The Final Hurdles to Technical Implementation of Vehicle-to-Grid

A Grounded Theory Study on Institutional Barriers and Socio-Technical Change

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by

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Executive Summary

The European Union (EU) aims to reduce greenhouse gas emissions significantly and achieve climate neutrality by 2050. However, the reliance on intermittent renewable energy sources poses challenges to grid stability, potentially leading to power outages. Smart charging, particularly bidirectional charging (V2G), emerges as an innovative solution, allowing electric vehicles (EVs) to discharge energy back to the power grid. V2G offers flexibility, supports load balancing, and helps prevent grid congestion.

The automotive industry is transitioning to EVs, creating a higher electricity demand. Concurrently, the utility sector is shifting to a renewable energy system. V2G technology allows EVs to both consume and deliver electricity to the grid, introducing a dynamic interaction. However, integrating EVs into the grid raises challenges related to grid safety, such as the risk of overloading. To address this, additional technical specifications are needed. The EV charging industry relies greatly on international standards. Therefore, market players seek clear guidelines for products enabling bidirectional power flows. However, technical requirements specific to V2G systems remain unspecified or divergent, creating obstacles for technology development and implementation by the industry. Harmonisation and standardisation of technical specifications are considered effective means for overcoming these challenges.

However, existing literature lacks insights into the necessity and realisation of harmonisation. This study fills this gap by exploring the extent, reasons, and coordination efforts required for harmonisation of technical requirements specific to V2G. Particularly, this study investigates barriers stemming from the technical implementation of V2G and their impact on the adoption by key stakeholders. The main research question guiding this study is as follows:

How do institutional barriers in the technical implementation of vehicle-to-grid technology influence its adoption?

Technical implementation entails the technical specifications and requirements essential to the integration of EVs into the electricity grid, enabling bidirectional power flows. For example, this includes product requirements related to bidirectional power delivery, safety features, or data exchange. Technical specifications and requirements for V2G are considered institutions, since these 'rules', either formal or informal, structure the interactions between actors and entities within the charging ecosystem. This study focuses on shortcomings within these rules (e.g., insufficient harmonisation) and how these affect stakeholders interactions and in turn the technical implementation of V2G.

An open-minded approach following the grounded theory principles identified primary obstacles in the technical implementation of V2G. The grounded theory approach included conducting semi-structured interviews with ten participants, which helped explore stakeholder perspectives and needs. This approach develops a hypothesis rather than testing it. The hypothesis provides insight into a specific phenomenon where little is known, such as V2G implementation, and arises from the empirical data. The research participants represented Charge Point Operators (CPOs), Distribution System Operators (DSOs), EV supply equipment (EVSE) manufacturers, EV manufacturers, and regulators. These were considered key stakeholder groups based on an initial stakeholder analysis.

The emerging theory grounded in the data is identified by utilising coding tools and methods. Empirical data collection and analysis were guided by the following sub-questions:

SQ1: *What are the main barriers in the technical implementation of vehicle-to-grid technology obstructing its adoption?*

SQ2: *What underlying factors contribute to the emergence of the barriers identified?*

SQ3: *How do the barriers identified affect the key stakeholders in the vehicle-to-grid ecosystem?*

A comprehensive framework is consulted to provide a theoretical lens assisting the interpretation and analysis of the empirical results. Integrating the widely adopted Institutional Analysis & Development (IAD) framework and Multi-Level Perspective (MLP) aided in identifying and understanding the interplay between institutional arrangements, such as technical requirements and standards, and technology adoption. This novel approach has proven to be valuable in analysing the relationships between micro-level interactions (IAD) and macro-level influences (MLP). This has offered insights into how institutional arrangements within the regime, i.e., the conventional, centralised power system, impact the V2G niche. This study has proven the value of this approach in

complex socio-technical contexts such as the EV charging system. Identifying system failures within the regime helps in understanding the dynamics between rules and actor interactions. Moreover, a focus on transformational system failures and their impact on multi-level dynamics complements the analysis of socio-technical transitions. While the landscape level puts pressure on the regime due to the need for renewable energy and flexibility services, regulatory frameworks are destabilised, in turn creating disruptions in other dimensions, such as prevailing technical standards and infrastructures.

This study has identified four main barriers obstructing stakeholders from implementing and experimenting with V2G technology. These are the following:

1. Charging Standard Ambiguity: lack of unified vision on charging standard resulting in uncertainties and financial risks to manufacturers and CPOs.
2. Network Codes: non-harmonised and undefined network codes in addition to lacking communication protocols resulting in implementation uncertainties.
3. DSO Integration: the lack of communication infrastructure between DSO and CPO, and the affiliated communication standard ambiguity.
4. Control Authority V2G Sessions: conflicting stakeholder views due to business model risks slow coherent vision on who should control V2G sessions.

