access data and rectification is included in the GDPR.

According to EurElectric (2015) consumers would be willing to share their data when confident enough that it is stored securely and safeguards privacy. Moreover, there must be ensured that consumers' data is only used for the purposes agreed upon. The perception towards data protection is also of key importance (Schweiger et al., 2020) and could play a key role in the uncertainty towards investing in behind-the-meter storage technologies. Consumers could be hesitant to participate in smart energy systems because there are possibilities data could be exposed (Annala et al, 2013).

All in all, privacy issues or the perception towards these issues are considered in the literature as a crucial barrier for investing in technologies and is therefore included.

### 4.3.4 *Lack of communication protocols*

Multiple communication systems are in place when integrating behind-the-meter storage technologies, however, a lack of standardization within communication protocols or the complexity of integrating energy management systems could be a hurdle for consumers to invest in such technologies.

*Communication protocols*

V2G communication protocols are standards used for the interaction between EVs and the central system (i.e. back-end software that receive and control charging session information, reservations and updates). The Open Charge Point Protocol (OCPP) is an open international standard which allows communication between the charging point and the central system operated by the CPOs. This protocol is used to exchange charging data and trades information between the electric vehicle and the electricity grid, as shown in figure 12.

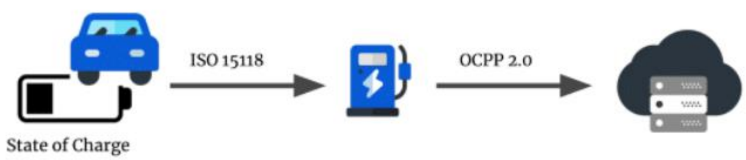


*Figure 12: Relationship OCPP & ISO 15118 (Source: Hivepower, 2021)*

The OCPP 2.0 supports the ISO 15118 communication protocol, an international communication standard, enables bi-directional charging hence the provision of V2G services. Currently in the Netherlands and Germany, the ISO 15118 protocol is used as standard without the involvement of the government (ELaad, 2021). Authorization to start charging or discharging is triggered simply by connecting the EV to a charger (Greenflux, n.d.). However, car manufacturers and battery manufacturers are testing on interoperability and compatibility so that cars can communicate correctly with different types of charging stations.

*Energy management system*

A behind-the-meter energy management system refers to a system designed to meet consumption needs of the consumer while at the same time achieving certain objectives, such as improving energy efficiency, reducing operating cost, and reducing the carbon footprint (Bayram & Ustun, 2017); (Nair & Garimella, 2010).

An energy management system should offer the following functions:

- Storage of surplus solar energy
- Reduction in peak power loads (peak shaving)
- Reducing energy consumption from the grid at peak hours

- Compensation of reactive power
- Balanced consumption

With regard to V2G integration, it is important that the energy management system receives correct data such as battery size of the vehicle, the SOC, the time period when it's allowed to charge and discharge and the time in which the battery should be fully charged again. When this data is provided correctly, potentially by aggregators, network operators could activate the flexibility source to procure the necessary ancillary services (Bayram & Ustun, 2017).

## 4.4 Market & Regulatory barriers

Market barriers & regulatory frameworks can indirectly and directly influence the deployment of behind-the-meter energy storage. Three overall barriers are found in the literature: lack of signals for self-consumption, lack of a clear regulatory framework, and entry barriers for the participation in electricity markets. In this section the market & regulatory barriers of behind-the-meter storage technologies are discussed and analyzed.

### 4.4.1 *Lack of signals for (self-)consumption*

A lack of signals for self-consumption forms an important barrier for the deployment on behind-the-meter energy storage technologies, since the optimal management of (self-)consumption is a major application of behind-the-meter energy storage but requires adequate signals for customers to develop and manage (self-)consumption (IRENA, 2019a). Signals for (self-)consumption are impacted by the following aspects and are analyzed one-per one:

- Net-metering;
- The height of retail and wholesale electricity prices
- Electricity retail price components issues;
    - Energy taxes (the height of electricity prices, double taxation)
    - Supply tariffs (lack of dynamic pricing)
    - Network tariffs (capacity-based, energy-based; lack of time-differentiated network tariffs)

In table 8 an overview is shown of the (lack of) signals for self-consumption, thereafter an explanation per signal and how its affecting behind-the-meter storage technologies is given.

**Table 8: Overview lack of signals for self-consumption per sector and per technology**

| | **Residential – Li-ion battery system** | **C&I – Li-ion battery system** | **V2G - residential** | **V2G – C&I** |
|---|---|---|---|---|
| Net-metering | **NL:** Net-metering is an incentive to inject electricity back into the grid and therefore a barrier for the deployment of behind-the-meter energy storage technologies, however will be slowly phased out starting from 2025 (Rijksoverheid, n.d.). Only applicable to small-scale consumers < 3x80A. | | | |

<table>
<tr><td></td><td colspan="3">DE: Not applicable to Germany, however feed-in tariffs are existent, fixed payment per kWh for injecting electricity back into the grid.</td></tr>
<tr><td rowspan="3">Energy taxation</td><td colspan="3">NL/DE – German electricity prices are significantly higher compared to the Netherlands due to taxes. Electricity prices for households: DE - 0,3234 euro/kWh NL - 0,1449 euro/kWh (including taxes). Non-households 0,2298 Euro/kWh vs 0,1498 euro / kWh. (including taxes) data of the second half of 2021(Eurostat, 2021a;Eurostat, 2021b). Higher electricity prices may lead to an increased incentive for the installation of behind-the-meter storage systems due to financial considerations.<br><br>Moreover, in Germany the occurrence of negative pricing appeared more often compared to the Netherlands (298 versus 97 in day-ahead markets) (ACER, 2021b). The occurrence of negative pricing could be an incentive for commercial and industrial consumers to install behind-the-meter storage technologies to prevent curtailing of solar PV systems.</td></tr>
<tr><td>NL: Due to net-metering no double taxation is applied, however double taxation could become an issue for provision of explicit demand-side flexibility when net-metering rule is phased out.</td><td>NL: For large scale consumers double taxation is removed from the 1st of January 2022 (RVO, n.d.).</td><td>NL: As a result of net-metering (when combined with solar PV system) no double taxation exist for private charge points at low-volume consumers < 3x 80 A (PWC, 2017).<br><br>Without net-metering rule EV drivers are charged twice for taxation. (PWC, 2021).</td></tr>
<tr><td colspan="2">DE: No information identified on removal double taxation. Double taxation issues may occur for offering explicit demand-side flexibility.</td><td>DE: Double taxation issue for bi-directional charging of EVs. (PWC, 2019)</td></tr>
<tr><td>Lack of dynamic pricing</td><td>NL: Possibilities exist to opt for dynamic pricing contracts, however still not broadly available. (Dynamische-Energieprijzen, n.d.)</td><td>NL: C&I sector exposed to volatile prices, both time-of use contracts and real-time energy pricing (per 15 minutes intervals) (USEF,</td><td>NL: Possibilities exist to opt for dynamic pricing contracts. (Dynamische-Energieprijzen, n.d.)</td></tr>
</table>

| | | | |
|---|---|---|---|
| | | 2021a;SmartEN, 2019). | |
| | **DE**: Dynamic pricing is possible, however lack of smart meters means that dynamic price tariffs are barely used (USEF, 2021) | | |
| Network tariffs | **NL:** Active Consumers < 3x 80A pay a capacity-based distribution tariff (USEF, 2021a) | **NL:** Active Consumers < 3x 80A pay a capacity-based distribution tariff (USEF, 2021a). For large scale consumers capacity-based tariff is based on peak demand (SmartEN, 2019) | **NL:** Active Consumers < 3x 80A pay a fixed capacity-based distribution tariff (USEF, 2021a) |
| | **DE:** Distribution charges are volumetric based for households with an annual consumption of 3500 kWh. Customers with an annual consumption lower than 100000 kWh are charged with a fixed lump sum and an energy-based charge (ACER, 2021b)<br><br>There are peak/off peak tariff options, but not commonly used, which leads to not incentive consumers to optimize grid tariffs (USEF, 2021a).<br><br>**DE:** Active consumers are protected from having to pay double charges (ACER, 2021b) | | |

*Net-metering*

Currently in the Netherlands, for small-scale consumers who self-generate renewable electricity and have a grid connection up to maximum of 3x 80A, the so-called net-metering rule is applied. In general, next to feed-in tariffs, net-metering is considered as an instrument to improve the financial case for the residential sector investing in solar PV systems (Londo et al, 2020). Net-metering is a mechanism which subtracts self-generated energy fed into the grid from the energy taken from the electricity grid (Rijksoverheid, n.d.) and effectively means that extra produced electricity fed back into the grid equals the value of the consumer tariff. Therefore, the net-metering mechanism gives consumers an incentive to inject energy back into the grid instead of storing the generated electricity and hinders the deployment of behind-the-meter energy storage for small-scale consumers (Gastel et al, 2021).

In the Netherlands, it is decided that the net-metering rule will be phased out, starting from 2025 by 36% until 2031 (Rijksoverheid, n.d; Gastel & Baas, 2022). More specifically, it means that in 2025 64% of the injected electricity can be netted by PV owners and this percentage is decreasing to 0% in 2031. In Germany, no net-metering schemes are applied. Eventually, due to the phasing out of net-metering, stationary batteries as well as V2G will become more attractive (PWC, 2021).

*Energy taxes, supply tariffs and network tariffs*

The deployment of behind-the-meter storage systems is affected by the design of the subcomponents of the electricity retail price in the Netherlands and Germany: energy taxes, supply tariffs and network tariffs. The design of three components could affect consumers' choices on the amount of self-consumption and on the use of behind-the-meter storage, and are therefore included.

*Energy taxes*

- The height of retail electricity prices

Energy taxation (or the exemptions of) can provide adequate signals to consumers of behind-the-meter storage systems and increase electricity wholesale prices. Energy taxes are paid per kWh when, among which, electricity is delivered via consumers' grid connection and when electricity is delivered to charging installations for EVs. In Germany, seven different taxes and surcharges are applied to the electricity bill, mostly with the aim to support renewable energy technologies. Since this year, the EEG levy is removed for all consumers as of 1 July 2022 (Bundesregierung, 2022), thereby decreasing the overall electricity price.

The incentive to self-consume whilst using energy storage is directly related to the level of retail electricity prices which differ significantly between the Netherlands and Germany. More specifically, the higher the price difference between self-consumed electricity and electricity purchased from the grid, the bigger the incentive becomes to optimize self-consumption and to install battery energy storage system (Ugarte, 2015). According to Keiner et al (2019) in countries with high retail electricity prices the amount of solar PV + behind-the-meter storage systems are increasing. Germany is known for one of the highest prices for electricity in the EU due to their taxes and is therefore increases the deployment of energy storage technologies (SmartEN, 2019).

- Double energy taxation

Most electricity taxes, levies and tariffs have been designed on the assumption that electricity flows in one direction, from producer to consumer. The tariff or tax is charged at the point of consumption or injection, which generally leads to each unit of consumed electricity being charged once. But when electricity is stored and reinjected into the grid this may lead to a situation where the final consumption of electricity is effectively taxed twice thereby causing additional costs. The barrier of double taxation can apply to multiple storage technologies, grid connection levels and whether the storage capacity is placed in front-of-the-meter or behind-the-meter.

An issue for behind-the-meter storage systems regarding double taxation is that it is hard to distinguish between energy that is consumed and energy that is stored and energy that is self-produced and energy that is fed back from the storage unit into the grid as this all happens behind the meter. The issue for behind-the-meter storage is also more difficult due to the ability to avoid taxes by storing self-produced electricity at times of excess supply and using it later, thereby avoiding taxes, charges and tariffs on the electricity that would be taken from the grid otherwise (in case no net metering scheme applies). Because of the net-metering mechanisms in the Netherlands no double taxation issues occur for the small-scale consumers, since the injected electricity is netted from the withdrawn electricity of the grid. From the 1st of January 2022 the double taxation on energy storage is removed for large-scale consumers (RVO, n.d.) .. In Germany, no information is identified on the removal of double taxation and therefore the assumption is that the double energy taxation is an issue for the deployment of energy storages systems when utilized for offering explicit demand-side flexibility.

In the Netherlands and Germany, double taxation issues exist for bi-directional charging of electric vehicles since it increases the energy bill according to the research of (PWC, 2017 ; PWC, 2019). In the Netherlands, double taxation does not occur for private charging points at the residential sector, due to the net-metering rule.

To conclude, both the level of retail electricity prices due to high taxes and double taxation issues due to storage not being defined in the regulatory framework impacts the deployment of behind-the-meter systems negatively.

*Lack of dynamic pricing*

With the introduction of smart meters, it becomes possible to provide implicit and explicit demand-side flexibility and opt for a supply agreement including dynamic pricing or other forms of time-differentiated retail prices. Financial incentives are the most promising incentives when talking about engaging consumers to participate in demand-response (Verbong et al., 2013 ; Donker et al, 2015). According to Donker et al (2015) by linking demand and supply via dynamic electricity tariffs the technical pressure on the electricity system decreases and improves economic efficiency. By using dynamic pricing, consumers can adjust their energy consumption to the energy prices of that moment and thus offers opportunities to reduce electricity bills and increase self-consumption. The passing on of actual prices is referred to as: ‘Time of Use’ (ToU) or ‘Real time’ pricing.

Electricity prices are settled per hour on the day-ahead market and per fifteen minutes on the intraday markets. Nevertheless, small-scale consumers pay a fixed price throughout the year in

Germany and divided into fixed off-peak and peak hours tariffs in the Netherlands. In the Netherlands, since 2017, some energy retailers offer dynamic day-ahead hourly prices to consumers (Pricewise, n.d.), however, the use of these flexible energy prices are not widespread. In Germany, due to a lack of smart-meters dynamic pricing contracts are barely used (USEF, 2021a).

Possible downsides of dynamic pricing contracts are that price uncertainty increases due to seasonal fluctuations and other market conditions, and could lead to higher prices compared to fixed energy contracts (ACM, n.d.;Dynamische Energieprijzen, n.d.). Especially with the current energy crisis, consumers will probably not opt for a dynamic pricing contract.

*Network tariffs*

Network tariffs can play a key role in the deployment of energy storage due to their impact on total electricity prices and are therefore considered as important subfactor in this study. Network tariffs are paid for the use of the electricity grid and transporting the electricity from generator to the final consumer. Network tariffs exist for DSOs and TSOs to recuperate costs for building and operating their network (SmartEN, 2019).

Different network tariff components exist:

- Volumetric based or energy-based (€/kWh)
- Capacity-based or power based (€/kW)
- Fixed (lump-sum) (€)

In the Netherlands, the distribution network tariff is a capacity-based charge and therefore based on the active consumers connection size and applies to consumers with a grid connection < 3x80A. More specifically, this means that the distribution tariffs are not based on actual amounts of consumption, but on the connection size. If the consumer increases the capacity of the grid connection, the network tariff increases as well. However, this capacity-based network tariff will not incentivize active consumers to shift their consumption in time and avoid high loads (USEF, 2021a) and will therefore not incentivize the deployment of behind-the-meter storage technologies.

Contrary to households and the commercial sector, for industrial customers a more active approach of their energy consumption is required in the Netherlands. For industrial consumers, a capacity-based tariff on the measured peak (on weekly or monthly basis) is in place, meaning that the capacity tariff is depending on the measured peak and therefore incentivizes a more active approach of industrial consumers to lower their peak.

In Germany, the vast majority of distribution network tariffs are largely volumetric-based in combination with a fixed component (ACER, 2021b), meaning that the design of the network tariff encourages consumers connected to the distribution grid to optimize self-consumption. The height of the tariffs is based on the consumer’s peak load occurring simultaneously with the networks annual peak load. Network tariffs for the industry, because they could be connected to transmission networks, are organized differently, the network tariff is capacity-based and volumetric based. For the industrial sector discounts on the network tariffs are available. However, since there is a lack of smart meters installed, DSOs may charge a basic price to households and other customers < 100000 kWh/year (instead of the abovementioned charge) to adjust for the lack of accuracy (SmartEN, 2019).

Moreover, double network tariffs could occur due to the lack of a storage definition in the regulatory framework. Both residential as commercial and industrial consumers can be charged double for injecting and withdrawing electricity from the grid. In the Netherlands, both injection and withdrawal charges are applied for active consumers whereas in Germany, active consumers are protected from having to paying double charges (ACER, 2021a).

Designing network tariffs is complex and there must be emphasized that network tariffs should not be designed to specifically incentivize the roll-out of behind-the-meter storage systems, but are designed to recuperate costs incurred by network system operators. However, the design of network tariffs influences the choices made by end-consumers to self-consume and well-designed tariffs should incentivize network users to manage their (self-)consumption in a way that reduces network and system costs. According to SmartEN (2019) it is expected in the Netherlands that within a few years the current low voltage capacity-based tariff will be replaced by a volumetric measure hence increasing the incentive to self-consume and utilize behind-the-meter storage systems.

Currently in the Netherlands & Germany no time-differentiated network tariffs (i.e. tariffs reflecting the use of the network, for example, higher tariffs when congestion occurs) are applied in the distribution tariffs (ACER, 2021b). Time-differentiated network tariffs could benefit customers owning behind-the-meter storage systems, since at the times congestion occurs in the grid and thus an increasement of energy prices is expected, consumers can supply themselves with 'cheap' energy. And, storing the cheap energy when no congestion occurs in the grid and when prices are high use this stored energy for self-consumption.

To conclude, the design of energy taxes, supply tariffs and network tariffs is influencing consumers' choices on investing in behind-the-meter storage technologies. Yet, the design of these taxes and tariffs is not based on the roll-out of storage systems, but are in place to function different goals as for example the roll-out renewable energy sources or to cover network costs. There are multiple complex trade-offs in re-designing electricity tariffs, however the deployment of behind-the-meter storage systems is affected and should therefore be considered whilst re-designing the tariffs.

### 4.4.2 *Lack of clear regulatory framework*

An important barrier for the deployment of energy storage, both in-front and behind-the-meter, is the incomplete definition of energy storage. In the Netherlands, storage is not defined in the Electricity Act and therefore storage facilities are seen as both producer and consumer (ACM, 2021). This subdivision of energy storage can lead to double taxation issues and double network tariffs, as discussed above, and therefore affects behind-the-meter energy storage.

In the Netherlands, the current Electricity Act 1998 will be replaced and modernized by the Energy Law and should implement the regulatory framework determined on EU level and to give substance to the Climate Agreement of 2019, yet the implementation date is unknown. Part of what should be determined, is the role and responsibilities of the aggregator which are currently not fully incorporated in legislation and thereby increasing the amount of uncertainty for investors (PWC, 2017). The role of the aggregator is proposed in the Energy Law proposal and is currently under consultation (USEF, 2021a;Wetsvoorstel Energiewet, 2021).

The regulatory rules for the aggregator may differ for residential, industrial and commercial consumers. Aggregators are able to fulfill their role for commercial and industrial consumers, since a subset is able to enter electricity markets themselves and to take program responsibility (i.e. consumers responsible for planning daily electricity transactions). More specifically, the aggregator can provide flexibility due to large-scale consumers who able to adjust their energy programs. However, residential consumers do not bear program responsibility and therefore aggregators can only provide their services when owning a supplier license. The lack of a supplier license leads to lack of access to measuring data of residential consumers and therefore the aggregator can not provide flexibility services (ACM, 2019). In Germany, the role of the aggregator is formalized, however, no roles formalized for capacity service providers or congestion management providers (USEF, 2021a).

The Electricity Directive, article 15, established a framework for active consumers at EU level. In table 9 an overview of the incorporation in national law of rules on active consumers of the Electricity Directive is shown. According to the ACER (2021a) study, the Netherlands is lacking in the transposition of EU law.

**Table 9: Transposition of EU law into national law (ACER, 2021a)**

| | **Netherlands** | **Germany** |
|---|---|---|
| Active consumers are entitled to sell self-generated electricity | Incorporated | Incorporated |
| Active consumers are entitled to operate either directly or through aggregation | Not incorporated | Incorporated |
| Active consumers are entitled to participate in flexibility schemes and efficiency schemes | Not incorporated | Incorporated |
| Active consumers are protected from having to pay double charges, including network charges, for storage electricity | Not incorporated | Incorporated |

To conclude, the lack of a storage definition leads to multiple issues such as double taxation and double network tariffs for consumers utilizing behind-the-meter storage. Moreover, a lack of a definition of the (independent) aggregator means that it becomes more difficult to provide explicit demand side flexibility to the system and independent aggregators can not fulfill their role due to the absence of a supplier license. Since these aspects are affecting behind-the-meter energy storage systems, the lack of a clear regulatory framework is included as barrier in this study.

### 4.4.3 *Entry barriers for the participation in electricity markets*

In the Netherlands and Germany, entry barriers exist for the participation of behind-the-meter storage technologies in electricity markets. Storage technologies can participate in the day-ahead markets (DA), intraday market (ID), ancillary (frequency and non-frequency) markets, capacity mechanisms and local flexibility markets and hence, generate extra revenue streams. In table 10 an overview of the identified entry barriers is shown and a short explanation per market is given.