Grid operators, contracting authorities, and regulators fail to provide clear guidelines on what is meant by "V2G-ready". The first three barriers listed above are arising from requirements deficiency and disparities within the V2G ecosystem. First of all, the lack of clarity regarding the charging standard, either alternating current (AC) or direct current (DC), creates uncertainty for EV manufacturers aiming to provide a universal product for the European market. AC charging stations are widely adopted in many countries, but the implementation of V2G powered by AC might necessitate additional hardware in both EVSE and EVs. Conversely, V2G could leverage the more expensive DC-powered charging stations, potentially reducing costs for EV manufacturers. However, this leads to significantly higher investments in charging infrastructure.

Simultaneously, the charging standard determines which entity, either the charging station or the vehicle, must comply with the applicable grid connection codes (i.e., network codes) for a secure connection to the power grid. While the specific requirements for V2G remain undefined, the non-stationary nature of EVs requires harmonised network codes across Europe. This presents the second barrier identified.

Third, beyond ensuring a secure grid connection, V2G demands the development of new infrastructures and protocols. This includes facilitating data exchange between CPOs and DSOs and amending the promising ISO 15118-20 protocol to enable network code communication between EVSE and EVs. Addressing these challenges arising from disparities and deficiencies in technical requirements underscores the importance of European standardisation and harmonisation. Striking a balance is crucial to maximising innovation efforts while preventing market fragmentation and segmentation.

In addition to technical requirements and regulations, the fourth barrier arises in other institutional arrangements complicating the implementation of V2G technology. DSOs are expected to play a more proactive role in overseeing discharging sessions to maintain grid balance and prevent congestion. However, CPOs and EV manufacturers are exerting influence to secure control over these sessions, aiming to optimise their profits. These conflicting interests hinder the establishment of a unified vision regarding the control authority of discharging sessions. Governmental organisations and regulators are hesitant to take a definitive position in this ongoing discussion to maintain a competitive market.

The incomplete and diverging requirements and ongoing discussions about control authority pose constraints on the conditions necessary for pilot projects. Realistic pilot conditions are crucial for scaling V2G activities, and these projects are essential for exploring the potential of V2G technology. However, the absence of favourable conditions hinders the development of definitive V2G configurations required for widespread adoption. Two significant chicken-and-egg dilemmas are identified as key contributors to the slow adoption of V2G. Niche actors are in a state of anticipation, waiting for each other to continue their research and development activities. EV manufacturers seek V2G-compatible EVSE to experiment with V2G technology, while EVSE manufacturers and CPOs await V2G-compatible EVs. Additionally, niche actors await definitive technical standards, while standardisation organisations and regulators depend on insights from practical experimentation to formulate effective standards and regulations. Addressing these challenges necessitates a coordinated approach to empower and stabilise V2G technology development for widespread diffusion. Niche actors are encouraged to take a proactive role in standardisation and requirement-setting. Furthermore, fostering collaborations among niche actors across Europe is essential to prevent market fragmentation and segmentation, as these outcomes would negatively impact all V2G actors and the overall system. Table 1 summarises key practical implications for V2G actors arising from the analysis of the empirical data.

Table 1: *Practical Implications for V2G Actors.*

General	Actions	Actors
Specify "V2G-ready"	Actively involve industry. Define V2G strategy next to smart charging strategy, align with European strategies. While standards and requirements are lacking, recognise implications for industry. Make clear agreements with CPOs and manufacturers in response to potential hardware adjustments due to future requirements.	DSO, Regulator, Contracting Authority
Define charging standard	Define national charging standard if no European decision is to be made. Could also stimulate the use of both standards, as long as this is clear to the industry so they could adjust accordingly.	Contracting Authority, Regulator
Adopt EU network code	Adopt the amendment of the network codes specific to V2G quickly, and prevent significant variations of implementing the requirements. Align with neighbouring DSOs. Also align with EV manufacturers to ensure compliance.	DSO, EV Manufacturer
Implement DSO-CPO communication standard	Implement a DSO-CPO communication standard. Assess whether European standard is preferred and its potential effect on EVSE requirements. Prevent market fragmentation for EVSE manufacturers.	DSO, CPO, Contracting Authority, EVSE Manufacturer
Select control authority	Investigate how to determine the designated control authority. Assess whether CPOs should maintain their position and how EV manufacturers and CPOs can be compensated for their services and products.	DSO, CPO, EV Manufacturer
Actively contribute to standard-setting	Experiment with latest/proposed specifications V2G and share lessons learned. Contribute actively to standardisation and requirement-setting.	CPO, EV Manufacturer, EVSE Manufacturer
Adopt amendment ISO 15118-20	Adopt the amendment of ISO 15118-20 once published.	EV Manufacturer, EVSE Manufacturer

This study suggests several avenues for future research. Firstly, exploring the role of self-organisation in socio-technical transitions, specifically in the EV charging industry, can contribute to understanding challenges related to control authority in V2G operation. Moreover, subsequent research could explore the impact on CPO business models if EV manufacturers gain control in V2G activities. Additionally, research could examine limitations of (European) standardisation in the EV charging industry, considering the potential hindrance to innovation. Furthermore, based on the charging standard ambiguity, future studies could focus on optimal roll-out strategies of V2G-compatible charging infrastructures ensuring sufficient flexibility to the power grid.

It is essential to note that grounded theory research emphasises theory development rather than hypothesis testing. Complementary studies could test proposed hypotheses by analysing existing pilot projects, employing focus groups, or conducting case studies. In addition, expanding sample sizes of stakeholder groups could provide nuanced insights for specific groups. This study highlights pathways for achieving harmonisation and standardisation to address critical challenges in the current system, a dimension not adequately addressed in existing literature. The results emphasise the significance of technical standards and uniform requirements for V2G development, showcasing the influence of the V2G technical architecture on business models. Overall, effective stakeholder coordination and collaboration are identified as viable pathways to accelerate the transition to a flexible energy system driven by bidirectional EV charging.

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List of Abbreviations

AC Alternating Current.

CPO Charge Point Operator.

DC Direct Current.

DSO Distribution System Operator.

EC European Commission.

eMIP e-Mobility Interoperation Protocol.

eMSP e-Mobility Service Provider.

EU European Union.

EV Electric Vehicle.

EVSE Electric Vehicle Supply Equipment.

IAD Institutional Analysis & Development.

IEC International Electrotechnical Commission.

IS Innovation System.

ISO International Standardisation Organisation.

MLP Multi-Level Perspective.

OCHP Open Clearhing House Protocol.

OCPI Open Charge Point Interface.

OCPP Open Charge Point Protocol.

OEM Original Equipment Manufacturer.

OSCP Open Smart Charging Protocol.

SCSP Smart Charging Service Provider.

TSO Transmission System Operator.

V2B Vehicle-to-Building.

V2G Vehicle-to-Grid.

V2H Vehicle-to-Home.

V2L Vehicle-to-Load.

V2V Vehicle-to-Vehicle.

V2X Vehicle-to-Everything.

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1 A Need for Flexibility

The Member States of the European Union (EU) have committed to cutting greenhouse gas emissions by at least 55% compared to 1990 by 2030. Moreover, they have committed to becoming climate neutral by 2050 (State of the Union, 2020). Subsequently, the Dutch government has set a goal of having at least 70% of energy be supplied by renewable energy sources in 2030 (Rijksoverheid, 2022). These ambitions are necessary to stimulate the energy transition and mitigate global climate change. However, power grids relying greatly on renewable energy sources observe several challenges concerning the reliability of the system. Many of these renewable sources, such as wind turbines and solar panels, are intermittent technologies relying on meteorological conditions, meaning their power output fluctuates. These fluctuations in supply often mismatch with energy demand patterns, resulting in unstable electricity grids (Ourahou et al., 2020). This affects the security of the electricity supply and, in the worst case, can lead to large-scale power outages (Rob Koster, 2023; Sinsel et al., 2020). In some cities in the Netherlands, there is already insufficient capacity for connecting new houses to the power grid (NOS Nieuws, 2023b).

Smart charging of electric vehicles (EVs) is seen as a breakthrough technology in the e-mobility industry. It provides flexibility services to electricity grid operators, could increase renewable energy use, and offers an adaptable charging experience to its users (Directorate-General for Environment, 2022; Nationale Agenda Laadinfrastructuur, 2022). Smart charging entails "adapting the charging cycle [of electric vehicles] to both the conditions of the power system and the needs of vehicle users" (Anisie et al., 2019, p. 3). For example, with smart charging, users would be able to command the vehicle charger to shift charging cycles to times when electricity prices are relatively low to save costs. Grid operators could also benefit from smart charging. In particular, it offers the possibility to adjust charging speeds and power supply to the grid conditions. This limits peak loads on the grid. Bidirectional charging, also known as vehicle-to-grid (V2G), is a variant of smart charging gaining attention from both the industry and policymakers. V2G is seen as a potential solution to help balance and regulate the electricity grid (Clement-Nyns et al., 2011; Van de Weijer, 2022). With the help of this technology, electric vehicles connected to a charging station can discharge their batteries and deliver electricity back to the grid (Kempton & Tomić, 2005). These vehicles can be either battery-electric vehicles, fuel cell vehicles, or plug-in hybrids. For simplicity, this thesis refers to these concepts by using the general term 'electric vehicles' (EVs). In the Netherlands, cars are idle for 23 hours a day on average (De Vries, 2015; Wijngaarden, 2018). Moreover, batteries of EVs that are currently on the market are already large enough to facilitate zero-emission commuting (milieucentraal, n.d.). This leaves time and battery space for bidirectional charging purposes. Some EV batteries are even large enough to power a house for a week (Kraan, 2022). If EVs become active players in grid operations, they can enable utilities to manage electricity resources better and help balance the mismatches in supply and demand to prevent power outages (EenVandaag, 2020; Guille & Gross, 2009; Horlings, 2022; Kempton & Tomić, 2005; Sovacool & Hirsh, 2009). V2G offers decentralised flexibility, enabling charging flows to be controlled and adjusted based on the state of the electricity grid and electricity prices (Sovacool & Hirsh, 2009).