**Table 10: Overview entry barriers for the participation behind-the-meter storage technologies in electricity markets**

| | **Residential - battery system** | **C&I - battery system** | **Residential – V2G** | **C&I – V2G** |
|---|---|---|---|---|
| Participation in day-ahead (DA) and intra-day (ID) markets | **NL:** Minimum bid size for participation in DA and ID markets is 100 kW (TNO, 2021), therefore small active consumers can not participate themselves, only via the aggregator. DA and ID markets are not yet open for independent aggregators (USEF, 2021a)<br><br>**DE:** ID and DA markets the minimum bid size is 100 kW, compliant with article 7-8 of the Electricity Regulation (smartEN, 2021). The aggregation of loads only possible by (independent) aggregators when there is permission from energy suppliers (smartEN, 2021), so not yet open for independent aggregators. | | | |
| Providing ancillary services (balancing markets, voltage control and black start capability) | **NL:** Distributed resources, thus behind-the-meter storage systems, can participate in the FCR market. Moreover, the FCR market is open for aggregation (USEF, 2021a). Minimum bid size to participate in FCR market > 1 MW, so aggregation required. (ENTSO-E, n.d.)<br><br>Distributed resources can also participate in aFRR and mFRR via pooling (i.e. aggregation) (USEF, 2021a).<br><br>**DE**: Minimum bid size in balancing markets is +/- 1 MW. (mFRR, aFRR: 1MW, FCR:+/- 1MW). Non-discriminatory participation of all decentralized energy resources is ensured (smartEN, 2021). FCR, aFRR and mFRR (minute Reserve) market is open for demand side flexibility, and (independent) aggregation (USEF, 2021a) | | | |
| Capacity mechanisms | **NL:** NAP<br><br>**DE:** Minimum bid size to participate in CM > 5MW, makes participation of behind-the-meter storage almost impossible. | | | |

| | | | |
|---|---|---|---|
| | Moreover, aggregation of smaller storage units is not allowed (ACER, 2021a). | | |
| Local flexibility markets (local congestion markets) | **NL:** No information identified to participate in GOPACS and offer flexibility to DSOs via aggregator. | **NL:** Possible for large consumers to participate in GOPACS directly (GOPACS, n.d.) | **NL:** No information identified that it is possible to participate in local flexibility markets in the Netherlands. |
| | **DE:** Active consumers are eligible to provide congestion management services for DSOs. Offering flexibility to DSOs is still in trial (SmartEN, 2021), for example ENERA is a local flexibility market in pilot phase (EPEXspot, n.d.) and SINTEG, DA/RE, BNE Flexmarkt are proposals for local flexibility markets, however not being employed either. | | |

*Participation in DA & ID markets*

The day-ahead market (DA) covers the shorter term and consists of demand and supply volumes of electricity for the next day. Around 20% of all Dutch electricity is traded on the DA market and volumes in this market are calculated on an hourly basis. After the closing time of the auction, the market operator, EPEX, clears the market and the market clearing price is determined (Slingerland et al, 2015). The ID market is used for market participants to adjust their positions considering short-term changes in supply and demand. In the Netherlands, (small-scale) active consumers (AC) are not allowed to participate in DA and ID markets and could only participate via the aggregator. However, the minimum bid size in the DA and ID markets is 1 MW and this means that active consumers with storage capacities higher than 1 MW can participate in these electricity markets. Moreover, it is possible to combine and aggregate multiple assets, for example it requires at least 300 EVs, or other assets (Malmgren, 2016;Tennet, 2018). The aggregators use price arbitrage between off-peak hours and peak hours to generate revenues.

In Germany, active consumers (> 100 kW) are eligible to participate in DA and ID markets, complying to article 7-8 of the Electricity Regulation. However, currently, the (independent) aggregator still needs a requirement from energy suppliers when aggregating and selling customer load flexibility to DA and ID markets. (SmartEN, 2021).

*Providing ancillary services (frequency and non-frequency services) (FCR, aFRR, mFRR, RR)*

Ancillary services refer to services that help grid operators maintain a reliable electricity system and can be divided into frequency ancillary services (i.e. the balancing of the system) and non-frequency ancillary services (i.e. voltage control and black-start capability) (IRENA, 2019b). With the entrance of renewable energy sources in the grid, the ancillary services need to be adapted to increase system flexibility.

- *Frequency ancillary services*

Behind-the-meter storage systems are able to provide balancing services in the Netherlands and Germany by making the capacity of the storage assets available for balancing purposes. The Frequency Containment Reserve (FCR) market is one of the balancing markets and "represents primary regulation control which automatically ensures a constant ratio between frequency change and power change within a maximum time period of 30 seconds". (DNV, 2021).

In the Netherlands and Germany, according to USEF (2021a) the FCR market is open to demand side flexibility and distributed resources, meaning that behind-the-meter storage systems can participate, and aggregation is possible. Moreover, the participation of batteries on the FCR market is suitable since batteries possess high response rates. However, active consumers < 1 MW are currently not allowed to participate in the FCR market due to bid-limits. Yet, aggregators can participate in the balancing markets by aggregating multiple storage assets to meet the entry standards and in this manner behind-the-meter storage systems can benefit of the participation.

This study focuses only on FCR, instead of aFRR, mFRR and RR since this is the fastest, primary control reserve that is activated after imbalances and batteries are able to provide this service.

- *Non-frequency ancillary services*

'Ancillary service' means a service necessary for the operation of a transmission or distribution system, including frequency (balancing) and non-frequency ancillary services (IRENA, 2019b). Since the balancing ancillary services are already discussed in the balancing market this section focuses on the non-frequency ancillary services, such as voltage control and black-start capability. According to ENTSO-E survey in 2021 demand side and independent aggregators are not able to provide voltage control services in the Netherlands and Germany.

In Germany, according to USEF (2021a) there will be a new market for non-frequency ancillary services, also known as nicht-frequenzgebundene Systemdienstleistungen, for reactive power and black start capability, however the details are not yet clear.

*Capacity mechanism*

Capacity mechanisms are measures taken to secure electricity supply by enabling generating assets and in exchange, the mechanisms provide payments to these generating assets. With regard to behind-the-meter systems capacity mechanisms are not a major application due to shorter discharge durations, however theoretically they could participate in this market. In the Netherlands capacity remuneration mechanisms do not exist yet. In Germany, capacity mechanisms exist, however, some requirements such as minimum eligible capacity, restrictions to aggregation and the minimum bid excludes the usage of behind-the-meter storage technologies. More specifically, the minimum bid size for the capacity mechanism is 5MW, meaning that small storage units below 5MW cannot participate. Moreover, aggregation of smaller storage units is not allowed (ACER, 2021a).

*Local flexibility markets (local congestion markets)*

Across Europe, markets that can provide local flexibility are being developed to create tools for congestion management in the distribution grids (Radecke et al, 2019). Local flexibility markets are markets that gather local flexibility offers to help maintaining grid imbalances and preventing grid congestion, among other services. There are possibilities for behind-the-meter energy storage technologies to participate in local flexibility markets and thereby providing services for grid balancing. However, local flexibility is still emerging and in development with pilots and trials currently ongoing, even in the more advanced countries (SmartEN, 2021b).

Market parties can provide flexibility by means of bilateral contracts with network operators for congestion management. In addition to bilateral contracts, network operators in the Netherlands established the congestion platform GOPACS - a platform operated by multiple grid operators (DSO-TSO platform) and uses the ETPA market platform (ID platform). On this platform, network operators request flexibility, which can be provided by storage operators, among others. The Netherlands (and Great-Britain) are currently the only countries who commercialized distribution flexibility (SmartEN, 2021). In Germany, there are currently no wide-scale local flexibility markets existent, although a lot of pilots and proposals are happening which is shown in appendix A.

In Germany, according to the new Redispatch 2.0, network operators are allowed to control generation and storage units with a minimum size of 100 kW for constraint management services (USEF, 2021a).

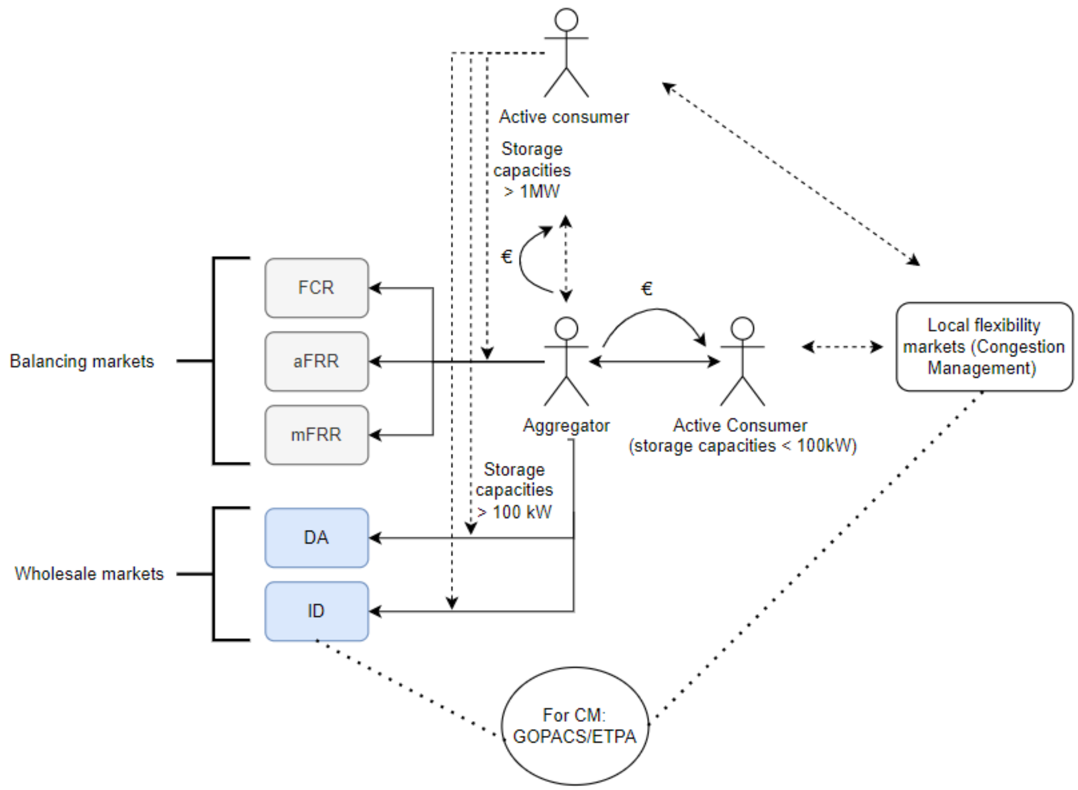


*Figure 13: Participation in electricity markets*

To summarize, entry barriers exist for the participation in multiple electricity markets in the Netherlands and Germany and an overview is given in figure 13. It depends on the storage capacities if active consumers are able to participate in DA, ID, and balancing markets. Overall for residential consumers who have storage capacities smaller than the required bid size, participation via an aggregator is necessary. If the aggregator meets the entry rules for participation it could benefit by value-stacking in different electricity markets, which could indirectly improve the pay-back time of active consumers. For some commercial and industrial consumers who can meet the minimum bid size, extra  revenue streams can be generated by participating in these electricity markets, however, the question arises if these consumers would be willing to participate due to complexity of energy markets and energy being not their core business.

Additionally, opportunities exist for behind-the-meter storage systems to potentially offer non-frequency ancillary services and congestion management services as local flexibility markets are in development. Only in the Netherlands the usage of local flexibility markets is currently deployed whereas in Germany only pilots are conducted.

## 4.5 Stakeholder complexity

Dependency on other actors can be problematic when consumers are willing to invest in behind-the-meter storage technologies and therefore this chapter identifies the most important stakeholder dependencies. The three main stakeholder dependencies are explained.

### 4.5.1 *The dependency on other actors*

There are three main dependencies identified in the literature: dependency on an aggregator for both residential as commercial and industrial consumers, dependency on the homeowner from a tenants' perspective and the interaction between supplier and aggregator.

*Dependency on an aggregator*

An aggregator is a market participant who aggregates flexibility from active consumers and their flexible assets and can be seen as a third party who empowers flexibility owners to use the capacity of the battery for grid balancing purposes (Herbes et al, 2017). The aggregator aggregates multiple batteries in order to provide flexibility to the system and trades on several electricity markets. The differences between an aggregator and independent aggregator is that an independent aggregator aggregates energy but does not supply energy. As discussed in section 4.4.3., the (independent) aggregator could participate in different electricity markets, whereas small active consumers can not. Therefore, these active consumers are dependent on the aggregator since the aggregator increases the value of behind-the-meter storage systems, both for stationary battery systems as for V2G technology. However, conflicting values could be an issue, for example, the conflicting values between the aggregator and EV drivers regarding battery degradation. More specifically, the interest of the aggregator could be to acquire financial benefits by maximizing (dis)charging cycles for grid balancing services whereas this differs for the EV drivers' interest (Heuvelen, 2020).

The study of Immonen et al (2020) identified barriers and opportunities of consumer's participation in the electricity sector. Results are that half of the respondents would be willing to allow a third party to collect data on devices and to remotely control their energy devices so that consumers still achieve the benefits. Thus, the dependency of active consumers on the aggregator exists and values should be considered, however, it does not necessarily have to be an issue.

*Dependency tenant – home owner*

The dependency between a tenant and the home-owner is also known as the "user-investor dilemma" and considered as a major barrier for the use of solar PV systems on roofs (Held et al, 2021). Similarly to solar PV systems, tenants could be interested in low-cost electricity (provided from generated solar energy) and optimizing their self-consumption by installing a storage system. Tenants, however, may not have an interest to invest in the storage technology as they would not benefit from the property value increase whereas landlords are able to invest, but usually would not benefit themselves with regard to energy bill savings.

Germany adopted a benefit sharing scheme, called "landlord-to-tenant electricity supply" and exempts tenants from charges, such as grid surcharges, electricity taxes and concession fees. Additionally, home-owners receive funding for every kWh of electricity supplied to the tenant (Ministry for Economic Affairs and Climate Action, n.d.). This could be a solution to reduce the dependency of the tenant on the home-owner with regard to the willingness to invest in storage technologies.

*Dependency interaction supplier/aggregator*

Possible lost revenues for the energy supplier are involved when an independent aggregator utilizes behind-the-meter storage systems. More specifically, the optimization of self-consumption and control of flexible behind-the-meter storage assets for participation in electricity markets leads to less electricity withdrawn from the grid and thus lost revenues for the energy supplier. The question arises if the supplier should be compensated by the aggregator by using certain schemes. According to Baker (2016), one of the solutions for the compensation of the supplier, is that a part of the compensation costs should be socialized.

## 4.6 Behavior

Besides financial or market and regulatory aspects, behavioral aspects could be barrier as well for the deployment of behind-the-meter storage systems. More precisely, consumers possibly need to change their behavior in order to adopt a new storage technology and should be aware of possible opportunities to install the 'new' technology. Therefore, the behavioral aspects 'lack of knowledge' and 'changing behavior patterns' are considered as barriers in this study.

### 4.6.1 *Lack of knowledge*

According to the conclusions of the Dutch Report of ESNL (2019) consumers are too little aware of possible savings that can be made by making their electricity consumption more flexible with the help of storage technologies. With regard to V2G technology, according to research of Meijssen et al (2019) 34% of 148 Dutch EV drivers never heard of V2G technology before. Moreover, 18% of the 148 respondents heard of the V2G concept but do not know. Possible reasons for the lack of knowledge could include absence of information campaigns, perception issues or just not being aware of possible opportunities.

### 4.6.2 *Changing behavior patterns*

Changing consumption patterns as a means to shift the timing of electricity usage requires change in behavior of consumers. There are several studies on the impact of behavioral change and lifestyle shifts to accelerate the energy transition. However, for this study it is mostly interesting to know if there is a necessity to change behavioral patterns in order to implement the storage technologies successfully.

Regarding the necessity of changing behavior for the usage of stationary li-ion batteries, it might depend on the purpose of utilizing the battery. As identified in the chapter on pay-back time, implicit and explicit demand-side flexibility exist and opting for one of the two schemes impacts the necessity of changing behavior patterns. Utilizing the stationary battery to carry out implicit demand-side flexibility and thus optimizing self-consumption, requires anticipation to price signals accordingly for which a change in behavior is needed (IRENA, 2019a). Whereas the utilization of the batteries' capacity for grid balancing services by the aggregator surpasses its goal if consumers are required to change their consumption behavior.

Range anxiety and possible discomfort from V2G participation is one of the most important barriers for adaptation towards V2G technology according to Heuvelen (2020). Additionally, according to Meijssen et al (2019) Dutch EV drivers are mostly concerned about discharging cycle causing battery degradation and the guaranteed minimum battery capacity which can be constraint due to V2G participation. According to Lazzeroni et al (2019) the utilization of an EV as (movable) battery storage is directly related to the drivers' behavior pattern. Plug-in duration (i.e. the amount of time the electric vehicle is plugged in and thereby available) is an important indicator to determine EV availability according to Zonneveld (2019). The plug-in duration contributes to predictable number of participants in V2G programs and enlarge the energy capacity that is available. Possible drawbacks of participating in V2G programs, is the possibility of the EV users not being able to use their electric vehicle as they are required to be plugged in for several hours and therefore the necessity arises to change their behavior or expectations. As the necessary plug-in time increases, the amount of participants decreases (Parsons et al, 2014).

# 5. Results

This chapter presents the results of the Y-factor analysis, including the results of the expert interviews for the Netherlands and Germany which have provided the inputs to the Y-factor curve. Additionally, this chapter includes the variances within scores and identified links between the factors.

## 5.1 Results Y-factor curve

This section presents the Y-factor scores for the deployment of behind-the-meter energy storage technologies. Firstly, the Y-factor curve from the expert interviews is shown and the overall analysis of barriers for the deployment of behind-the-meter storage technologies in both countries is given. Secondly, the barriers scored as significant are analyzed and compared between the Netherlands and Germany.

### 5.1.1 *Y-factor curve*

The Y-factor curve, derived from the scores given in the interviews, is presented in figure 14 and enables a immediate overview of barriers regarding behind-the-meter storage technologies. The Y-factor curve allows the reader to spot what barriers need to be dealt with in order to implement a certain technology (Chappin, 2020).

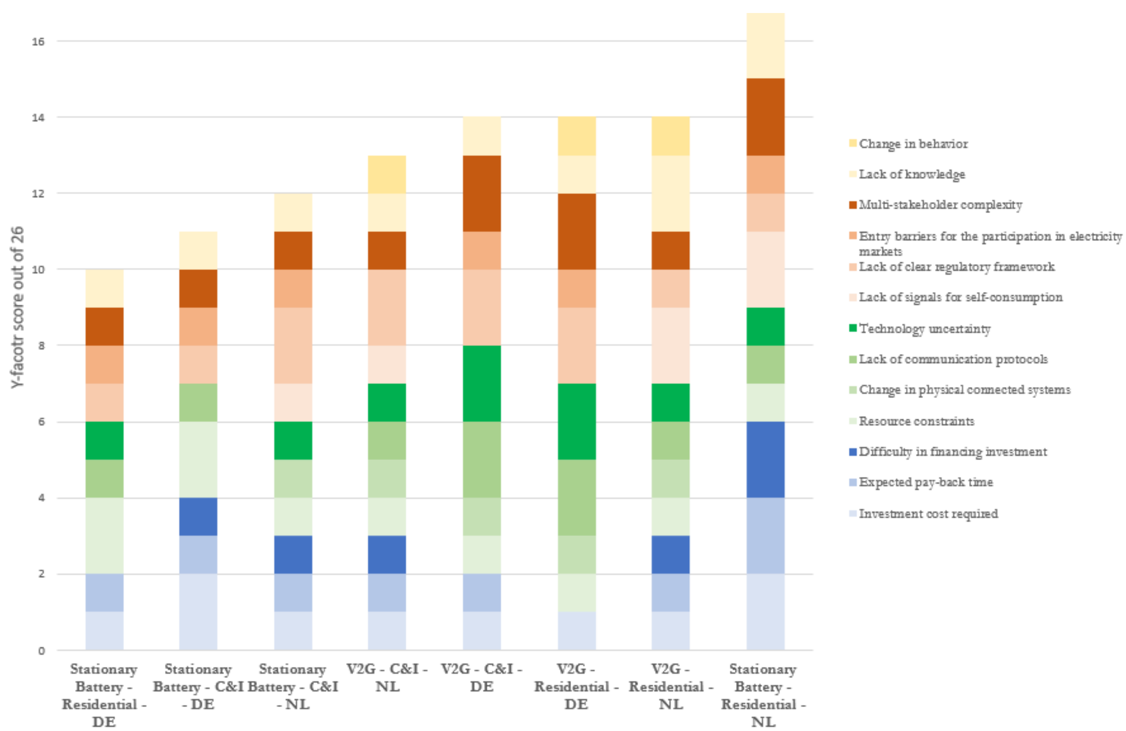


*Figure 13: Y-factor scores NL & DE. *the weight of each barrier is 1, meaning that all barriers are equally important to one another*

The combination of technology, sector and country with the lowest scores and thus the lowest perceived barriers, are placed on the left. The technologies with the highest Y-factor scores, meaning that several barriers exist, can be found on the right. In general, almost all technologies score relatively high (equal to or above the Y-factor score of 10 out of 26), meaning that the deployment of behind-the-meter storage systems still faces major barriers, which should be considered by policy makers in order to facilitate the deployment of these systems. Stationary battery systems for the residential sector in Germany received the lowest Y-factor score, 10, meaning that at the current moment the implementation of the technology is subject to less problematic barriers compared to the other technologies, however resource constraints is found to be a significant barrier when implementing residential storage in Germany. Stationary batteries in the Netherlands for the residential sector received the highest Y-factor score, more specifically, the significant barriers are financial barriers (such as investment cost, pay-back time and difficulty in financing the investment) as well as a lack of signals for self-consumption and multi-stakeholder dependency. It is remarkable that residential stationary battery systems in Germany and residential stationary battery systems in the Netherlands received the lowest and highest Y-factor score accordingly.

Whilst looking at the Y-factor curve, the main conclusion is that **all technologies and sectors face significant barriers for the deployment of behind-the-meter storage systems**, although different per technology and sector, requiring tailored measures to address the identified barriers in order to increase the deployment of behind-the-meter storage systems. In general, **financial barriers are hindering the deployment of stationary battery systems** to a larger extent compared to V2G technology, **whereas technical barriers as well as behavioral barriers play a larger role for the deployment of V2G technology**.

**In the Netherlands, commercial and industrial consumers face less barriers with regard to stationary battery systems and V2G technology compared to residential consumers.** A lack of a clear regulatory framework is the most significant barrier for commercial and industrial consumers to invest in storage technology, whereas in the residential sector a lack of knowledge and of signals for self-consumption are found to be impeding the deployment. For residential storage in the Netherlands, costs & financing barriers, lack of signals for self-consumption, and dependency on other actors form the most significant barriers.

In Germany, it can be noticed that **not the financial barriers, but technical barriers as well as market & regulatory barriers should be overcome when implementing V2G technology**. To be more precise, a lack of a clear regulatory framework, dependency on other actors, technology uncertainty and a lack of communication protocols form the major barriers with regard to the deployment of V2G technology. Moreover, in Germany, **commercial and industrial consumers face larger barriers compared to the residential sector with regard to stationary battery systems**, more precisely, the required investment costs and acquiring funds are more difficult for these consumers. Moreover, there can be noticed that **a change in behavior does not form a barrier for stationary battery systems in both the Netherlands and Germany.**

The main differences between the Netherlands and Germany are that in the Netherlands, cost & financing barriers, lack of signals for self-consumption and a lack of knowledge play a crucial role contrary to Germany. In Germany, however, resource constraints, technology uncertainty, lack of communication protocols seem to form a major barrier, which is not as signifciant as in the Netherlands. Hence, policy recommendations to reduce the barriers of behind-the-meter storage systems should be country-specific.

### 5.2 Overview significant barriers per country, technology and sector

In this section an overview is given what significant barrier plays in role in what country or what sector. The experts scored the barriers based on their expertise for the different technologies and sectors. The result is that the following factors are ranked as "significant barrier":

**Table 21: Significant barriers (X) per country, technology and sector**

| | **Netherlands** | | | | **Germany** | | | |
|---|---|---|---|---|---|---|---|---|
| **Significant barriers** | Stationary battery - *Residential* | Stationary battery – *C&I* | V2G – *Residential* | V2G – *C&I* | Stationary battery - *Residential* | Stationary battery – *C&I* | V2G – *Residential* | V2G – *C&I* |
| Investment cost required | X | | | | | X | | |
| Expected pay-back time | X | | | | | | | |
| Difficulty in financing investment | X | | | | | | | |
| Resource constraints | | | | | X | X | | |
| Technology uncertainty | | | | | | | X | X |
| Lack of communication protocols | | | | | | | X | X |
| Lack of signals for self-consumption | X | | X | | | | | |
| Lack of clear regulatory framework | | X | | X | | | X | X |
| Stakeholder dependency | X | | | | | | X | X |
| Lack of knowledge | X | | X | | | | | |

The motivations behind the given scores for each of the abovementioned significant barriers are analyzed in appendix C. A total of 10 out of 13 factors in both the Netherlands and Germany are scored as significant barrier during the interviews. The factors *'change in physical connected systems', 'change in behavior', and 'entry barriers for the participation in electricity markets'* are still hurdles to overcome in order to increase the deployment of behind-the-meter storage systems, however, the focus is on the significant barriers.

### 5.2.1 *Variance in scores*

The experts in the field of behind-the-meter storage provided different scores and arguments for their scores. As a result, variance exist in the scores for the barriers. Variances in scores exist due to approaching the barriers from different perspectives (e.g. researchers, market operators or network operators), inaccurate interpretation (or formulation) of the barriers or the barriers being formulated on a too high, abstract level.

The following method is used to arrive at final scores for all barriers: Firstly, the average of all experts interviews is rounded up or downwards to 0, 1 or 2. Secondly, the variance in scores is translated into low, medium or high uncertainty and based on the experts deviating from the average:

- Low uncertainty: 1 or less experts deviate from the average;
- Medium uncertainty: 2 experts deviate from the average;
- High uncertainty: < 3 or more experts deviate from the average.

For Germany, the uncertainty scoring is slightly different, since only three experts in the field of behind-the-meter energy storage are interviewed:

- Low uncertainty:  No experts deviate from the average;
- Medium uncertainty: 1 experts deviate from the average;
- High uncertainty: 2 or more experts deviate from the average.

In figure 15 & 16 the results are shown for the Netherlands and Germany respectively. For all barriers, a score is given from low to high barrier and a score from low to high uncertainty. In appendix C, the analysis of the significant barriers (the red areas) are analyzed per country and per technology and the main differences between the Netherlands and Germany are presented.


*Figure 15: Barrier and uncertainty scale results from the interviews the Netherlands*

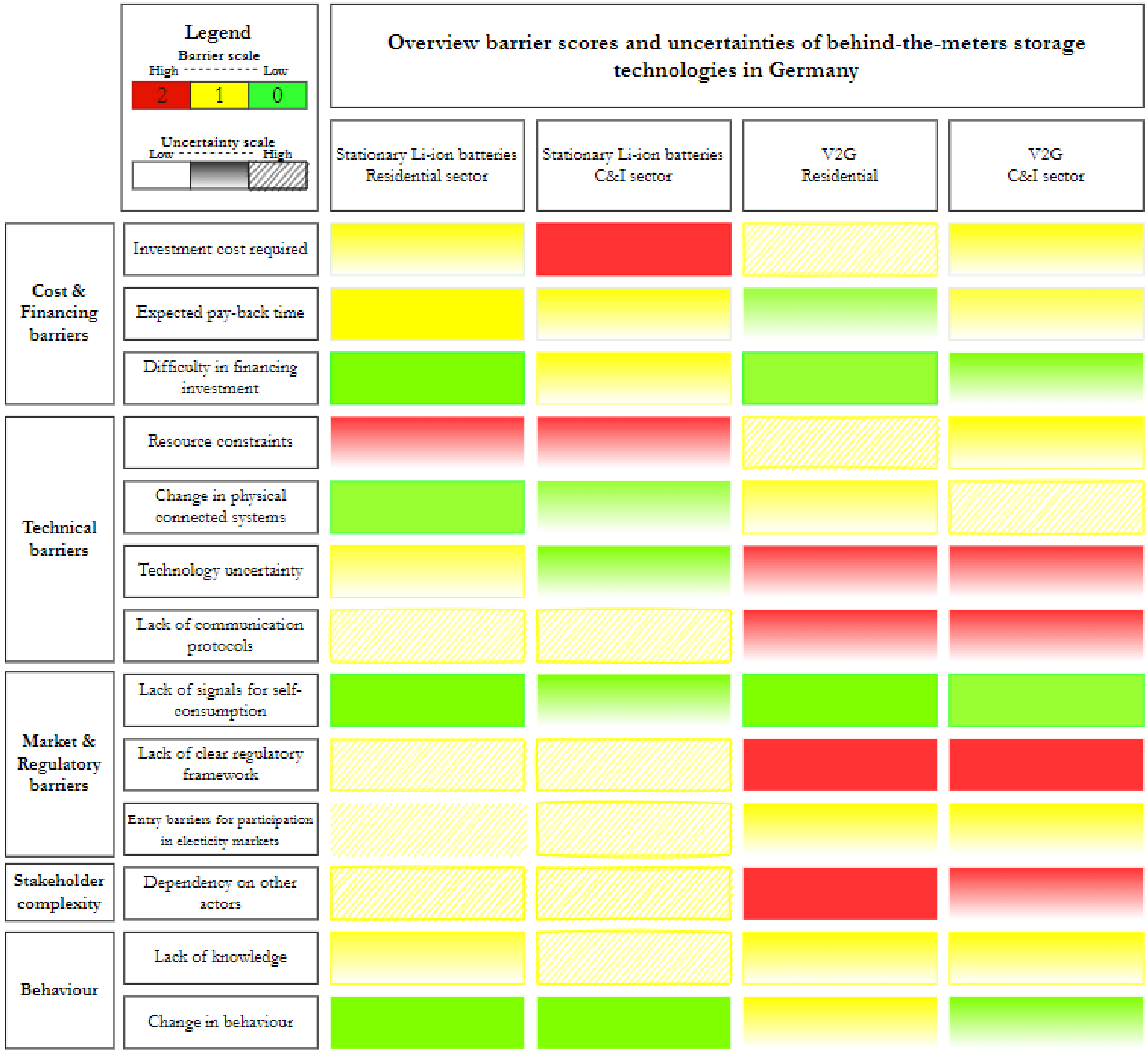


*Figure 16: Barrier and uncertainty scale results from the interviews in Germany*

The main conclusion is that multiple barriers (13) exist with regard to behind-the-meter storage systems, however, not all barriers are as significant. Experts in the field of behind-the-meter storage systems do not agree upon the significance of all the barriers and thus for some barriers high uncertainty exists. Although this does not necessarily mean that the identified barrier is not significant, with certainty can be said that the following barriers are significant for the deployment of behind-the-meter storage systems:

Netherlands

- Investment costs required, expected pay-back time and a difficulty in financing investment for stationary Li-ion batteries in the residential sector.
- Lack of signals for self-consumption in the residential sector.

Germany

- Investment costs required for commercial and industrial consumers
- Resource constraints for stationary battery systems in both the residential as the C&I sector
- Technology uncertainty with regard to V2G technology in both sectors
- Lack of communication protocols for V2G technology in both sectors
- Lack of clear regulatory framework for V2G technology in both sector
- Dependency on other actors for V2G technology in both sectors

## 5.3 Links between factors & missing factors

Links between factors and missing factors are identified by the experts during the interviews. In this sector both aspects are addressed.

### 5.3.1 *Links between factors*

The deployment of behind-the-meter storage technology requires that a wide range of barriers be addressed. However, the factors are not stand-alone factors and interrelations exist. The experts in the field of behind-the-meter storage systems are asked to indicate links between the barriers and a visualization of the links is shown in figure 17. The thicker the line between the factors is, the more often the link is indicated. There must be noted that not all experts in the field were able to indicate links between the barriers, due to time constraints during the interview.

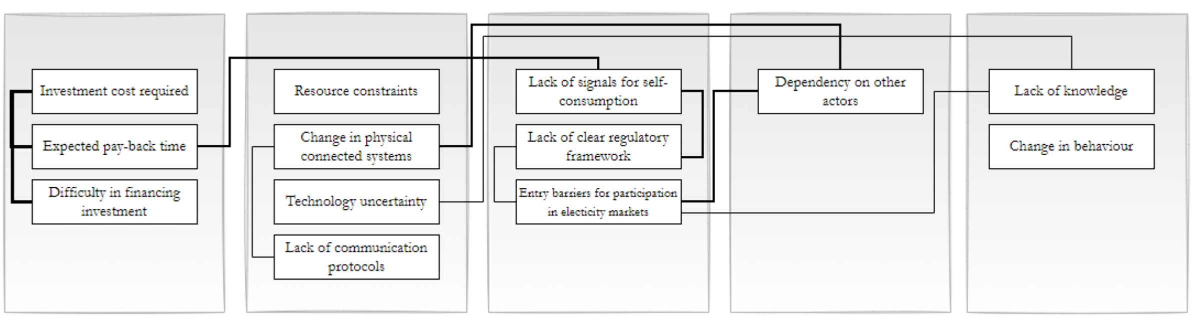


*Figure 17: Links between factors*

Overall, the links give insight in the complexity of behind-the-meter storage systems and the interrelationship of barriers. The interrelationship of the cost & financing barriers is mentioned the most often since the difficulty in financing investment and the expected pay-back time both influence the required investment costs. Moreover, the relationship between expected pay-back and lack of signals for self-consumption is often mentioned. Additionally, the link between entry barriers for participation in electricity markets and dependency on other actors is often mentioned as well as lack of signals for self-consumption and a lack of clear regulatory framework.

### 5.3.2 *Missing barriers*

At the end of all interviews, the question is asked: *"Did you miss any barriers regarding behind-the-meter storage technologies, and if so, which one?"* Only participant *Huawei* mentioned the absence of the sustainability aspect of behind-the-meter storage systems. For both sectors, the amount of minerals needed and the impact it has on the environment could be a reason to not install the technology for investors. The barrier *lack of resources* is only focused on the availability of the technology thereby not considering the impact the technology has on the environment.

# 6. Conclusion and discussion

This chapter represents the answers to the research questions. Moreover, policy recommendations are given to address the barriers regarding the deployment of behind-the-meter storage technologies and the discussion is included to highlight limitations of the research.

## 6.1 Answers to the research questions

This research aims to find the answer for the following main research question:

**What barriers affect the deployment of behind-the-meter storage technologies (e.g. stationary battery systems and vehicle-to-grid)?**

The study consists of a factor identification, experts interviews to score the identified barriers, and an analysis of the significant barriers. The analysis of the interviews resulted in various insights on barriers regarding stationary battery systems and EVs enabled for bi-directional charging. Overall, the study resulted in a Y-factor curve which can be used for policy-makers to feed the policy debate on barriers and associated measures for behind-the-meter storage technologies.

The study was divided in three sub questions. Each sub-question is answered individually and leads to the answer of the main research question. The first sub question is:

- *"What factors may contribute to barriers for the deployment of behind-the-meter energy storage technologies (e.g. stationary battery systems and vehicle-to-grid) in the Netherlands and Germany?"*

The question is answered by conducting a literature study on behind-the-meter storage systems. The definition used to go through the literature is:

1. A barrier is "*anything that prevents or obstructs or hinder the progress, movement or development of something*" (Gupta et al., 2017). With reference to the deployment of behind-the-meter energy storage in this thesis, this means that a barrier is anything that *hinders* the progress, movement or development of stationary Li-ion battery systems or electric vehicles with V2G capabilities.

2. The barriers identified concern the residential *or* commercial & industrial sector, focused on *behind-the-meter storage systems who are connected to distribution networks or transmission networks (the latter possible for the C&I sector)*.

3. The barriers identified concern *technological, economical, and behavioral or regulatory aspects of behind-the-meter storage systems.*

The literature study resulted in 37 factors that hamper the deployment of stationary battery systems and EVs able to provide bi-directional charging in the Netherlands and Germany.

The second sub question answered in this study is:

- *How can we modify the Y-factor method to capture barriers for the deployment of behind-the-meter storage systems?*

To answer the second sub question, the 37 identified factors from the literature study are held against the 13 factors of the Y-factor method constructed by Chappin (2020). The financial and behavioral barriers did fit in the Y-factor framework, nonetheless, other barriers, such as the market & regulatory barriers and purely technical barriers, were not covered by the research of Chappin (2020) and therefore added to the present framework. Although the Y-factor is initially designed to provide insights into barriers that may hinder the realization of $CO_2$ abatement technologies, the method is found to be able to provide also insights into the understanding of barriers related to behind-the-meter storage systems. And thus, the Y-factor method is found suitable, with modifications, for the application to more specific technologies.

The third research question answered in this study is:

- *What barriers may significantly hamper the deployment of specific behind-the-meter storage technologies (e.g. stationary battery systems and vehicle-to-grid) in the Netherlands and Germany?*

The Y-factor scores are given to two technologies (stationary battery systems and V2G technology) and two sectors (residential and commercial & industrial) by experts in the field. First, the following barriers – which are country specific - are identified as significant:

| | **Netherlands** | | | | **Germany** | | | |
|---|---|---|---|---|---|---|---|---|
| **Significant barriers** | Stationary battery - *Residential* | Stationary battery – *C&I* | V2G – *Residential* | V2G – *C&I* | Stationary battery - *Residential* | Stationary battery – *C&I* | V2G – *Residential* | V2G – *C&I* |
| Investment cost required | X | | | | | X | | |
| Expected pay-back time | X | | | | | | | |
| Difficulty in financing investment | X | | | | | | | |
| Resource constraints | | | | | X | X | | |
| Technology uncertainty | | | | | | | X | X |
| Lack of communication protocols | | | | | | | X | X |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lack of signals for self-consumption | X | | X | | | | | |
| Lack of clear regulatory framework | | X | | X | | | X | X |
| Stakeholder dependency | X | | | | | | X | X |
| Lack of knowledge | X | | X | | | | | |

Secondly, an uncertainty score is given to each final score, based on the variances in scores. From the analysis we learn that a lot of uncertainty exists in the scores due to different perspectives (e.g. researchers, market operators or network operators), inaccurate interpretation (or formulation) of the barriers or the barriers being formulated on a too high, abstract level. Therefore, the following barriers are significant and include high certainty, for a given combination of sector, country and technology:

Netherlands

- Investment costs required, expected pay-back time and a difficulty in financing investment for stationary Li-ion batteries in the residential sector.
- Lack of signals for self-consumption in the residential sector.

Germany

- Investment costs required for commercial and industrial consumers
- Resource constraints for stationary battery systems in both the residential as the C&I sector
- Technology uncertainty with regard to V2G technology in both sectors
- Lack of communication protocols for V2G technology in both sectors
- Lack of clear regulatory framework for V2G technology in both sector
- Dependency on other actors for V2G technology in both sectors

To address the identified barriers, some policy recommendations in the Netherlands and Germany are formulized.

## 6.2 Policy recommendations for the Netherlands and Germany

Significant barriers are identified for the Netherlands and Germany regarding behind-the-meter storage systems, and hence, recommendations can be given in order to incentivize the deployment of behind-the-meter storage technologies in these two countries:

- **Remove net metering in the Netherlands to incentivize stationary battery systems.** Net metering is one of the main reasons that behind-the-meter storage technologies are not as widely deployed as compared to Germany. The removal of net-metering addresses the barrier *'lack of signals for self-consumption'* and would probably increase the amount of self-consumption. The Dutch government announced the phasing out of net-metering by 2023, however the target is postponed to 2025.

- **Provide subsidies or loan schemes for stationary battery systems in the Netherlands to address the difficulty in financing investment.**
  In order to address the high required investment costs for behind-the-meter storage systems, the Netherlands could learn from Germany by providing subsidies or loans schemes for residential and commercial/industrial consumers. However, the provision of subsidies on stationary battery systems is currently debated in the Netherlands, since this money ends up by more wealthy consumers and thereby increasing inequality according to Ten Brink (2022). Therefore, it is advised that the (dis)advantages of such a subsidy should be carefully considered, both the benefits on system level as for all consumers.

- **Remove double taxation and/or double grid charging in national regulatory frameworks**
  The lack of storage definitions in the regulatory frameworks in both the Netherlands and Germany leads to multiple barriers for the deployment of stationary battery systems and the provision of V2G services, such as double taxation and double grid tariffs. Germany can learn from the Netherlands by removing double taxation for large-scale consumers whereas both countries should consider the removal of double taxation for small-scale consumers. In the Netherlands, due to the net metering rule no double taxation is applied to small scale consumers, however after 2025 this could be the case.

- **Define the role of the independent aggregator in both the Netherlands and Germany to provide more flexibility to the system.**
  In Germany and the Netherlands, aggregation is allowed to participate in balancing markets, however, the necessity of prior consent by suppliers is the main barrier for independent aggregators (smartEN, 2021). Germany removed the necessity of prior consent by suppliers for balancing markets, however not for DA and ID markets. removing the need for prior consent would increase competition and eventually lead to lower prices for consumers.

- **Focus on the qualification of technicians by identifying the measures that are needed in this regard.**
  The majority of the interviewees indicated the lack of technicians as a major bottleneck, not only for the deployment of behind-the-meter storage systems, but for the energy transition in general. Moreover, the resource constraints are found to be the barrier that will increase even more in 15 years and hence, action should be taken to address the shortage of technicians. The government should start a study on how to increase the number of technicians and what measures are necessary in order to address this barrier.

- **Address the lack of knowledge by stimulating stationary batteries and V2G information provision**
  The lack of knowledge on stationary systems as well as V2G technology is lacking in both the Netherlands and Germany. In the Netherlands, the focus should lie more on information provision through marketing and communication efforts focused on the residential sector whereas in Germany the focus should lie more on the information provision of V2G technology in general.

- **The Netherlands should consider partially energy-based network tariffs to incentivize self-consumption**
  Currently in the Netherlands, capacity-based tariffs are charged for active consumers connected to the distribution grid. However, the capacity-based network tariff does not incentivize active consumers to optimize their self-consumption and to avoid high loads (USEF, 2021a) since the network tariff is fixed and is not based on the energy consumption per kWh. Therefore, capacity-based network tariffs do not incentivize the deployment of behind-the-meter storage technologies. The Netherlands could learn from Germany, for which the vast majority of distribution network tariffs are largely volumetric-based in combination with a fixed component (ACER, 2021b), meaning that the design of the network tariff encourages consumers connected to the distribution grid to optimize self-consumption.

- **Germany should accelerate the provision of smart-metering systems so that explicit demand-side flexibility can be offered.**
  Without a smart meter, dynamic pricing and thus the provision of signals to (active) consumers to optimize self-consumption is not possible. By using dynamic pricing, consumers can adjust their energy consumption to the energy prices of that moment and thus offers opportunities to reduce electricity bills and increase self-consumption. Moreover, the implementation of smart metering systems provides the possibility to provide explicit demand-side response, which is currently lacking in Germany.

## 6.3 Discussion

This section discusses the findings and reflects on the limitations of this research.

*Perception of barriers & subjectivity*

The perception of a barrier differs from the factual existence of a barrier. This was noted by one of the experts who indicated the importance of the perception towards a barrier versus the real barrier. To give an example, the factor 'technology uncertainty' could receive a higher score due to interviewees perceiving issues related to fire risks, however, the 'real' barrier could be lesser in extent. However, in practice, it can be argued that perceived barriers does not differ as much from the 'real' barriers, since existing barriers are always perceived by other persons.

*Uncertainty in scores*

As shown in the analysis of the results, multiple barriers received high uncertainty, meaning that variances exist in the final scoring of experts. This, however, does not mean that the barrier is non-existent. The variances in scores can have multiple reasons, such as differences in perspectives and knowledge, inaccurate interpretation (or formulation) of the barriers or the barriers being formulated on a too high, abstract level. Although motivations are analyzed per barrier, only low and medium uncertainty scores are included as final significant barriers, to reinforce that these barriers should be addressed first. While interviewing more experts in the field might have led to differences in final scores, the Y-factor scores with low uncertainty are unlikely to change.

*Differences in geographical scope*

Some interviewees indicated the possible differences in scores due to geographical areas, meaning that in some regions of the Netherlands or Germany the deployment of behind-the-meter storage could be more beneficial to users and therefore barriers are less significant. For example, in regions where network congestion occurs more often, investment costs could be less of a barrier since the business case of renewable energy + storage becomes more interesting when located in a congestion area. Since specific regions are not included in this study, this is a limitation, and conclusions are only formulized for the Netherlands and Germany as a whole.

*Behind-the-meter storage is not the end goal*

There should be emphasized that behind-the-meter energy storage is one of the options to provide more flexibility to the system, however multiple provisions of flexibility are possible. Moreover, certain aspects, such as the design of electricity tariffs and markets should not be focused specifically on incentivizing the deployment of behind-the-meter storage systems. Yet, the design of these tariffs does influence the choice made by end-consumers with regard to self-consumption and should be carefully considered. The decarbonization of the energy system and increasing the system flexibility, whilst ensuring security of supply, is rather the end goal.

*Y-factor scores are use-case dependent*

Some interviewees indicated the differences in use-cases per factor and subsequently, resulted in different end-scores. More specifically, the provision of implicit and explicit demand-side flexibility are both included in all factors, and for some factors this have led to 'average' instead of more extreme end-scores.

For example, regarding the factor *'change in physical connected systems,'* the integration of smart-meters is not required when only utilizing the storage system for implicit demand-side flexibility whereas a smart meter is required for explicit demand-side flexibility and thus offering grid related services. To address the differences in use-cases, in each interview the dual provision of services is highlighted, which have led sometimes to an average score.

Nonetheless, it can be argued that implicit and explicit demand-side flexibility co-exist, meaning that both types of flexibility are needed to accommodate different consumer preferences and to exploit both user benefits as well as system benefits, and therefore the approach on combining the dual provision of behind-the-meter storage systems is valid.

Besides the dual provision of services of behind-the-meter storage systems, differences in end-scores within the sectors are found. For example, regarding the factor *'dependency on other actors'* the dual provision is noted for the residential sector. Consumers renting apartments are highly dependent on their homeowner to install storage technologies, whereas private homeowners can decide themselves to invest in certain technologies. During the interviews this sometimes led to an average score given by the experts.

### 6.4 Future research

- **Future research for multiple countries is recommended** to provide more insights in the significance of country-specific barriers for the deployment of behind-the-meter storage systems. Currently, the Netherlands and Germany are researched, however, it could be interesting for policy-makers to add new countries and to observe mutual barriers between countries and the differences.
- **The barriers which received 'high uncertainty' should get more attention** and it is recommended to discuss in depth with multiple experts in the field to understand the origin of the uncertainty. The question is if the uncertainty is based on subjectivity of the experts or that other issues are underpinning for the variances in opinions.
- **Future research could be focused on the interrelationship between each barrier**. Currently, the weight of the barriers relatively to each other is one, however, it could be argued that one barrier is more important compared to the other one. With the online Y-factor tool that is made during this thesis, the weight of each barrier can be adjusted to observe the mutual relationship of technologies, sectors and countries.
- **Future research could add other behind-the-meter storage technologies such as other battery technologies, or for example, heat or hydrogen storage** to provide a broader overview of the barriers that play a crucial role when considering the deployment of such systems.
- Future research could focus **on the application of the Y-factor method to, for example, in-front-of-the meter energy storage technologies**, an upcoming and crucial aspect in the energy transition. When increasing the amount of technologies in the framework, the factors should be less specific again, however, it would give policy makers handles to discuss the main barriers that play a role when deploying in-front-of-the meter energy storage technologies.

### 6.5 Personal reflection

Concluding this master thesis, this section includes a personal reflection on the usage of the Y-factor method and how to improve it.

**Identification factors**

The identification of factors and its definition is the core of this study. However time-consuming it could be convenient to interview at least three experts, with different backgrounds, to validate the found indicators and definitions before you go into the 'real' interviews to be sure you covered the whole spectrum of barriers. Regarding this study, I interviewed one expert before the interviews and this resulted in the removal of the barrier *'lack of TSO-DSO coordination'*, since she said, this would not be a barrier for consumers to not invest in the technology since it has a very indirect effect on the investment decision.

All interviews confirmed at the end of the interviews that the identified factors covered the hurdles of the deployment of behind-the-meter storage systems. This means that, by conducting an extensive literature search maybe even more barriers can be found then identifying factors whilst using interviews. Two interviewees recommended to add a barrier regarding sustainability. For example, adding: *'lack of sustainability'* within the Y-factor framework. This could be done by adding the definition '*the degree to which the carbon footprint of the implementation and/or manufacturing of the technology is significant*' which can influence the investment choice of the consumer accordingly.

**Decreasing uncertainty**

Overall, multiple barriers are found to be 'uncertain' due to the variances in scores. The variances in scores are there since each expert have different perspectives on the problem or, different perceptions towards the barrier. When increasing the amount of participants, the significance of the average score would improve, however the uncertainty, the variances in opinion, would probably not decrease. The uncertainty could be reduced by, instead of having individual interviews, organizing group interviews, in which the experts follow a structured discussion, agree on the end-score and provide arguments for their end-scores. This will lead to less uncertainty in the score and more insights due to the discussion.

Due to the need to keep the barrier framework tractable due to cognitive limitations, time limits in interviews and scoping of the 37 initially identified barriers for behind-the-meter storage systems, the barriers are scaled to a more abstract level which have led, in the end, to barriers with high uncertainty end-scores. To give an example, regarding the factor *'technological uncertainty'* (i.e. safety, reliability, privacy, lifetime), expert x may find safety more important then privacy whereas expert y may find lifetime more important compared to safety. The uncertainty of a score could increase by how larger the range of sub factors is within a factor, and therefore, the definition of the barrier should be well formulized.

**Improvement factors**

During the interviews and with current knowledge, I would change and improve the following factors and/or definitions:

- Factor name: '*Lack of communication protocols'* → Lack of **control and communication systems:** During the interviews I noticed that not the number of communication protocols is the problem, but the lack of standardization is. Moreover, communication protocols are a specific mechanism, which is meant as part of the barrier, but also energy management systems was meant to be included. Therefore, I would change the factor to 'lack of control and communication systems'.

- Definition of '*lack of signals for self-consumption*': the degree to which existent incentives for injecting electricity into the grid instead of storing self-generated energy is significant → The degree to which **current signals resulted from the design of network tariffs, supply tariffs, taxation or other incentives lead to lesser self-consumption**. I think that the current definition is too focused on the net-metering policy, whereas the design of supply tariffs, network tariffs and taxation could play a major role as well. Therefore, the new definition focuses more on the broader aspects that lead to a lack of self-consumption.

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# Appendices

## Appendix A: Overview of local flexibility markets in Germany.

| Proposal | Region | State of Imp. | Key Objectives |
|---|---|---|---|
| Bne Flexmarkt | DE | Proposal | Reform German grid fee regulation to tap existing and incentivize new resources for congestion management in the distribution grid and reduce concurrence |
| SINTEG C/sells: Altdorfer Flexmarkt (ALF)* | DE | Pilot | Develop a platform to solve congestion management issues in the distribution grid using decentralized assets (focus on small-scale assets) |
| SINTEG C/sells: ReFLEX Dillenburg* | DE | Pilot | Develop a market platform to tap flexible assets in the distribution grid to improve system operation and reduce renewable energy curtailment (focus on load potential) |
| SINTEG C/sells: Comax* | DE | Pilot | Develop a coordination platform to promote congestion management with small-scale flexibility on lower voltage levels and improve grid operator coordination |
| SINTEG WindNode: Flexibilitätsplattform | DE | Pilot | Expand congestion management options by tapping additional flexibility sources connected to the distribution grid |
| SNTEG Enera: Flexmarkt | DE | Pilot | Develop a platform to coordinate flexibility demand and supply, improve congestion management options for grid operators, and reduce renewable energy curtailment |
| SINTEG New 4.0: ENKO | DE | Pilot | Develop a coordination mechanism for grid operators to showcase the potential of local loads as an alternative to redispatch, and renewable energy curtailment |
| DA/RE | DE | Pilot | Develop IT platform to tap flexibility potential located on the distribution grid for congestion management and improve coordination between grid operators |
| Nodes Market | Europe | Business case | Create a marketplace to improve grid operation, tap additional flexibility potential and enhance congestion management options for grid operators |
| Grid Integration | DE | Proposal | Develop a flexibility market platform with largely automated processes to improve congestion management in the distribution grid |
| GOPACS/ IDCONS | NL | Pilot | Develop a mechanism to increase available flexibility volume, reduce costs, and standardize and harmonize grid operator products and processes to address congestion on lower voltage levels |

## Appendix B: Interviews

In appendix B the overview of the interviews and the scoring of the identified factors is shown. Moreover, the answers to the questions and the motivations behind the given scores is summarized.

### Participant 1 interview study - NL

Output:

| Scoring barriers for behind-the-meter storage technologies | | | Definitions barriers: | Residential - Stationary battery system - NL | C&I - stationary battery system - NL | Residential - V2G - NL | C&I - V2G - NL |
|---|---|---|---|---|---|---|---|
| | | | | 0 = no barrier 1 = medium barrier 2 = significant barrier | | | |
| Costs and financing | 1 | Investment cost required | *The degree to which the investment costs* | 2 | 1 | 1 | 1 |
| | 2 | Expected pay-back time | *The degree to which the expected pay-bac* | 1 | 2 | 1 | 2 |
| | 3 | Difficulty in financing investment | *The degree to which attracting appropria* | 2 | 2 | 2 | 2 |
| Technological barriers | 4 | Resource constraints | *The degree to which the resources and/or* | 0 | 0 | 0 | 0 |
| | 5 | Change in physicial connected systems | *The degree to which physical change is re* | 0 | 1 | 2 | 2 |
| | 6 | Lack of communication protocols | *The degree to which the access to, or man* | 1 | 0 | 2 | 2 |
| | 7 | Technology uncertainty | *The degree to which technological reliabi* | 1 | 0 | 1 | 0 |
| Market & regulatory barriers | 8 | Lack of signals for self-consumption | *The degree to which existent incentives fo* | 2 | 1 | 1 | 0 |
| | 9 | Lack of clear regulatory framework | *The degree to which the regulatory frame* | 2 | 2 | 2 | 2 |
| | 10 | Lack of incentives for participation in electrici | *The degree to which the lack of incentives* | 2 | 1 | 0 | 0 |
| Multi-stakeholder complexity | 11 | Dependency on other actors | *The degree of dependency on other actors* | 0 | 0 | 0 | 0 |
| Behavior | 12 | Lack of knowledge | *The degree to which the investor does not* | 1 | 1 | 1 | 1 |
| | 13 | Change in behavior | *The degree to which the investor need to c* | 2 | 2 | 2 | 2 |

### Interview questions:

1. What is your position/experience towards behind-the-meter storage systems?
   - Research institution, researcher, experience in energy markets and the overall energy system.
   - Lack of TSO-DSO coordination > Removed

2. Could you explain for each factor the rationale behind your choice for the barrier score?

| | Barriers | Rationale |
|---|---|---|
| 1 | **Investment cost required** | V2G less investment costs (when already purchasing EV); Less share of investment costs for C&I sector compared to |
| 2 | **Expected pay-back time** | Pay-back time important indicator for C&I sector. Residential less important. |
| 3 | **Difficulty in financing investment** | No opportunities for financing investment, especially for batteries. |
| 4 | **Resource constraints** | On the short-term no problems expected. |
| 5 | **Change in physicial connected systems** | V2G more problematic, no standardications; C&I sector implementation of the physical system requires customization. |
| 6 | **Lack of communication protocols** | C&I; when the physical connected systems are standardized, the communication protocols are that as well; V2G the technology is not mature enough therefore no communication protocols. |
| 7 | **Technology uncertainty** | Residential consumers more sensitive towards negative newsitems; C&I will insure either way |
| 8 | **Lack of signals for self-consumption** | Net-metering residential sector, C&I less of a barrier; V2G payed by different subscriptions; C&I V2G no barrier since this will improve the businesscase of V2G |
| 9 | **Lack of clear regulatory framework** | Significant barrier for all; uncertainty about grid tariffs; congestion managment |
| 10 | **Lack of incentives for participation in ele** | Residential only via aggregator or suppliers participating on electricity market; there are possibilities for C&I to participate |
| 11 | **Dependency on other actors** | No barrier; residential & C&I sector does not want to participate on markets by them selves; |
| 12 | **Lack of knowledge** | A small barrier; still specific people who know about the technology, however improving |
| 13 | **Change in behavior** | Enterprises and consumers do not want to adjust their behavior, significant barrier. |

3. Are there any links between the barriers according to you?
    - Dependency of other actors / lack of incentives for participation in electricity markets
    - Lack of clear regulatory framework / lack of signals for self-consumption
4. What barriers do you expect to increase in the coming 10 years?
    - Resource constraints

## Participant 2 interview study – NL

Output:

| Scoring barriers for behind-the-meter storage technologies | | | Definitions barriers: | Residential - Stationary battery system - NL | C&I - stationary battery system - NL | Residential - V2G - NL | C&I - V2G - NL |
|---|---|---|---|---|---|---|---|
| | | | | 0 = no barrier 1 = medium barrier 2 = significant barrier | | | |
| Costs and financing | 1 | Investment cost required | The degree to which the investment costs are significant in size for the investor | 2 | 1 | 2 | 2 |
| | 2 | Expected pay-back time | The degree to which the expected pay-back time is significant | 2 | 1 | 2 | 2 |
| | 3 | Difficulty in financing investment | The degree to which attracting appropriate financial means is difficult | 2 | 1 | 2 | 1 |
| Technological barriers | 4 | Supply chain constraints | The degree to which the resources and/or the technology is constraint | 0 | 0 | 0 | 0 |
| | 5 | Change in physicial connected systems | The degree to which physical change is required in connected or related technical system | 0 | 1 | 0 | 1 |
| | 6 | Lack of communication protocols | The degree to which the access to, or management of real-time data between storage uni | 0 | 0 | 0 | 1 |
| | 7 | Technology uncertainty | The degree to which technological reliability, safety, privacy and performance are uncert | 1 | 0 | 2 | 1 |
| Market & regulatory barriers | 8 | Lack of signals for self-consumption | The degree to which existent incentives for injecting electricity into the grid instead of sto | 2 | 1 | 2 | 1 |
| | 9 | Lack of clear regulatory framework | The degree to which the regulatory framework is unclear | 1 | 1 | 1 | 1 |
| | 10 | Lack of incentives for participation in electricity markets | The degree to which the lack of incentives to participate in electricity markets (i.e. DA, ID, | 1 | 1 | 1 | 1 |
| Multi-stakeholder complexity | 11 | Dependency on other actors | The degree of dependency on other actors to successfully implement the technology | 1 | 1 | 1 | 1 |
| Behavior | 12 | Lack of knowledge | The degree to which the investor does not know about possible opportunities to install te | 2 | 1 | 2 | 1 |
| | 13 | Change in behavior | The degree to which the investor need to change their behavioral patterns | 0 | 0 | 1 | 0 |

## Interview questions:

1. What is your position/experience towards behind-the-meter storage systems?
    - Innovation Analyst Smart Energy Systems
2. Could you explain for each factor the rationale behind your choice for the barrier score?

| | Barriers | Rationale |
|---|---|---|
| 1 | **Investment cost required** | Stationary li-ion battery still very expensive > significant barrier; C&I less expensive to install large-scale battery; V2G charging points bi-directional still very expensive, moreover adjustment cars needed |
| 2 | **Expected pay-back time** | Residential sector, expected pay back time is really large for both V2G as storage system; C&I sector multiple possible revenues so less of a barrier; V2G more in development therefore less certainty and possible higher pay-back times. |
| 3 | **Difficulty in financing investment** | No subsidies in the residential sector for stationary storage systems in C&I and residential sector. More options for subsidies in the C&I sector. |
| 4 | **Supply chain constraints** | Currently no constraints. |
| 5 | **Change in physicial connected systems** | Residential sector no barrier to install technology physically. In the C&I sector larger storage systems necessary and requires more space > higher barrier. |
| 6 | **Lack of communication protocols** | Protocols are already existing, only C&I V2G multiple smart systems entails multipe protocols, could be a barrier to combine these smart systems. |
| 7 | **Technology uncertainty** | Mostly the safety of li-ion batteries is a barrier for the residential sector, C&I sector li-ion batteries in containers; V2G residential problem lies within the fact that you want your battery full and will not always be the case; C&I V2G More privacy sensitive, however less of a barrier for battery capacity requirements. |
| 8 | **Lack of signals for self-consumption** | Residential sector no incentives for self-consumption, main barrier; C&I self-consumption important for businesscase, however less of a barrier compared to residential sector |
| 9 | **Lack of clear regulatory framework** | Lack of a clear regulatory framework gives uncertainty to all investors. |
| 10 | **Lack of incentives for participation in electricity markets** | No participation for residential sector possible, however should the residential sector be willing to participate? C&I sector easier to leave it at the aggregator, depends per C&I. |
| 11 | **Dependency on other actors** | There is definitely dependency, however, for residential sector, the barrier lies mostly in relation homeowner - tenant; dependency C&I also in DSO - enterprise and municipalitiy - enterprise |
| 12 | **Lack of knowledge** | For the residential sector there is a lack of knowledge; C&I sector knows a bit more about possibilities |
| 13 | **Change in behavior** | For V2G residential sector there is a need for changing your behavior towards implementing the technology and could form a barrier. |

3. Are there any links between the barriers according to you?

    a. Investment costs / pay-back time / difficulty in financing investment
    b. Uncertainty technology / lack of knowledge
    c. Lack of clear regulatory framework / lack of signals for self-consumption / participation in electricity markets

4. What barriers do you expect to increase in the coming 10 years?
    a. Resource constraints, hopefully the barrier on the business case improves as well as the uncertainty of the regulatory framework

**Participant 3 interview study 3 – NL**

Output:

| Scoring barriers for behind-the-meter storage technologies | | | Definitions barriers: | Residential - Stationary battery system - NL | C&I - stationary battery system - NL | Residential - V2G - NL | C&I - V2G - NL |
|---|---|---|---|---|---|---|---|
| | | | | 0 = no barrier 1 = medium barrier 2 = significant barrier | | | |
| Costs and financing | 1 | Investment cost required | *The degree to which the investment costs are significant in size for the investor* | *2* | *2* | *1* | *1* |
| | 2 | Expected pay-back time | *The degree to which the expected pay-back time is significant* | 2 | 2 | 2 | 2 |
| | 3 | Difficulty in financing investment | *The degree to which attracting appropriate financial means is difficult* | 2 | 1 | 1 | 1 |
| Technological barriers | 4 | Resource constraints | *The degree to which the resources and/or the technology is constraint* | 2 | 2 | 2 | 2 |
| | 5 | Change in physicial connected systems | *The degree to which physical change is required in connected or related technical systems or* | 1 | 1 | 1 | 1 |
| | 6 | Lack of communication protocols | *The degree to which the access to, or management of real-time data between storage unit an* | **0** | **0** | 1 | 1 |
| | 7 | Technology uncertainty | *The degree to which technological reliability, safety, privacy and performance are uncertain* | 1 | 1 | **1** | **1** |
| Market & regulatory barriers | 8 | Lack of signals for self-consumption | *The degree to which existent incentives for injecting electricity into the grid instead of storing* | 2 | 2 | 2 | 2 |
| | 9 | Lack of clear regulatory framework | *The degree to which the regulatory framework is unclear* | 1 | 1 | 1 | 1 |
| | 10 | Entry barriers for participation in electricity markets | *The degree to which the lack of incentives to participate in electricity markets (i.e. DA, ID, bal* | 2 | 1 | **1** | **1** |
| Multi-stakeholder complexity | 11 | Dependency on other actors | *The degree of dependency on other actors to successfully implement the technology* | 2 | 1 | 2 | 2 |
| Behavior | 12 | Lack of knowledge | *The degree to which the investor does not know about possible opportunities to install techn* | 1 | 1 | 2 | 2 |
| | 13 | Change in behavior | *The degree to which the investor need to change their behavioral patterns* | 0 | 0 | 1 | 1 |

**Interview questions:**

1. What is your position/experience towards behind-the-meter storage systems?
    - Energy Storage Specialist

2. Could you explain for each factor the rationale behind your choice for the barrier score?

| | Barriers | Rationale |
|---|---|---|
| 1 | Investment cost required | *High investment costs for the residential & C&I sector (not only the battery packs, but also converters, BTW etc, really high upfront costs); The investment costs for the charging points are not so high, but higher compared to a 'normal' charging point.* |
| 2 | Expected pay-back time | *Barrier pay-back time for all significant, important indicator for both sectors to invest in technology.* |
| 3 | Difficulty in financing investment | *No subsidy home battery, compared to Germany or Belgium; C&I sector bit more easy, however still a barrier to finance the investment (acquiring a loan);V2G hard to say, not a lot of developments in the Netherlands* |
| 4 | Resource constraints | *Currently, in all sectors all components of storage technologies is challenging to acquire, long lead-times, shortages in resources. As well as being really dependent on China for both technologies.* |
| 5 | Change in physicial connected systems | *For all technologies, adjustments are necessary, however no 'really' big changes necessary, can be overseen.* |
| 6 | Lack of communication protocols | *Battery storage a lot of developments, is working fine. V2G harmonization necessary for protocols* |
| 7 | Technology uncertainty | *All technologies are commercial available so meet certain goals on privacy, safety etc. , however still uncertainty exist regarding safety and warranties.* |
| 8 | Lack of signals for self-consumption | *Currently, no incentives for self-consumption for both batteries and V2G, really significant barrier.* |
| 9 | Lack of clear regulatory framework | *For all technologies and sector medium barrier, PGS 37 currently under development for the safety of li-ion batteries.* |
| 10 | Entry barriers for participation in electricity markets | *Residential sector should be able to buy a battery + service that connects the user to the market, is currently not there, therefore high barrier; c&I sector medium barrier, aggregators are more used to responding on developments in the C&I sector, however still difficult to particpate in markets;* |
| 11 | Dependency on other actors | *Residential other actors, such as the house-owner, will determine if its succesful to implement technology, C&I bit less compared to residential sector. V2G really dependent on what stakeholders in the market are going to do* |
| 12 | Lack of knowledge | *Definitely lack of knowledge, however, people are exposed to this knowledge more often, especially for batteries. V2G high barrier, hard to even understand how 'normal' charging works, so V2G is bit too complex still.* |
| 13 | Change in behavior | *For batteries, no change in behavior necessary, you dont even notice when a battery is installed whether electricity is taken from the grid or from you battery (few seconds to which the converter decides).  V2G people have to think more since the battery is moving, and people want to have a full battery when leaving.* |

**Participant 4 interview study 4 – NL**

Output:

| Scoring barriers for behind-the-meter storage technologies | | | Definitions barriers: | Residential - Stationary battery system - NL | C&I - stationary battery system - NL | Residential - V2G - NL | C&I - V2G - NL |
|---|---|---|---|---|---|---|---|
| | | | | 0 = no barrier 1 = medium barrier 2 = significant barrier | | | |
| Costs and financing | 1 | Investment cost required | *The degree to which the investment costs are significant in size for the inves* | 2 | 0 | 1 | 0 |
| | 2 | Expected pay-back time | *The degree to which the expected pay-back time is significant* | 2 | 0 | 2 | 1 |
| | 3 | Difficulty in financing investment | *The degree to which attracting appropriate financial means is difficult* | 2 | 0 | 1 | 1 |
| Technological barriers | 4 | Supply chain constraints | *The degree to which the resources and/or the technology is constraint* | 1 | 1 | 1 | 1 |
| | 5 | Change in physicial connected systems | *The degree to which physical change is required in connected or related te* | 2 | 1 | 0 | 0 |
| | 6 | Lack of communication protocols | *The degree to which the access to, or management of real-time data betwe* | 1 | 0 | 1 | 1 |
| | 7 | Technology uncertainty | *The degree to which technological reliability, safety, privacy and performa* | 0 | 0 | 2 | 2 |
| Market & regulatory barriers | 8 | Lack of signals for self-consumption | *The degree to which existent incentives for injecting electricity into the gri* | 2 | 0 | 1 | 1 |
| | 9 | Lack of clear regulatory framework | *The degree to which the regulatory framework is unclear* | 1 | 1 | 1 | 1 |
| | 10 | Entry barrier for participation in electricity markets | *The degree to which the lack of incentives to participate in electricity mark* | 1 | 0 | 0 | 0 |
| Multi-stakeholder complexity | 11 | Dependency on other actors | *The degree of dependency on other actors to successfully implement the te* | 2 | 1 | 2 | 1 |
| Behavior | 13 | Lack of knowledge | *The degree to which the investor does not know about possible opportunit* | 2 | 0 | 1 | 1 |
| | 14 | Change in behavior | *The degree to which the investor need to change their behavioral patterns* | 0 | 0 | 0 | 0 |

**Interview questions:**

1. What is your position/experience towards behind-the-meter storage systems?
    - Business analyst behind-the-meter systems.

2. Could you explain for each factor the rationale behind your choice for the barrier score?

| | Barriers | *Rationale* |
|---|---|---|
| 1 | Investment cost required | Net-metering still exist, so high barrier for the residential sector.For the C&I sector congestion plays a central role, due to the congestion there are no grid connections available, more important to proceed the job in stead of looking to the investment of installing storage technology. V2G not yet available for everyone, medium barrier, since residential consumers are not aware of V2G service. Investment cost not the problem for C&I, pay-back time more important. |
| 2 | Expected pay-back time | Pay-back time high for the residential sector; Its not about the pay-back time, but its more important that the C&I sector can proceed with their business (and therefore installing a battery); Really high pay-back time for V2G; more options for revenue streams C&I sector |
| 3 | Difficulty in financing investment | No subsidy available therefore high barrier; C&I sector can get subsidies when combined with solar PV; |
| 4 | Supply chain constraints | Li-ion batteries more standardized battery, both medium barrier for C&I and residential. The problem with V2G lies in supply chain problems within the car industry. |
| 5 | Change in physicial connected systems | High barrier for residential, change necessary in current systems; C&I design and engineering done before-hand; V2G less physcial space necessary. |
| 6 | Lack of communication protocols | Compability can be complex for stationary battery system and not standardized; C&I bit further, therefore less of a barrier; V2G less engineering due to APIs, however not yet existent. |
| 7 | Technology uncertainty | Batteries not so uncertain, developed technology, warranties given when staying within certain boundaries; V2G warranty on battery more difficult; high barrier. |
| 8 | Lack of signals for self-consumption | Batteries high barrier for residential, one of the important barriers, however no barrier for C&I, same argument due to congestion they want to continue working and therefore installing the battery; V2G residential can be stimulating to drive on self-generated energy. |
| 9 | Lack of clear regulatory framework | Its a barrier for the development of the systems, so the C&I sector and residential are indirectly involved, moreover the lack of a clear regulatory framework gives a lot of uncertainty to all investors, therefore for all medium barrier. |
| 10 | Lack of incentives for participation in electricity markets | Dynamic energy contract possible, so medium barrier; Smart charging provisions, the options are there, however, the clients have to follow. |
| 11 | Dependency on other actors | Residential high barrier as tenant; less of a barrier for the C&I sector, however still depedent on energy supplier; V2G still depedent from house owners/grid operators. |
| 12 | Lack of knowledge | Residential sector not aware of storage technologies, C&I are aware of the opportunities and self-consumption; V2G residential aware of electric vehicles, however, v2g services still bit unknown; C&I V2G not sure if this sector knows about balancing behind-the-meter with electric vehicles. |
| 13 | Change in behavior | Residential and C&I sector will give others the responsibility over their energy consumption and therefore it is not a barrier. |

3. Are there any links between the barriers according to you?
    - Protocols and change in physical connected systems; installing physical gateway, influences necessity API.
4. What barriers do you expect to increase in the coming 10 years?
    - Change in physical connected systems; in the future more systems connected to each other, problems with the capacity of grid connection.

## Participant 5 interview study 5 – NL

Output:

| Scoring barriers for behind-the-meter storage technologies | | | Definitions barriers: | Residential - Stationary battery system - NL | C&I - stationary battery system - NL | Residential - V2G - NL | C&I - V2G - NL |
|---|---|---|---|---|---|---|---|
| | | | | 0 = no barrier 1 = medium barrier 2 = significant barrier | | | |
| Costs and financing | 1 | Investment cost required | The degree to which the investment costs are significant in size for the investor | *2* | *1* | *0* | *0* |
| | 2 | Expected pay-back time | The degree to which the expected pay-back time is significant | 2 | 1 | 2 | 1 |
| | 3 | Difficulty in financing investment | The degree to which attracting appropriate financial means is difficult | 2 | 2 | 0 | 1 |
| Technological barriers | 4 | Supply chain constraints | The degree to which the resources and/or the technology is constraint | 1 | 1 | 1 | 1 |
| | 5 | Change in physicial connected systems | The degree to which physical change is required in connected or related technical systems or p | 0 | 1 | 1 | 1 |
| | 6 | Lack of communication protocols | The degree to which the access to, or management of real-time data between storage unit and | 1 | 0 | 2 | 1 |
| | 7 | Technology uncertainty | The degree to which technological reliability, safety, privacy and performance are uncertain | 1 | 1 | 1 | 1 |
| Market & regulatory barriers | 8 | Lack of signals for self-consumption | The degree to which existent incentives for injecting electricity into the grid instead of storing s | 2 | 1 | 2 | 1 |
| | 9 | Lack of clear regulatory framework | The degree to which the regulatory framework is unclear | 0 | 2 | 2 | 2 |
| | 10 | Entry barriers for participation in electricity markets | The degree to which the lack of incentives to participate in electricity markets (i.e. DA, ID, bala | 0 | 0 | 0 | 0 |
| Multi-stakeholder complexity | 11 | Dependency on other actors | The degree of dependency on other actors to successfully implement the technology | 2 | 2 | 0 | 2 |
| Behavior | 12 | Lack of knowledge | The degree to which the investor does not know about possible opportunities to install technol | 2 | 2 | 2 | 2 |
| | 13 | Change in behavior | The degree to which the investor need to change their behavioral patterns | 0 | 0 | 0 | 0 |

## Interview questions:

5. What is your position/experience towards behind-the-meter storage systems?
    - Selling batteries, head of digital energy.
6. Could you explain for each factor the rationale behind your choice for the barrier score?

| | Barriers | Rationale |
|---|---|---|
| 1 | Investment cost required | *Residential sector, batteries are very expensive, small amount would be able to invest in the technology. C&I sector less of a barrier investmodel is different compared to the residential sector. V2G residential, the infrastructure required for V2G is quite low, only the connection should be implemented.* |
| 2 | Expected pay-back time | *Significant barrier for residential sector, still possible to apply for net-metering, will last five years before pay-back time becomes more interesting for residential sector. C&I sector differs per installment, differs per case and per SME; For V2G same arguments.* |
| 3 | Difficulty in financing investment | *No subsidy available residential sector, C&I subsidies possible , however acquiring loans more difficult, business case necessary therefore hard to acquire. Possible to opt for subisidy electric vehicle, so the barrier lies not within the difficulty in financing. C&I if dependent for a loan, then hard to prove the businesscase, and therefore hard to acquire the loan.* |
| 4 | Supply chain constraints | *There are problems regarding the supply chain, in general within the supply chain there are too few human resources to install batteries.* |
| 5 | Change in physicial connected systems | *Residential sector low barrier since there are few adjustments to be made; C&I more complex to install technology, however can be opportunity as well when you are in congestion area. V2G no barrier to install technology, however space necessary (1/3 of Dutch people have own parkinglot).* |
| 6 | Lack of communication protocols | *There is no lack in protocols, but the amount of protocols makes it complex, no standardization. The question is are there standard protocols and open protocols. Residential sector too much choice, hard to know if the protocols of the heatpump and or solarpanels could work with each other.; C&I sector low barriers, many participants want to combine the protocols and are seeing businesscases. ; v2G same arguments, however bit newer in the V2G sector therefore higher barrier compared to the battery technology.* |
| 7 | Technology uncertainty | *Residential sector complexity high and therefore uncertain for residential sector what the technology can do; C&I sector more development, more technologies on the market and therefore more choice opportunities, medium barrier; V2G technology for residential & C&I sector battery warranty uncertain therefore both medium barrier.* |
| 8 | Lack of signals for self-consumption | *High barrier for residential sector, when net-metering is existent; C&I sector lower compared to residentail sector, V2G same arguments.* |
| 9 | Lack of clear regulatory framework | *Residential, everyone could install a battery, however for the C&I sector more difficulties for intstalling batteries with insurances, safety; V2G lease companies who have to pay for energy tariffs, no regulatory framework between lease companies and leasers yet. Same for C&I sector.* |
| 10 | Entry barriers for participation in electricity markets | *No barrier for the residential sector, no idea about possible tradings on electricity markets, only optimizing own energy consumption; C&I sector don't want to trade by themselves on the energy markets; V2G same arguments* |
| 11 | Dependency on other actors | *Division between tentants and non-tenants, as houseowner no dependency, as tenant high barrier; C&I sector high dependency on other actors if its possible to install battery; V2G residential already electric vehicle and high capital, therefore no barrier to implement technology. C&I V2G high dependency, everything is connected with each other.* |
| 12 | Lack of knowledge | *High barrier for all, lack of knowledge is enormous in the residential and C&I sector.* |
| 13 | Change in behavior | *Low barrier to invest in technology, the barrier is to cope with technology and to adjust behavior to make it a businesscase, however no barrier to invest in technology.* |

7. Are there any links between the barriers according to you?
    - Physical connected systems and dependency on other actors (parking lot); pay-back time and investment costs.
8. What barriers do you expect to increase in the coming 10 years?
    - Resources constraints. Hopefully in the future standardization protocols, or open protocols for future smart systems, decrease expected in investment costs and pay-back time.

**Missing factors:** Sustainability not totally involved; people are not aware of the amount of materials used to build all these batteries.

## Participant 6 interview study 6 - NL

Output:

| Scoring barriers for behind-the-meter storage technologies | | | Definitions barriers: | Residential - Stationary battery system - NL | C&I - stationary battery system - NL | Residential - V2G - NL | C&I - V2G - NL |
|---|---|---|---|---|---|---|---|
| | | | | 0 = no barrier 1 = medium barrier 2 = significant barrier | | | |
| Costs and financing | 1 | Investment cost required | *The degree to which the investment costs are significant in size for the investor* | 2 | 1 | 0 | 0 |
| | 2 | Expected pay-back time | *The degree to which the expected pay-back time is significant* | 2 | 1 | 0 | 0 |
| | 3 | Difficulty in financing investment | *The degree to which attracting appropriate financial means is difficult* | 2 | 1 | 0 | 0 |
| Technological barriers | 4 | Resource constraints | *The degree to which the resources and/or the technology is constraint* | 2 | 2 | 0 | 0 |
| | 5 | Change in physicial connected systems | *The degree to which physical change is required in connected or related technical s* | 0 | 1 | 1 | 1 |
| | 6 | Lack of communication protocols | *The degree to which the access to, or management of real-time data between stora* | **1** | **1** | **0** | **0** |
| | 7 | Technology uncertainty | *The degree to which technological reliability, safety, privacy and performance are* | 2 | 2 | 2 | 2 |
| Market & regulatory barriers | 8 | Lack of signals for self-consumption | *The degree to which existent incentives for injecting electricity into the grid instead* | 2 | 2 | 2 | 2 |
| | 9 | Lack of clear regulatory framework | *The degree to which the regulatory framework is unclear* | 2 | 2 | 2 | 2 |
| | 10 | Entry barriers for participation in electricity markets | *The degree to which the lack of incentives to participate in electricity markets (i.e.* | 1 | 0 | 1 | 0 |
| Multi-stakeholder complexity | 11 | Dependency on other actors | *The degree of dependency on other actors to successfully implement the technolog* | 1 | 0 | 1 | 0 |
| Behavior | 12 | Lack of knowledge | *The degree to which the investor does not know about possible opportunities to ins* | 2 | 2 | 2 | 1 |
| | 13 | Change in behavior | *The degree to which the investor need to change their behavioral patterns* | 0 | 1 | 2 | 2 |

## Interview questions:

1. What is your position/experience towards behind-the-meter storage systems?
    - Network operator, Congestion & flexibility management analyst

2. Could you explain for each factor the rationale behind your choice for the barrier score?

| Barriers | Rationale |
|---|---|
| Investment cost required | *Residential sector high investment costs battery system, high barrier; C&I higher income and other assets, investment cost less share; V2G less investment costs, not so expensive to install infrastructure for V2G.* |
| Expected pay-back time | *No business case for residential consumers, less incentives since fixed energy tariffs are existent for the residential sector; C&I smaller, other tariff structure, more opportunities behind-the-meter for the C&I sector; V2G pay-back time less important, more opportunities when installing V2G services.* |
| Difficulty in financing investment | *Residential sector no possibilies to get subsidies, as long as there are no subsidies available people will not invest in the technology; C&I sector; more possibilities to acquire financial opportunities; V2G the investment is not too big, so will form a low barrier.* |
| Resource constraints | *Noticing resource constraints, so high barrier for battery technology. V2G infrastructure still possible to implement current moment.* |
| Change in physicial connected systems | *Does not ask for too much change in physical systems for the residential sector, the goal of the battery is not to reinforce your grid connection; C&I sector reinforcement grid connection maybe necessary; V2G differs within the residential sector, medium barrier.* |
| Lack of communication protocols | *Doubt in answers, V2G furhter in development with protocols compared to batteries* |
| Technology uncertainty | *Safety (fire) issues regarding stationary batteries, is a high barrier for both sectors to invest in technology; V2G higher degradation of battery high barrier + vehicle not always available, high barrier as well.* |
| Lack of signals for self-consumption | *High barrier, no incentives for self-consumption in both sectors.* |
| Lack of clear regulatory framework | *Insurance aspects harder for residential sector; still double tariffs for large-scale consumers; different aspects of the regulatory framework per sector, however for every technology and sector high barrier.* |
| Entry barriers for participation in electricity markets | *Its not possible to participate in the market, however, seen as medium barrier for residential sector since they are not familiar with trading on the market; C&I sector more eager to use third party and more familiar with energy exchange.* |
| Dependency on other actors | *Residential sector when tenant more dependent on other actors, therefore medium barrier; C&I sector more familiar with energy management and are therefore already less depedent on other actors.* |
| Lack of knowledge | *High barrier, less knowledge on system intergration mostly for stationary batteries; residential V2G not knowing about opportunities, C&I sector more knowledge and research on combining multiple EVs.* |
| Change in behavior | *Residential battery, goal of the battery should be to fill the gap between generation and consumption, and therefore to not change your behavior; C&I sector dependent on how efficient they want to be, high efficiency defenitly; V2G high barrier since its a movable object, thus moving battery.* |

3. Are there any links between the barriers according to you?
    - Entry barriers for participation and lack of knowledge, people are not aware of trading on electricity markets.
4. What barriers do you expect to increase in the coming 10 years?
    - Resource constraints, already problematic, in the future expected to be even more problematic. Hopefully, energy streams will be more smartly aligned and therefore pay-back decreases.

**Participant 7 Interview study – NL**

Output:

| Scoring barriers for behind-the-meter storage technologies | | | Definitions barriers: | Residential - Stationary battery system - NL | C&I - stationary battery system - NL | Residential - V2G - NL | C&I - V2G - NL |
|---|---|---|---|---|---|---|---|
| | | | | 0 = no barrier 1 = medium barrier 2 = significant barrier | | | |
| Costs and financing | 1 | Investment cost required | The degree to which the investment costs are significant in size for the investor | 2 | 1 | 1 | 1 |
| | 2 | Expected pay-back time | The degree to which the expected pay-back time is significant | 2 | 2 | 1 | 1 |
| | 3 | Difficulty in financing investment | The degree to which attracting appropriate financial means is difficult | 1 | 2 | 0 | 1 |
| Technological barriers | 4 | Resource constraints | The degree to which the resources and/or the technology is constraint | 0 | 0 | 1 | 1 |
| | 5 | Change in physicial connected systems | The degree to which physical change is required in connected or related technical systems or | 0 | 0 | 1 | 1 |
| | 6 | Lack of communication protocols | The degree to which the access to, or management of real-time data between storage unit ar | 1 | 0 | 0 | 0 |
| | 7 | Technology uncertainty | The degree to which technological reliability, safety, privacy and performance are uncertain | 1 | 0 | 1 | 1 |
| Market & regulatory barriers | 8 | Lack of signals for self-consumption | The degree to which existent incentives for injecting electricity into the grid instead of storin | 2 | 2 | 1 | 1 |
| | 9 | Lack of clear regulatory framework | The degree to which the regulatory framework is unclear | 0 | 2 | 0 | 2 |
| | 10 | Entry barriers for participation in electricity markets | The degree to which the lack of incentives to participate in electricity markets (i.e. DA, ID, ba | 2 | 1 | 1 | 1 |
| Multi-stakeholder complexity | 11 | Dependency on other actors | The degree of dependency on other actors to successfully implement the technology | 2 | 1 | 1 | 1 |
| Behavior | 12 | Lack of knowledge | The degree to which the investor does not know about possible opportunities to install techn | 1 | 1 | 1 | 1 |
| | 13 | Change in behavior | The degree to which the investor need to change their behavioral patterns | 1 | 0 | 1 | 1 |

**Interview questions:**

1. What is your position/experience towards behind-the-meter storage systems?
    - Manager Innovation & Development, network operator
2. Could you explain for each factor the rationale behind your choice for the barrier score?

| Barriers | Rationale |
|---|---|
| Investment cost required | High costs for residential sector to invest in battery, high barrier especially due to net-metering rule. C&I high investment costs as well, however less share compared to residential sector. V2G residential and C&I bi-directional charging points need investment, however smaller in size. |
| Expected pay-back time | The pay-back time and thus businesscase is a really high barrier. >15 yyears pay-back time for stationary battery. V2G pay back time important as well, however, compared to stationary battery, smaller investment so smaller pay-back time. |
| Difficulty in financing investment | In general, no loans required for residential sector to invest in technology, however no subsidies available, so medium barrier. C&I sector hard to acquire loans due to the difficulty in providing valid businescase. Smaller investment for V2G, residential, however C&I higher investments and therefore acquire investment more important . |
| Resource constraints | Still possible to acquire and install batteries, no barrier. V2G medium barrier; V2G service not widely available, and lack of human resources to install such technology (lack of knowledge on this new technology) |
| Change in physicial connected systems | No barrier, for residential & C&I sector, possible to install battery physically, not seen as barrier. V2G replacement of charging point, could be a light barrier. C&I sector electrical system should change when high loads are injected back into the system |
| Lack of communication protocols | Residential sector, hard to communicate with Powerwalls for example, no standardization. C&I sector less of a barrier, since plug and play is less expected with bigger storage systems. V2G protools for charging point no issues, standardized (OCPP). |
| Technology uncertainty | Safety issue for residential sector barrier to invest in technology, less issue for C&I sector. V2B battery degredation and performance important, barrier. |
| Lack of signals for self-consumption | One of the most important barriers for residential sector (net-metering and double taxation). For C&I sector a problem SDE subsidy is lower for self-consumption compared to injecting solar energy back into the grid (2,5 cents). + lack of dynamic pricing. For V2G same problems, but less of a barrier compared to stationary batteries. |
| Lack of clear regulatory framework | Residential sector, uncertainty in regulatory framework not the problem. The problem consists of existing rules, such as net-metering which hinders the deployment of btm storage, not the uncertainty of it. Different for C&I sector, storage not defined leads to high transport costs (consumer + producer) |
| Entry barriers for participation in electricity markets | For the residential sector not possible to enter the market, only via aggregator, high barrier since it could be that consumers do not want to be dependent on third party (the aggregator); smart charging happens already for consumers, so barrier is not so high to integrate V2G. C&I sector possible to participate if they meet certain standards and bid sises, however energy is not there key business. |
| Dependency on other actors | Residential sector high dependency tenant-houseowner, high barrier; for the other sectors also dependency for installment technology, charging points, data etc. |
| Lack of knowledge | Overall lack of knowledge, the barrier is that consumers have to dive into the energy sector to understand how it works, + energy is low interest for C&I sector (not their core business) |
| Change in behavior | Batteries, depends on the use-case, battery used to optimize your own generated solar energy, hourly price differentation, then you could adjust your behavior to lower energy bills. C&I battery more of a solution. V2G; consumers have to adjust their behavior, certain SOC when leaving. |

3. Are there any links between the barriers according to you?
    a. Investment cost required, expected pay-back time and difficulty in financing investment
    b. Pay-back time dependent of lack of signals for self-consumption
    c. Dependency on other actors higher if entry barriers are higher
    d. Change in physical systems dependent on dependency of other actors
4. What barriers do you expect to increase in the coming 10 years?
    - Resources constraints. Hopefully future batteries are designed in a way that scarce resources are not required. Moreover, a lack of technicians expected.

## Participant 8 Interview study – DE

Output:

| Scoring barriers for behind-the-meter storage technologies | | | Definitions barriers: | Residential - Stationary battery system - DE | C&I - stationary battery system - DE | Residential - V2G - DE | C&I - V2G - DE |
|---|---|---|---|---|---|---|---|
| | | | | 0 = no barrier 1 = medium barrier 2 = significant barrier | | | |
| Costs and financing | 1 | Investment cost required | *The degree to which the investment costs are significant in size for the investor* | 2 | 2 | 2 | 2 |
| | 2 | Expected pay-back time | *The degree to which the expected pay-back time is significant* | 1 | 1 | 1 | 1 |
| | 3 | Difficulty in financing investment | *The degree to which attracting appropriate financial means is difficult* | 0 | 0 | 0 | 0 |
| Technological barriers | 4 | Resource constraints | *The degree to which the resources and/or the technology is constraint* | 1 | 1 | 2 | 2 |
| | 5 | Change in physicial connected systems | *The degree to which physical change is required in connected or related technical systems or physical change is* | 0 | 1 | 1 | 1 |
| | 6 | Lack of communication protocols | *The degree to which the access to, or management of real-time data between storage unit and smart meter is nc* | 0 | 0 | 1 | 1 |
| | 7 | Technology uncertainty | *The degree to which technological reliability, safety, privacy and performance are uncertain* | 0 | 0 | 2 | 2 |
| Market & regulatory barriers | 8 | Lack of signals for self-consumption | *The degree to which existent incentives for injecting electricity into the grid instead of storing self-generated ene* | 0 | 1 | 1 | 1 |
| | 9 | Lack of clear regulatory framework | *The degree to which the regulatory framework is unclear* | 0 | 0 | 2 | 2 |
| | 10 | Entry barriers for participation in electricity markets | *The degree to which the lack of incentives to participate in electricity markets (i.e. DA, ID, balancing) is significa* | 0 | 0 | 1 | 1 |
| Multi-stakeholder complexity | 11 | Dependency on other actors | *The degree of dependency on other actors to successfully implement the technology* | 2 | 1 | 2 | 1 |
| Behavior | 12 | Lack of knowledge | *The degree to which the investor does not know about possible opportunities to install technology* | 0 | 1 | 0 | 1 |
| | 13 | Change in behavior | *The degree to which the investor need to change their behavioral patterns* | 0 | 0 | 1 | 0 |

### Interview questions:

1. What is your position/experience towards behind-the-meter storage systems?
    - Researcher energy systems

2. Could you explain for each factor the rationale behind your choice for the barrier score?

| Barriers | Rationale |
|---|---|
| Investment cost required | *Investmentcosts are high, however the technology is quite popular, since you save a lot of charges when investing in the technology. However in general, still expensive to invest in the technology. AS well as for V2G, bidirectional charging points are around 5000 euro's, normal charging point around 500 euro's. Thus, way more expensive.* |
| Expected pay-back time | *For every technology between the 5-12 years.* |
| Difficulty in financing investment | *No barrier for the residential sector and C&I, because it is quite easy to get loans. Government supports programs on making your home more sustainable. Charging points were subisidies up to 9000 euro's, however not available anymore.* |
| Resource constraints | *Currently low demand for charging points, under development, so that is the reason that bi-directional charges are currently not available. Moreover, lack of technicians in Germany, sees it as the bottleneck for the energy transition.* |
| Change in physicial connected systems | *Residential batteries not an issue, smart meter not required since it is used for self-optimization.* |
| Lack of communication protocols | *Stationary systems not a barrier since it is a big market and thus it is working. For V2G the protocol is there, however not yet implemented, so still seen as barrier.* |
| Technology uncertainty | *No barrier for stationary battery systems, since only used for self-consumption so no privacy/data related issues. Data security issue for V2G.* |
| Lack of signals for self-consumption | *There is a strong incentive for self-consumption in Germany for both residential as C&I sector. However, the larger the company the less expensive electricity is, so medium barrier for the C&I sector. V2G scores not sure since it depends on self-consumption vs grid delivering services.* |
| Lack of clear regulatory framework | *Behind the meter no problems for self-consumption within the regulatory framework. For V2G large problem, problems regarding double charges, double taxation and flexible players that are not yet* |
| Entry barriers for participation in electricity markets | *There are high minimum bid sizes in Germany, however, since storage is used as self-optimization, and C&I uses is for peak shaving and self-consumption, is not a reason to not invest in the technology. This changes for V2G for for which delivering grid services is required, it is a barrier, however the investor finds the aggregator, so meidum barrier.* |
| Dependency on other actors | *Tentant-homewoner major issue in Germany in the residential sector. Public buildings for the C&I sector could ask for administrative problems as well as problems in acquiring certain contracts, so medium barrier.* |
| Lack of knowledge | *In the residnetial sector people are aware of stationary battery systems and V2G technology, however the C&I sector bit more lack of knowledge.* |
| Change in behavior | *consumption. V2G residential requires bit of change in behaviour. V2G C&I not since the pool of capacities is smart enough to not change your* |

## Participant 9 Interview study – DE

Output:

| Scoring barriers for behind-the-meter storage technologies | | | Definitions barriers: | Residential - Stationary battery system - DE | C&I - stationary battery system - DE | Residential - V2G - DE | C&I - V2G - DE |
|---|---|---|---|---|---|---|---|
| | | | | 0 = no barrier 1 = medium barrier 2 = | | | |
| Costs and financing | 1 | Investment cost required | The degree to which the investment costs are significant in size for the investor | 1 | 2 | 1 | 1 |
| | 2 | Expected pay-back time | The degree to which the expected pay-back time is significant | 1 | 1 | 0 | 0 |
| | 3 | Difficulty in financing investment | The degree to which attracting appropriate financial means is difficult | 0 | 0 | 0 | 0 |
| Technological barriers | 4 | Resource constraints | The degree to which the resources and/or the technology is constraint | 2 | 2 | 1 | 1 |
| | 5 | Change in physicial connected systems | The degree to which physical change is required in connected or related technical systems or phys | 0 | 0 | 0 | 0 |
| | 6 | Lack of communication protocols | The degree to which the access to, or management of real-time data between storage unit and sm | 2 | 2 | 2 | 2 |
| | 7 | Technology uncertainty | The degree to which technological reliability, safety, privacy and performance are uncertain | 1 | 1 | 1 | 1 |
| Market & regulatory barrier | 8 | Lack of signals for self-consumption | The degree to which existent incentives for injecting electricity into the grid instead of storing self | 0 | 0 | 0 | 0 |
| | 9 | Lack of clear regulatory framework | The degree to which the regulatory framework is unclear | 0 | 0 | 2 | 2 |
| | 10 | Entry barriers for participation in electricity | The degree to which the lack of incentives to participate in electricity markets (i.e. DA, ID, balanci | 1 | 1 | 1 | 1 |
| Multi-stakeholder complexity | 11 | Dependency on other actors | The degree of dependency on other actors to successfully implement the technology | 2 | 2 | 2 | 2 |
| Behavior | 12 | Lack of knowledge | The degree to which the investor does not know about possible opportunities to install technolog | 1 | 2 | 2 | 2 |
| | 13 | Change in behavior | The degree to which the investor need to change their behavioral patterns | 0 | 0 | 1 | 1 |

## Interview questions:

1. What is your position/experience towards behind-the-meter storage systems?
    - Researcher behind-the-meter energy systems
2. Could you explain for each factor the rationale behind your choice for the barrier score?

| Barriers | Rationale |
| --- | --- |
| Investment cost required | *The systems are much less distributed, limited cases for btm storage in C&I sector, mainly because you can easily self-consume more electricity since you produce more and the electricity price is lower , so the investment in the storage technology is less beneficial. Investment costs are there, but the barrier is limited.* |
| Expected pay-back time | *Residential sector & C&I higher investment cost are required for stationary battery systems and therefore pay-back time is more important compared to V2G.* |
| Difficulty in financing investment | *scheme indirectly incentives btm storage systems indirectly increase self-consumption rate.* |
| Resource constraints | *Setting up a home system (PV or storage) difficult to find human resources, market is overheated. V2G quite new technology, so also a lack of human resources available, therefore still a barrier.* |
| Change in physicial connected systems | *issue. For the C&I sector space is less relevant. Same argument for V2G technology* |
| Lack of communication protocols | *Significant barrier,if you want to actively manage those systems, this is still very relevant, significant barrier for all technologies. Moreover, acces to smart meter quite uncertain* |
| Technology uncertainty | *the system? Firerisks less seen as a barrier. V2G smililar, privacy, reliability issue as well.* |
| Lack of signals for self-consumption | *You have self-consumption privalege, dont have to pay levies & taxes for electricity you produced at home, big incentive for self-consumptionV2G: There is no incentive to get an signal to feed electricity back into the grid, so thats is an incentive to self-consume (no lack of sgnals).* |
| Lack of clear regulatory framework | *For self-consumption the regulatory framework is quite clear, stationary barriers no barrier. For V2G, the framework conditions are not clear, significant barrier, not yet defined how it shoud look like.* |
| Entry barriers for participation in electricity | *In balancing markets you need the aggregator, restricitons on capacity barriers, provide 1MW. Restrictions on aggregation minium levels to reach, so medium barriers. Some service providers who are provding these contracts, number of actors are limited.* |
| Dependency on other actors | *"you are defintily dependent on other actors", especially for V2G (service provider, setup communication technology) significant barrier.* |
| Lack of knowledge | *Stationary batteries medium barrier (a lot of market stories, buying systems for the false reasons). V2G significant barrier since its a new technology.* |
| Change in behavior | *Change in behavior is not required for stationary battery systems. Important to note differences in perceived barriers and real barriers regarding adoptation of behavior. V2G small barrier exist due to not using the car when needed.* |

## Participant 10 interview study – DE

Output:

| Scoring barriers for behind-the-meter storage technologies | | | Definitions barriers: | Residential - Stationary battery system - DE | C&I - stationary battery system - DE | Residential - V2G - DE | C&I - V2G - DE |
|---|---|---|---|---|---|---|---|
| | | | | 0 = no barrier 1 = medium barrier 2 = | | | |
| Costs and financing | 1 | Investment cost required | *The degree to which the investment costs are significant in size for the investor* | 1 | 2 | 0 | 1 |
| | 2 | Expected pay-back time | *The degree to which the expected pay-back time is significant* | 1 | 2 | 0 | 1 |
| | 3 | Difficulty in financing investment | *The degree to which attracting appropriate financial means is difficult* | 0 | 2 | 0 | 1 |
| Technological barriers | 4 | Resource constraints | *The degree to which the resources and/or the technology is constraint* | 2 | 2 | 0 | 1 |
| | 5 | Change in physicial connected systems | *The degree to which physical change is required in connected or related technical systems or physi* | 0 | 0 | 1 | 2 |
| | 6 | Lack of communication protocols | *The degree to which the access to, or management of real-time data between storage unit and sm* | 2 | 2 | 2 | 2 |
| | 7 | Technology uncertainty | *The degree to which technological reliability, safety, privacy and performance are uncertain* | 1 | 0 | 2 | 2 |
| Market & regulatory barrier | 8 | Lack of signals for self-consumption | *The degree to which existent incentives for injecting electricity into the grid instead of storing self-* | 0 | 0 | 0 | 0 |
| | 9 | Lack of clear regulatory framework | *The degree to which the regulatory framework is unclear* | 2 | 2 | 2 | 2 |
| | 10 | Entry barriers for participation in electri | *The degree to which the lack of incentives to participate in electricity markets (i.e. DA, ID, balancin* | 2 | 2 | 2 | 2 |
| Multi-stakeholder complexity | 11 | Dependency on other actors | *The degree of dependency on other actors to successfully implement the technology* | 0 | 0 | 1 | 2 |
| Behavior | 12 | Lack of knowledge | *The degree to which the investor does not know about possible opportunities to install technology* | 1 | 0 | 1 | 1 |
| | 13 | Change in behavior | *The degree to which the investor need to change their behavioral patterns* | 0 | 0 | 0 | 0 |

## Interview questions:

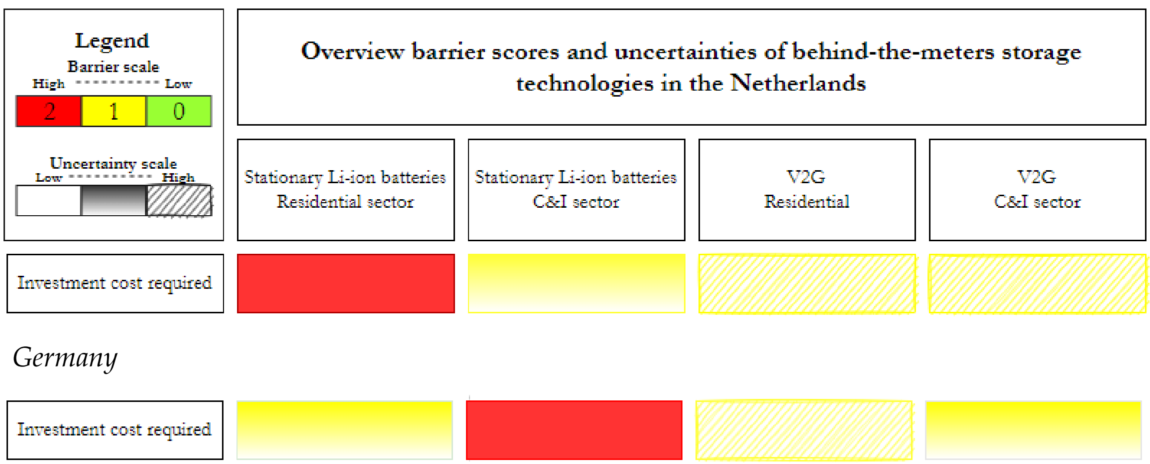
1. What is your position/experience towards behind-the-meter storage systems?
    - Battery manufacturer
2. Could you explain for each factor the rationale behind your choice for the barrier score?

| Barriers | Rationale |
|---|---|
| Investment cost required | *The average household will have problems investing in technology, however all storage systems sold out until next year. But looking at an average household and a battery system that cost approximately 7000 euro's, there is a medium barrier for the residential sector to invest in technology. For C&I sector high barrer, needs supporting financial model, therefore still expensive. V2G no barrier Wallbox able to charge bi-directional after software update therefore no barrier. V2G C&I complexity of integrating high loads into your system, increases the investment costs* |
| Expected pay-back time | *For the residential sector medium barrier (7/8 years). C&I battery systems price is higher and financial benefit limited, therefore higher barrier compared to the residential sector. V2G no investment, so no pay-back time. V2G same argument as above (higher complexity)* |
| Difficulty in financing investment | *People able to invest in the technology will not need financial supports therefore no barrier for the residential sector. C&I sector liquidity always an issue, difficult to acquire loans. V2G residential, no investment, C&I medium barrier due to complexity* |
| Resource constraints | *High barrier for batteries, batteries already sold out affecting availability of the technology. For enabling EV to V2G services, battery is already there, so no shortage regarding the battery installment, however for the C&I sector important to manage higher loads and lack of technicans can be seen as a barrier in this sector* |
| Change in physicial connected systems | *When talking only about storing energy, easy to install battery, no change in physcial connected systems; VPP still in childhood phase (dynamic pricing needed then). V2G C&I higher loads complicated to integrate.* |
| Lack of communication protocols | *Fragmented market, lack of integrated system. Problem is at the application layer, lack of standardization across the whole market.* |
| Technology uncertainty | *Residential consumers concerned about privacy and safety for batteries, C&I not an issue; V2G its not there so high barrier.* |
| Lack of signals for self-consumption | *residential, storage is used to optimize your self-consumption so no barrier overthere. C&I same arguments or used for peak shaving.* |
| Lack of clear regulatory framework | *Major barrier; among which problems with double taxation* |
| Entry barriers for participation in electri | *High barrier since its not possible* |
| Dependency on other actors | *No dependency if you buy it yourself, you could use the battery by yourself, however if you rent the appartment you are completely dependent on the landlord, not only storage system also regarding a PV system. Significant barrier when VVP is considered.* |
| Lack of knowledge | *Difficult to understand the system for residential sector, C&I sector used to work with complex systems (liquidity, pay-back etc).* |
| Change in behavior | *Battery helps maintain old behavior so no barrier. V2G used for storage then no change in behavior, change in behavior delivering grid services then you should.* |

## Appendix C: Analysis per significant barrier

In appendix C the analysis per significant barrier hence the analysis of the different expert interviews can be found. Additionally, existing and expected changes in policy and regulatory frameworks at the EU and or national level is included. The EU Electricity Regulation and Directive (EU) 2019/944 provides the basis for achieving the goals set in the European Green Deal and Green Recovery. Therefore, barrier related information on the Electricity Directive and Regulation is included since MSs are required to adjust the national regulatory framework towards the set ambitions and changes in the national framework can be expected.

### 6.5.1 *Investment cost required*




**Stationary batteries**

*The Netherlands*

In the Netherlands, with regard to stationary batteries systems in the residential sector, high investment costs are required. This score is given with low uncertainty since all participants agreed upon the final score of this barrier. All most all participants highlighted the high upfront investment stationary battery systems bring and emphases the importance of this barrier. Five out of the seven participants agreed on the medium barrier for the C&I sector since in general a smaller size of their revenue is dedicated to installing a stationary battery system compared to the residential sector. Yet, *participant 4* stated that investment costs are not that important for the C&I sector since a large share of this sector has to deal with problems of acquiring larger grid connections and therefore the installation of a battery system (and thus proceeding with their business) is considered more important then the required investment costs. Since two experts deviated from the average score a medium uncertainty is given to the score.

*Germany*

In Germany, *participant 8* states that in general, for an average household, it is still expensive to invest in the technology. However, according to *participant 10* all storage systems are currently sold out in Germany, so this could indicate the barrier 'required investment costs' is not so significant in the residential sector and therefore a medium barrier is given. All German experts agreed on the score for the C&I sector, for which the barrier is expected to be higher compared to the residential sector.

**Vehicle-to-grid**

*Netherlands*

The required investment costs for V2G enabled EVs in both sectors are medium in size, however high uncertainty exist in both scores. The required investment costs for enabling V2G capabilities in current EVs are adjusting or installing mono-directional charging points to bi-directional charging points and the installation of corresponding software. Possible extra investments are required for enabling EVs to bi-directional charging, depending on the choice for AC/DC charging. Some participants state that the extra investment costs are negligible compared to mono-directional charging, whereas *participant 2* states that bi-directional charging points are still very expensive and cars should be adjusted, therefore, forming a high barrier. Since there are some variances in the scores, high uncertainty is given.

*Germany*

In Germany, according to *participant 8*, bi-directional charging points are around 5000 euros compared to 500 euros for mono-directional charging points therefore the required investment costs being a significant barrier. However, according to *participant 10*, Wallbox, an EV charger, is already capable of bi-directional charging after a software update and therefore the expert indicates that no barrier exist. Due to the variances in scores, high uncertainty is given to the V2G technology in the residential sector. With regard to commercial and industrial consumers, high complexity exist for integrating V2G technology into the current system, due to high, new, loads into your system and therefore high investment costs are required according to *participant 10*. The other participants indicated a medium barrier.

**Overall comparison Netherlands and Germany**

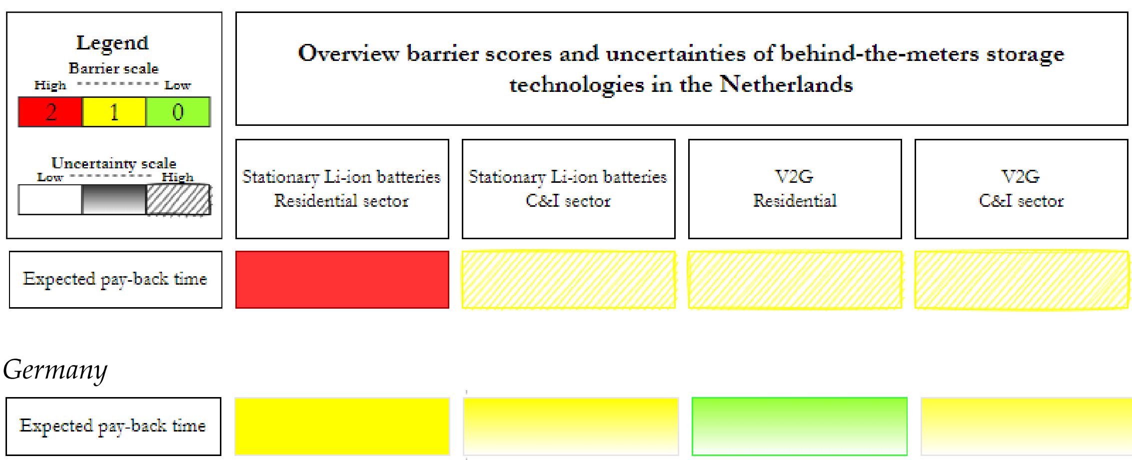
The differences in scores between the Netherlands and Germany for stationary battery systems is remarkable. Nonetheless, the difference can be explained due to a higher deployment of stationary battery systems in the residential sector in Germany, therefore, the investment costs are seen as less of a barrier. In the Netherlands, stationary battery systems are more beneficial for large-scale consumers compared to the residential sector whereas in Germany it is the other way around. A possible reason is that commercial and industrial consumers in the Netherlands are less exposed to net-metering schemes and therefore investments in storage technologies become more attractive whereas in Germany commercial and industrial consumers are less familiar with storage technologies compared to the residential sector.

To conclude, all experts of both countries indicated the high upfront investment costs and in order to increase the deployment of stationary battery systems, costs should decline. With regard to V2G technology, a lot of uncertainty exist in the scores in both countries. The variances in scores can be explained due to the V2G technology currently not being deployed in the Netherlands and Germany, besides pilot studies, and therefore the 'real' required investment costs are still uncertain.

**Existing and expected changes in the policy and regulatory framework at the EU and/or national level**

Neither the Electricity Directive nor Regulation include direct signals relating to investment costs for storage systems. As behind-the-meter storage technologies is more related to innovation policy and subsidies, other EU legislation could be relevant, for example, the European Battery Alliance which aims to develop innovative, competitive and sustainable battery value chain in Europe (EBA, n.d.) and could reduce, eventually, the required investment costs for battery systems.

### 6.5.2 *Expected pay-back time*




**Stationary batteries**

*Netherlands*

The expected pay-back time for installing a stationary battery in the residential sector is > 12 years and comprises low uncertainty. The pay-back time is according to *participant 3* an important indicator whether to invest in the technology and therefore high pay-back times lead to less investments in stationary battery systems. The expected pay-back time is considered to be a medium barrier for commercial and industrial consumers, however with high uncertainty. *Participant 2* states that the commercial and industrial consumers are more exposed to different revenue streams and expects therefore lower pay-back times whereas *participant 1* states that pay-back time is the most important indicator for the C&I sector and since the pay-back time is still quite long, rates it as a high barrier.

*Germany*

According to *participant 8* for every technology the pay-back time is between the 5-12 years, so a medium barrier exist for stationary battery systems in both sectors. *Participant 9 and 10* indicated a medium barrier as well, mentioning a pay-back time of around 7-8 years. Only *Participant 10* differed in opinion with regard to commercial and industrial consumers, indicating that battery systems are more expensive and therefore increases the pay-back time for this sector whilst the financial benefit is limited.

**Vehicle-to-grid**

*Netherlands*

Regarding V2G technology, for both the residential as the C&I sector the expected pay-back time is 5 – 12 years, however, high uncertainty exists for both scores. *Participant 2* states that V2G technology is still in development and therefore finds it difficult to estimate pay-back times due to increasing uncertainty in possible revenue streams. *Participant 6* states that pay-back time is less important for investors willing to invest in V2G technology since the focus lies more on the opportunities the technology brings. Since there is no overall consensus in the scores, high uncertainty exists.

*Germany*

*Participant 10* indicated, overlapping with his argument for investment costs, that since there are no investment cost, pay-back time is not a barrier to invest in V2G technology. Additionally, *participant 9* states that pay-back time is less of a barrier compared to the residential sector whereas *participant 8* indicates that the expected pay-back time of enabling EVs to V2G technology lies between the 5-12 years.

**Overall comparison Netherlands and Germany**

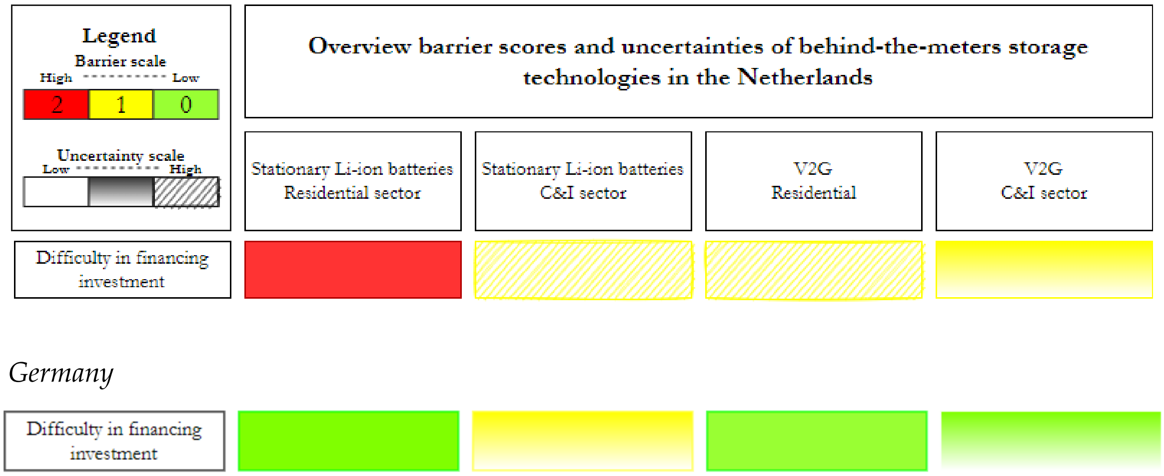
The highest variance in scores of the Netherlands and Germany is noticed for residential battery storage. More specifically, the pay-back time in the Netherlands is significantly higher compared to Germany and therefore being a larger barrier to invest in stationary battery systems. Possible reasons for the differences in pay-back time within the countries is the differences in acquiring financial loans or subsidies and there are more incentives for self-consumption in Germany, both decreasing the overall pay-back time.

There can be concluded that the barrier pay-back time in the Netherlands and Germany is existent for V2G technology, however still uncertain due to a new technology not yet being deployed and exact revenue streams are still quite unknown.

**Existing and expected changes in the policy and regulatory framework at the EU and/or national level**

Neither the Electricity Directive nor Regulation include direct signals relating to expected pay-back time for storage systems. Rules indicated on implicit demand-side flexibility are treated in the factor analysis "lack of signals for self-consumption".

### 6.5.3 *Difficulty in financing investment*




**Stationary batteries**

*Netherlands*

There is a high difficulty in financing investment for residential stationary battery systems. Almost all participants agreed on the high difficulty in attracting financing means due to the fact that subsidies are currently not available in the Netherlands. Only *participant 7* indicated that the residential sector does not need loans or subsidies to invest in the technology whereas for example *participant 6* indicated that households will not invest in the technology if there are no subsidies. Commercial and industrial consumers, however, have a medium difficulty in attracting financial means. There are more possibilities for the C&I sector to apply for funds when storage systems are combined with solar PV plants according to *participant 2 and 4.* However, according to *participant 3, 5 and 7* there is a high difficulty in acquiring loans due to invalid business cases and thus high uncertainty exist for the given score.

*Germany*

P*articipants 8, 9 and 10* indicated that there is no difficulty in acquiring loans or subsidies for the residential sector due to government support programs. Additionally, *participant 9* states that "barriers regarding behind-the-meter systems is not a financing issue". With regard to industrial and commercial consumers, p*articipant 10* differed in opinion for which liquidity is always an issue and indicates that it is more difficult to acquire loans.

**Vehicle-to-grid**

*Netherlands*

In the residential sector with regard to enabling EVs to V2G technology medium difficulty in acquiring loans and subsidies exist. According to *participant 7*, the required investment costs are lower for V2G compared to stationary battery systems and therefore the necessity of obtaining loans of subsidies is lower. Nonetheless, no subsidies are available for integrating bi-directional charging points in current infrastructure in the residential sector and therefore no opportunities exist for financing the investment. Although investment costs are lower, the difficulty of financing the investment still exist and therefore a medium score with high uncertainty is given. There is a medium difficulty of financing the investment for the C&I sector since there are opportunities to apply for (innovation) funds according to *participant 2*. Medium uncertainty exist for this score.

*Germany*

In Germany there is no difficulty in acquiring loans or subsidies regarding V2G according to the average score. *Participant 8* mentioned subsidies for charging points up to 9000 euro's, however not available anymore whereas *participant 10* indicated, again, that acquiring financial means is not an issue due to the lack of required investment costs.

**Overall comparison Netherlands and Germany**

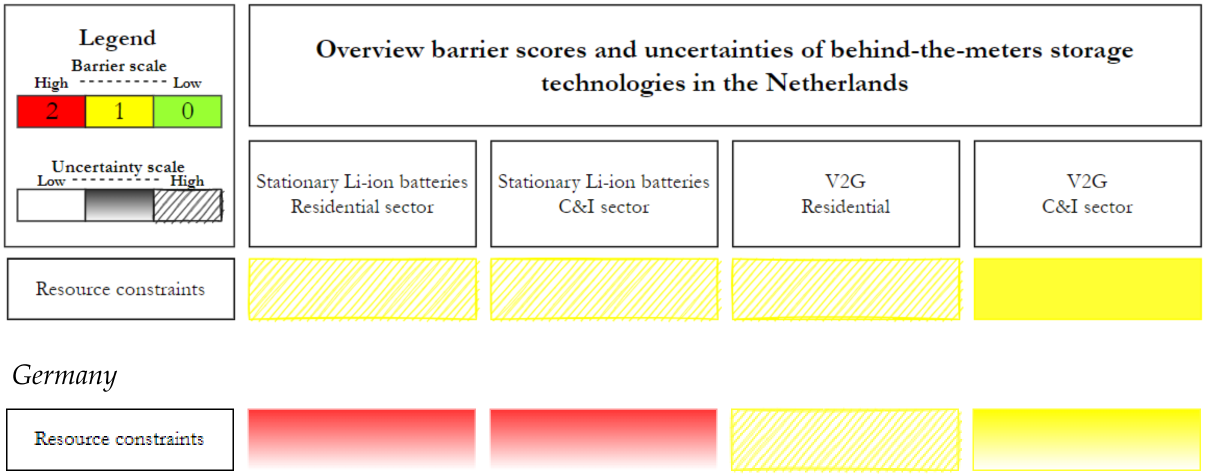
There can be concluded that regarding the difficulty of financing the investment in residential battery systems the results of the Netherlands are contrary to the results of Germany thereby confirming the literature on this factor. In Germany multiple government support programs exist, which makes it easier to invest in stationary batteries for the residential sector. In Germany the barrier becomes a bit larger for commercial and industrial consumers since it can be more difficult to acquire loans. In the Netherlands this applies as well, however more opportunities exist for the application of funds.

When comparing the Netherlands and Germany regarding V2G technology, a medium barrier exist for the Netherlands and no barrier exist for Germany. Both countries indicated the less required investment costs for enabling EVs to V2G technology and therefore the need for acquiring financial investment is less present. However, the Dutch participants indicated the lack of available subsidies for bi-directional charging and therefore the barrier may be a bit higher compared to Germany.

**Existing and expected changes in the policy and regulatory framework at the EU and/or national level**

Neither the Electricity Directive nor Regulation include direct signals relating to addressing the difficulty of financing investment. However, the Guideline on state Aid for Climate, Environmental protection and Energy (CEEAG), broadens the categories to invest in technologies that MSs can support and therefore allows MSs to provide subsidies to behind-the-meter storage technologies (European Commission, 2022). In the Netherlands, there is no indication that direct subsidies will be implemented in the near future.

### 6.5.4 *Resource constraints*




**Stationary batteries**

*The Netherlands*

The results differed across the resource constraints barrier, thereby increasing the uncertainty of the score. Regarding stationary battery systems *participants 3* & *6* indicate long lead-times and shortages in resources thereby impacting the overall availability for the two technologies in the residential and C&I sector. However, *participant 7* indicates that currently battery systems are still available and possible to buy so therefore no barrier exist. Almost all participants mentioned the lack of technicians to install the technology. Moreover, *participant 1 & 2* state that currently no problems are experienced with shortage of critical minerals. High variances exit in the scores possibly due to the different perspectives, on-site knowledge of installing storage technologies and experiencing long lead times versus research institutions who base themselves more on studies and projections.

*Germany*

In Germany, resource constraints is a significant barrier according to *participant 9 & 10* since the technology is currently sold out and therefore not available. Moreover, an overheated market regarding stationary battery systems is in place which results in a major lack of technicians according to *participant 9. Participant 8* agrees on the lack of technicians and sees is as the bottleneck of the whole energy transition, however scored the barrier as less significant compared to the other two participants, and therefore medium uncertainty exist in the scores.

**Vehicle-to-grid**

*The Netherlands*

In the Netherlands, overlapping with the scores of stationary battery systems, the provision of V2G services comprises medium resource constraints due to the utilization of similar minerals for manufacturing the batteries of newly build EVs. Moreover, a lack of technicians and chips within the EV industry impacts the availability of EVs with V2G capabilities and therefore the resources are partially constraint according to *participants 4 & 7.*

*Germany*

According to *participant 8* bi-directional charging points are currently not available, thereby impacting the availability of the technology. *Participant 9* indicates that "Since V2G is quite a new technology, not all technicians are able to install the technology and therefore contributes to being a barrier". According to *participant 10* there is a difference between residential and commercial and industrial consumers since the C&I sector needs to manage higher loads that are injected back into the grid and therefore the lack of suitable technicians to install these complexities can be seen as a larger barrier compared to the residential sector.

**Overall comparison Netherlands and Germany**

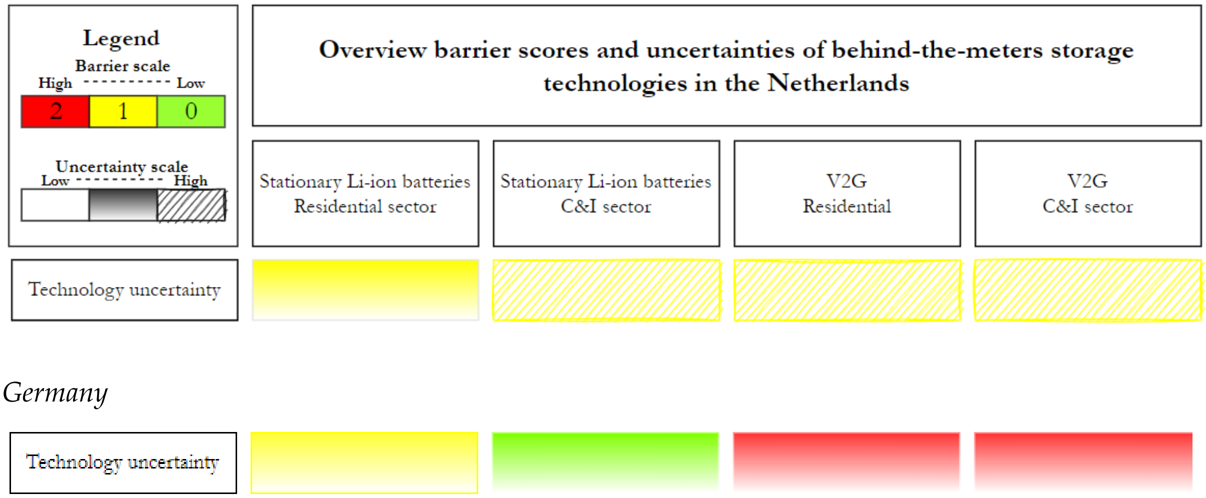
In the Netherlands, no significant resource constraints are seen for stationary battery systems whereas in Germany significant barriers are noticed. One of the reasons of the contrasting results is that in Germany storage systems are widely deployed and currently not available any more. In the Netherlands, however, due to stationary battery systems only been installed by a small market share, battery systems are currently still available and therefore not seen as significant barrier. Nonetheless, in both countries, the participants indicate the lack of technicians and the crucial role it plays for the deployment of behind-the-meter storage systems.

Extra note: the majority of experts agreed upon the fact that the factor *'resource constraints'* will become even more constraint in the coming 15 years due to lack of technicians and critical minerals used for building both technologies.

**Existing and expected changes in the policy and regulatory framework at the EU and/or national level**

Neither the Electricity Directive nor Regulation include direct signals relating to addressing the resource constraints. However, the European Battery Alliance who aims to develop an innovative, competitive and sustainable battery value chain in Europe helps securing access to raw materials for batteries and secures a highly skilled workforce along the whole value chain, meaning that the alliance helps creating an EU framework for re-up skilling European automotive workers. Both aspects should help partly address the barrier on European level and could impact the barrier on national levels as well.

## 6.5.5 *Technology uncertainty*




**Stationary batteries**

*The Netherlands*

Technological reliability, safety, privacy and performance is somewhat certain for stationary battery systems. The majority of the experts indicated that uncertainty regarding safety issues and acquiring warranties is most present when deciding to invest in stationary battery systems. However, participants do not agree on the significance of the barrier regarding commercial and industrial consumers. For example. *participant 3* indicates that stationary batteries are already commercialized and thus meet certain (market) standards, hence, decreases the uncertainty of the technology. P*articipant 6*, however, indicates that safety risks is an reason to not invest in stationary battery systems and therefore overall, high uncertainty exists in the scores for commercial and industrial consumers. Moreover, interesting is, that *participant 1* highlighted the differences between the perception of both sectors towards safety risks of batteries (e.g. created via negative news items) verses the real barrier impacting the investment choice.

*Germany*

The technological reliability, safety, privacy and performance is seen as somewhat certain for residential battery systems. According to *participant 10* residential consumers are concerned about privacy and safety when installing stationary battery systems, whereas for the commercial and industrial consumers this is seen as less of an issue and therefore no uncertainty exists. *Participant 9* adds "reliability could be an issue as well, next to privacy" for the residential consumers.

**Vehicle-to-grid**

*The Netherlands*

In the Netherlands, with regard to V2G technology, technological reliability, safety, privacy and performance is found to be somewhat certain. Increased uncertainty occurs for battery warranties due to unknown impact of providing grid services and adding charge/discharge cycles to the battery causing therefore the barrier for the investor. *Participant 2* indicates that the C&I sector is more privacy sensitive and creates a barrier for this sector to invest in certain new technologies. Next to safety and privacy, by delivering V2G services the EV might not always be available, hence, adds uncertainty to the reliability of the system. High uncertainty for both scores exist.

*Germany*

In Germany, technology uncertainty is seen as significant barrier for the deployment of V2G technology in both sectors. According to *participant 10*, since V2G technology is not yet deployed high uncertainty exists. Moreover, *participant 9* indicates similar barriers as stationary battery systems for V2G technology, namely: privacy issues as well as reliability issues. Additionally, *participant 8* mentions data privacy issues of V2G technology. Since two out of the three experts indicated a significant barrier, medium uncertainty is given to the score.

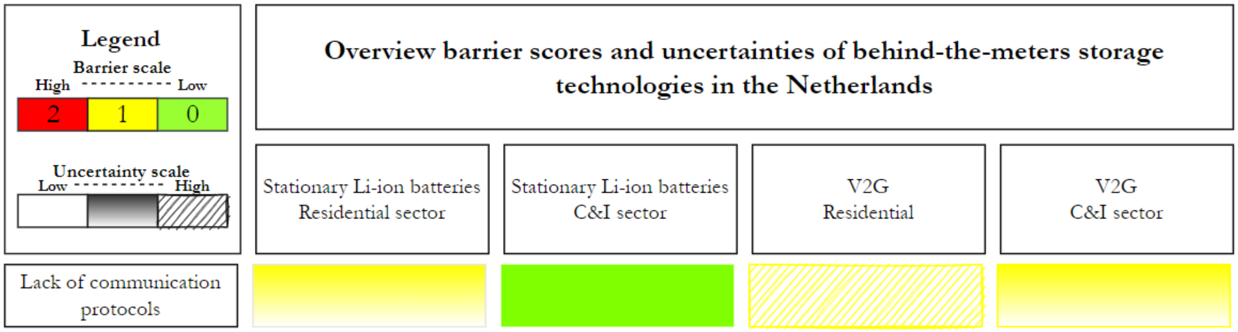
**Overall comparison Netherlands and Germany**

The major difference between the Netherlands and Germany is the differences in scores for V2G technology. Possible reasons are that German people are more aware on (data) privacy issues, and safety issues thereby influencing the choice to invest in V2G technology. Another reasons could be that V2G is a bit further deployed in the Netherlands, due to current pilots and therefore experts indicated less significant barriers compared to Germany.

**Existing and expected changes in the policy and regulatory framework at the EU and/or national level**

As mentioned in chapter 4, The European Union established the General Data Protection Regulation (GDPR), a number of rules to protect (automatic) processing of personal data (European Commission, 2016) which is currently implemented in the Netherlands and Germany. Next to the GDPR, there are no expected changes in the policy and regulatory framework at the EU and/or national levels regarding addressing technology uncertainty.

### 6.5.6 *Lack of communication protocols*




*Germany*


**Stationary batteries**

*The Netherlands*

In the residential sector there is medium access to or management of real time data between storage unit and energy management systems. According to *participant 3* there is a lot of development around battery energy storage, however currently well-functioning, whereas according to *participant 5* the problem is the lack of standardization of protocols meaning that there is too much choice for residential consumers thereby increasing compatibility challenges, also indicated by *participant 4.* Since 2 out of 7 participants differed in opinion, a medium uncertainty is given to the score. With regard to commercial and industrial consumers little problems are expected for accessing and managing real time data between storage unit and back-end systems. Possible reasons are that the C&I sector is bit further developed compared to the residential sector according to *participant 4* and plug and play is less expected according to *participant 7*.

*Germany*

In Germany, according to *participant 8* there is no lack of communication protocols since residential battery storage is widely deployed and "seems to work". However, *participant 9* indicated the uncertainty of accessing smart meter systems and the current difficulties of actively managing behind-the-meter storage systems and therefore scored the factor as significant barrier. Due to the variances in scores for stationary battery systems, high uncertainty exists.

**Vehicle-to-grid**

*The Netherlands*

Variances in scores are high for V2G technology in the residential sector. According to *participants 3 and 5* V2G is still in development and therefore the current systems need harmonization which is contrary to *participant 7*, who mentions that V2G protocols are not an issue since this is already standardized (OCPP/15118). With regard to the C&I sector, a medium lack of communication protocols is seen. Multiple smart systems could require multiple protocols and that could therefore be a barrier to implement the technology.

None of the participants mentions problems with energy management systems, smart meters, or access allowed by third parties. Moreover, the results of *participant 6* on the barrier lack of communication protocols are not used since the participant stated that he was not sure on his answers.

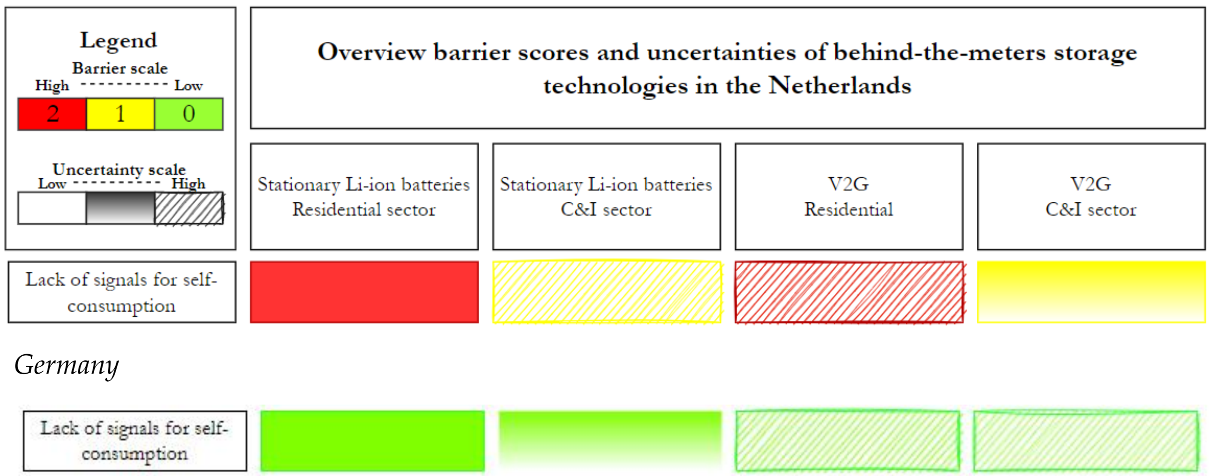
*Germany*

In Germany, the lack of communication protocols is seen as significant barrier for V2G technologies in both sectors. According to *participant 8* the V2G protocol is there, however, not yet implemented and therefore seen as barrier. Additionally, according to *participant 10* there is a lack of an integrated system and a major lack of standardization across the whole market which leads to problems for consumers willing to invest in the technology. The lack of communication protocols in combination with the protocols not being implemented leads to a significant barrier in both sectors.

**Existing and expected changes in the policy and regulatory framework at the EU and/or national level**

Neither the Electricity Directive nor Regulation include direct signals relating to addressing the resource constraints. However, it can be expected that the international standards of OCPP 2.0 and 15118 will be implemented and may contribute to deploying vehicle-to-grid technologies.

#### 6.5.7 *Lack of signals for self-consumption*




**Stationary batteries**

*The Netherlands*

There is a major lack of signals for self-consumption for the residential sector regarding stationary battery systems agreed upon all participants. Net-metering is by all participants mentioned and considered as one of the main barriers for the deployment of stationary battery systems. Double taxation becomes a problem for the residential sector when the net-metering rule will be slowly phased out from 2025 for the residential sector according to *participant 7.* With regard to the C&I sector there is medium lack of signals for self-consumption, however high uncertainty exist in this score. Net-metering is considered as a smaller barrier due to net-metering only being applicable to small-scale consumers according to *participants 1 & 5*. Nonetheless, *participant 7* highlighted a new hurdle for self-consumption regarding commercial and industrial consumers, namely: lower SDE subsidies for self-consumption. Enterprises who inject electricity back in the grid receive higher SDE subsidies which results to disincentivizing self-consumption. Overall, variances in the opinions results in high uncertainty.

*Germany*

There is no lack of signals for self-consumption in Germany regarding stationary batteries. *Participant 8* even mentioned that there are strong incentives for self-consumption in Germany for both the residential as the C&I sector. Moreover, *participant 9* indicates a "self-consumption privilege", meaning that there is reduction of levies and taxies for self-produced electricity.

**Vehicle-to-grid**

*Netherlands*

Regarding the residential sector, misunderstandings occurred with the interpretation of the barrier. The differences in use-cases became a problem in this factor, namely providing grid services is something different then using the EV for self-consumption. Therefore, high uncertainty is given to the scores. *Participant 3* mentions that there are currently "no incentives at all for self-consumption". Net-metering would be an incentive to feed your electricity back into the grid in stead of using it for self-consumption. *Participant 4* mentioned that it could be stimulating to drive on self-generated electricity, however not mentioning possible signals to increase self-consumption.

Only *participant 7* mentioned the lack of dynamic pricing within the Netherlands and its corresponding affect on self-consumption. In none of the interviews the influence of network tariffs, supply tariffs, or the height of electricity retail prices was mentioned.

*Germany*

With regard to enabling EVs to bi-directional charge, no barriers exist regarding self-consumption. However, *participants 8* indicates uncertainty in his scores due to the differences of self-consumption versus grid delivering services. *Participant 9* indicates that "there is no signal to feed electricity back into the grid, so that is an incentive to self-consume".

**Overall comparison Netherlands and Germany**

The results of the Netherlands regarding stationary battery systems are contrary to Germany. There is a major lack of signals for self-consumption in the Netherlands according to experts whereas in Germany only incentives exist for self-consumption. The differences in signals could be one of the reasons why the deployment of stationary battery systems differs widely between the two countries.

There can be concluded that there is some misunderstanding in the definition of the factor regarding V2G technology. V2G indicates that an EV is only used for grid delivering services, however, for the residential sector as well as for the C&I sector energy can be used to not only provide grid services, but could provide self-consumption as well. The factor lack of self-consumption indicates only implicit demand-side flexibility and therefore the overall scores for V2G technology in both countries are changed to uncertain.

**Existing and expected changes in the policy and regulatory framework at the EU and/or national level**

In the Recast Directive 2019/944 (10) is stated that "*However, the lack of real-time or near real-time information provided to consumers about their energy consumption has prevented them from being active participants in the energy market and the energy transition. By empowering consumers and providing them with the tools to participate more in the energy market, including participating in new ways, it is intended that citizens in the Union benefit from the internal market for electricity and that the Union's renewable energy targets are attained.*" There can be expected that the Netherland and Germany will empower consumers with tools to participate more in energy markets by implementing the following categories:

*Net-metering*

No information identified in the Electricity Directive or Regulation on the removal of net-metering.

*Lack of dynamic pricing/ Smart metering*

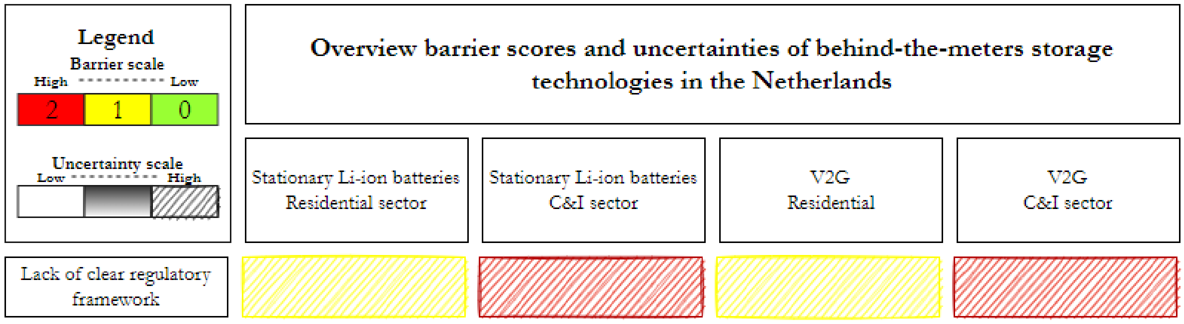
According to the Electricity Directive, article 19 *"Member States shall ensure the deployment in their territories of smart metering systems that assist the active participation of customers in the electricity market. Such deployment may be subject to a cost-benefit assessment which shall be undertaken in accordance with the principles laid down in Annex II."* Moreover, according to the recast of the Directive: *"Consumers should have the possibility of participating in all forms of demand response. They should therefore have the possibility of benefiting from the full deployment of smart metering systems and, where such deployment has been negatively assessed, of choosing to have a smart metering system and a dynamic electricity price contract. This should allow them to adjust their consumption according to real-time price signals that reflect the value and cost of electricity or transportation in different time periods, while Member States should ensure the reasonable exposure of consumers to wholesale price risk. Consumers should be informed about benefits and potential price risks of dynamic electricity price contracts ".* And: *"In order to maximize the benefits and effectiveness of dynamic electricity pricing, Member States should assess the potential for making more dynamic or reducing the share of fixed components in electricity bills, and where such potential exists, should take appropriate action" (38)*

Since as identified in the chapter 4, Germany is lacking in the roll-out of smart metering systems and this delay leads to a lack of available dynamic price contracts are hence hampers the deployment of explicit demand-side flexibility. Change in the availability of dynamic price contracts in Germany is expected when adjusting and/or implementing smart meter requirements.

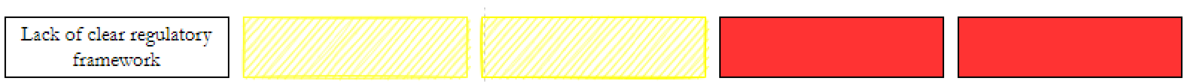
*Double taxation/double grid tariffs*

In article 5(b) of the Electricity Directive states that 'Member States shall ensure that "*active customers that own an energy storage facility are not subject to any double charges, including network charges, for stored electricity remaining within their premises or when providing flexibility services to system operators".* Currently, Germany exempts active consumers for double grid charges, whereas the Netherlands do not. Yet, the Netherlands did implement and anticipated by removing double taxation for large-scale consumers. In Germany, change regarding double taxation issues is expected as well.

### 6.5.8 *Lack of clear regulatory framework*




*Germany*




**Stationary batteries & Vehicle-to-grid**

*Netherlands*

The regulatory framework is found somewhat clear for the residential sector and unclear for the C&I sector, however the scores are both with high uncertainty due to variances in the scores. The plausible reason of the variances in scores is the direct correlation of this factor with other defined factors and the differences in interpretation of this factor. Since the 'regulatory framework' is a broad concept, participants interpreted the regulatory framework differently. For example, *participant 5* indicates the difficulty of acquiring insurance when investing in storage technologies within the C&I sector whereas *participant 3* referred to the development of PGS 37, a safety norm for Li-ion batteries. Additionally, *participant 6* mentioned the problem of double grid tariffs (part of the factor *lack of signals for self-consumption*) for large-scale consumers during the interview. Double grid tariffs are a result of the lack of definition of storage within the regulatory framework. *Participant 1* indicates the problem of uncertainty on future grid tariffs setting and congestion management. According to her the (to be determined) Energy Law will give more certainty to stakeholders, however since this is not yet implemented, she rated this factor as significant barrier.

There can be concluded that variances exist in the interpretation of the factor '*the lack of a clear regulatory framework.'* However, none of the participants indicate that there is no lack of a clear regulatory framework. Thus, uncertainty exist in the scoring, nonetheless there can be concluded that a lack of a clear regulatory framework gives uncertainty to investors in behind-the-meter storage technologies in both sectors.

*Germany*

According to *participant 8 and 9* the regulatory framework for stationary batteries used for self-consumption is clear. Only *participant 10* indicates the lack of a clear regulatory framework as a "major barrier", indicating the problem of double charges for provision of grid services for both technologies. Therefore, the regulatory framework is found somewhat clear for stationary batteries with high uncertainty.

According to *participant 8*, enabling EVs to provide grid services is a large barrier, since there are multiple problems, such as double grid charges, double taxation and flexible players who are not yet defined in the regulatory framework. Thus, in Germany, the regulatory framework is quite clear when utilizing stationary batteries for self-consumption, however, all Germany participants agreed on the unclarity of the regulatory framework regarding V2G technology, so therefore there is low uncertainty regarding that score.

**Overall comparison Netherlands and Germany**

There can be concluded that in the Netherlands more uncertainty in the regulatory framework exists compared to Germany. Overall, there can be noted that in Germany there are less variances in scores, possibly due to the widely adaptation of stationary batteries for self-consumption. However, uncertainty still exist in the score due to utilizing the technology not for grid services. Moreover, in both countries, but especially in Germany, there can be concluded that the regulatory framework for enabling EVs to provide grid services is unclear and still a lot have to be defined.

**Existing and expected changes in the policy and regulatory framework at the EU and/or national level**

An appropriate EU definition of energy storage is provided in the Directive on the internal market for electricity (Article 2, paragraph 59): *"'energy storage' means, in the electricity system, deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy or use as another energy carrier".* However, currently, Germany and the Netherlands do not have yet a coherent definition of storage nor have transposed the Directive so changes in the policy and regulatory framework is expected.

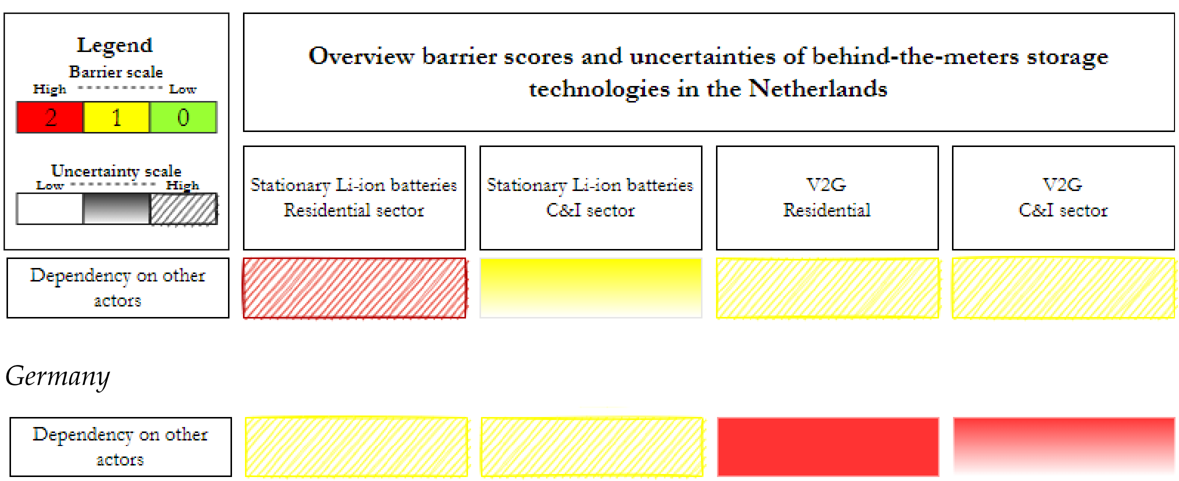
Additionally, the importance of independent aggregators has been acknowledged in the EU Clean Energy Package. The definition of the independent aggregator is defined in Directive (EU) 2019/944 as follows: *"a market participant engaged in aggregation who is not affiliated to the customer's supplier".* As mentioned in chapter 4, both independent aggregators as suppliers can take on the role as aggregator, however it can be expected, as the the role of the independent aggregator is defined in the Directive, independent aggregators will be able to participate in the market and may take up the role for providing explicit demand-side flexibility.

Additionally, the European Commission aims to address "various obstacles in the aggregation and mobility service provision market which hinder competition" in a new EC proposal in 2021 for a directive (EU, 2021). The aim is to amend the Renewable Energy Directive II, which applies to behind-the-meter storage systems, is as follows:

- "Option 3.1 (ensuring that the treatment of electricity storage systems or devices by network and market operators is not discriminatory or disproportionate irrespective of their size (small-scale vs large-scale) or whether they are stationary or mobile, so that they are able to competitively offer flexibility and balancing services) is a no-regrets option.
- Option 3.2 (independent) aggregators and mobility service providers to have access to basic battery information, such as state-of-health and state-of-charge is necessary in setting a level playing field and its early implementation would bring positive long-term effects in the availability, quality and cost of services provided to domestic battery owners and electric vehicle (EV) users.

To conclude, the abovementioned changes within the EU policy and regulatory framework regarding behind-the-meter storage systems are expected and will finally result in changes in the national regulatory frameworks of the Netherlands and Germany as well. However, when these changes will be implemented is unknown.

### 6.5.9 *Dependency on other actors*




**Stationary batteries**

*The Netherlands*

The scores of dependencies on other actors differ widely across the expert interviews in the Netherlands. Dependency on other actors is for both technologies and for both sectors present, however the interpretation of how high the impact of dependency is on the investment choice differ. A plausible reason for the variance in scores is that, again, dependency differs per use-case. Different segments within the residential sector (i.e., rental and private property) are present, impacting this factor differently. More specifically, almost all participants indicate a high dependency between tenant and homeowner in the rental segment influencing the choice on investing in stationary battery systems enormously. *Participants 2 and 6* indicate the tenant-home owner dependency, yet, scored it as a medium barrier due to the dependency not existing in the private sector. Regarding the C&I sector a medium dependency, with medium uncertainty, on other actors to successfully implement the technology is given. The dependencies for the C&I sector are mostly focused on the installation of the technology by technicians. Moreover, according to *participant 6*, commercial and industrial consumers are more familiar with energy management systems, so less dependent on other actors compared to the residential sector. *Participant 2* mentions the DSO – enterprise dependency for constructing grid connections. Overall, dependency on other actors is a barrier to invest in the technology, but there should be emphasized that differences exist within the residential segments.

*Germany*

Tenant-home owner dependency major problem for the residential sector who are willing to invest in stationary battery systems but are dependent on their landlord according to *participant 8*. However, as he indicates, this is only a problem for the rental segment, whereas as private residential sector, you can buy stationary battery systems without a lot of problems which is also a problem regarding the installment of solar PV systems according to *participant 10*, therefore a medium barrier is given as end-score.

**Vehicle-to-grid**

*The Netherlands*

Medium dependencies on other actors are existent to successfully implement V2G technology, however given with high uncertainty. An example of contrasting opinions is for example that *Participant* 7 indicates the dependency on other actors regarding the installment of bi-directional charging points and data management whereas *participant 1* agrees upon existing dependencies between actors, however, she thinks that both sectors do not want to act on electricity markets themselves, and therefore does not see it as a barrier.

*Germany*

High dependencies are seen regarding enabling EVs to bi-directional charge. *Participant 9* indicates that especially regarding V2G you are dependent on other actors, because you are dependent on the service provider, installment of charging point and set up communication technology. *Participant 10* highlighted the differences in use case, when utilizing the electric vehicle or stationary batteries as virtual power plant high dependencies exist, when it is only utilized for self-consumption less dependencies are seen, yet still existent. Overall, high dependencies exist for the deployment of V2G in Germany.

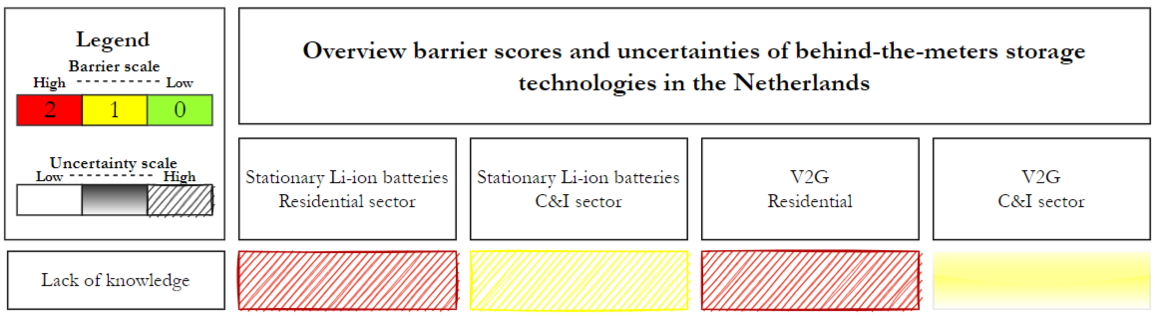
**Overall comparison Netherlands and Germany**

For both countries, the tenant-home owner discussion is mentioned multiple times and forms the barrier regarding stationary battery systems. High uncertainty in the scores exist due to the variances in scores caused by the division in the rental segment. Moreover, the difference in dependencies is also highlighted with regard to offering grid services or utilizing the EV for self-consumption. In Germany higher dependencies are seen compared to the Netherlands regarding V2G technology, however, the reason for the difference is difficult to pinpoint.

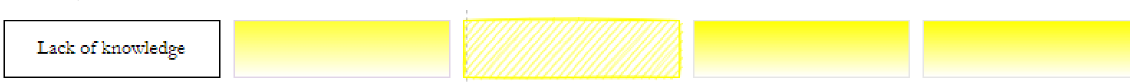
**Existing and expected changes in the policy and regulatory framework at the EU and/or national level**

Neither the Electricity Directive nor Regulation include direct signals relating to reducing the dependency on other actors.

### 6.5.10 *Lack of knowledge*




*Germany*




**Stationary batteries**

*The Netherlands*

Consumers in the residential sector are little aware of possible opportunities and benefits of installing behind-the-meter storage systems, however given with high uncertainty. According to *participant 5*, the lack of knowledge is enormous for all sectors and all technologies whereas *participant 1* sees it as a small barrier "there are still specific people who know about the technologies, however the situation is improving". According to *participant 4* commercial and industrial consumers are more aware of the opportunities the technologies can bring and to make more use of self-consumption. *Participant 7* indicates, nonetheless, the problem of "energy not being the core business of the commercial or industrial consumers and therefore due to low interest a lack of knowledge exists".

*Germany*

According to *participant 8*, there is no lack of knowledge in the residential sector, meaning that people are aware of investing in stationary battery systems. However, *participants 9 and 10* do indicate a medium lack of knowledge to invest in stationary battery systems. More specifically, p*articipant 9* indicates that residential consumer could invest in stationary battery systems "for the false reasons", due to market stories whereas *participant 10* indicates the complexity of understanding the system. With regard to the C&I sector *participants 8 and 9* indicate both a higher lack of knowledge for the C&I sector whereas *participant 10* indicates less complexity for the C&I sector, since they are used to work with complex systems. Due to the variances in scores, high uncertainty exists.

**Vehicle-to-grid**

*Netherlands*

There is a high lack of knowledge offering V2G services in the residential sector, as a result of V2G being a relatively new technology and therefore currently being "too complex to understand" according to *participant 3*. The C&I sector, nevertheless, is more aware of possible opportunities for integrating multiple EVs with V2G capabilities due to increased interest in optimizing self-consumption and ongoing pilots according to *participant 4.* Additionally, according to *participant 6* there is more knowledge and research done for C&I V2G and therefore the lack of knowledge is less compared to the residential sector.

*Germany*

*Participant 8* mentioned that the residential sector is aware of V2G technology which is contrary to the opinion of *participant 9* who indicates that enabling EVs to provide V2G services is still an innovative technology and therefore a high lack of knowledge exists. In the interviews there is no differences indicated between the residential and the C&I sector, thus, for both sectors medium lack of knowledge exists with medium uncertainty in the scores.

**Overall comparison Netherlands and Germany**

Overall, no major differences exist in scores for the Netherlands and Germany. There can be concluded that in the Netherlands a higher lack of knowledge exists for the residential sector regarding both stationary batteries as enabling EVs to providing grid services compared to Germany.

**Existing and expected changes in the policy and regulatory framework at the EU and/or national level**

Neither the Electricity Directive nor Regulation include direct signals relating to improving the lack of knowledge at consumer levels.