V2G is not the only application of bidirectional vehicle charging. Vehicle-to-everything, also known as V2X, is the overarching term for bidirectional vehicle charging architectures (EVBox, 2022). Vehicle-to-home (V2H), vehicle-to-load (V2L), vehicle-to-vehicle (V2V), and vehicle-to-building (V2B) are additional applications of V2X technology (Hyundai Motors, 2022). With V2L and V2V, EVs are able to provide power to other vehicles (V2V) or electronic devices (V2L) by discharging the battery. V2H systems, on the other hand, provide power to residential buildings, while V2B systems provide power to other types of buildings (e.g., office buildings, hospitals, schools, etc.) (García-Villalobos et al., 2015). V2H and V2B systems can be either connected to the electricity grid or islanded. An islanded system is self-sufficient, meaning it is not connected to the grid and meets its electricity demand with local production. This way, the charging system does not have to comply with grid connection requirements. This thesis research, however, focuses on V2X systems connected to the grid, meaning the islanded systems are not within scope. These systems are referred to using the term 'V2G', which can be either public V2G or grid-connected V2H and V2B. Figure 1 visualises a conceptual architecture for public V2G, showcasing the physical connection between V2G-enabling EVs and the power grid. As mentioned earlier, grid operators are struggling with maintaining a balanced power grid and demand flexibility services. However, enabling V2X in the public power grid is much more complicated than realising islanded V2X systems. These systems connected to the grid are complex due to the involvement of more stakeholders with different needs and roles, such as grid operators, energy suppliers, and Charge Point Operators (CPOs). In addition, connecting to the power grid requires adherence to stricter safety rules, complicating implementation. Therefore, the complexity of grid-connected V2X systems demands research to help shift towards a V2X-supported grid effectively. In the Netherlands, seven out of ten households rely on public parking facilities (Dutch National Charging Infrastructure Agenda, 2022). Therefore, public charging stations represent a high share of the charging infrastructure, signifying the importance of grid connected solutions and the potential impact of V2G.

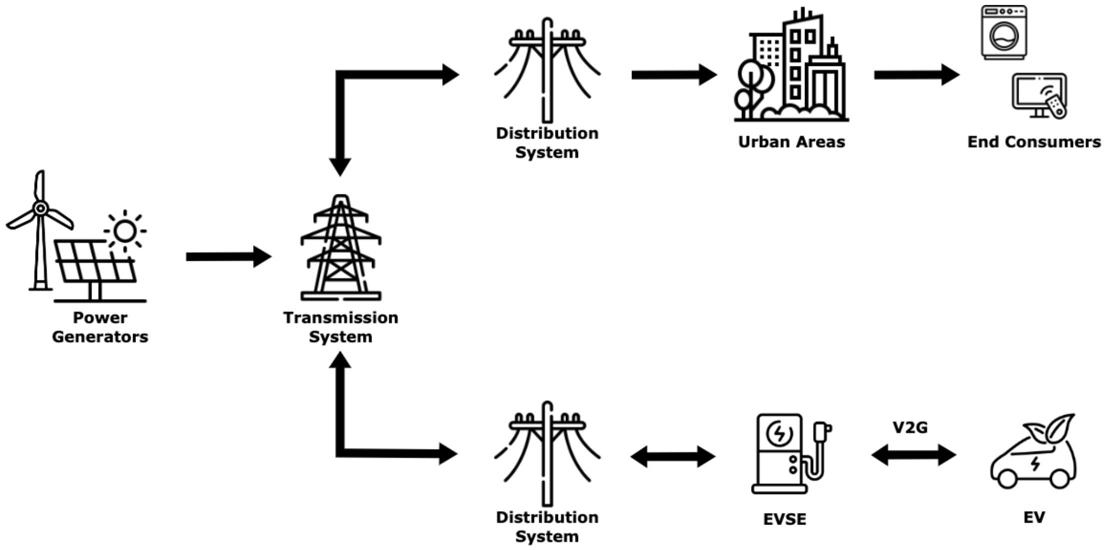

Figure 1: *Simplified Schematic of a V2G System (adapted from Ala et al. (2020)).*

The automotive industry is in full transition towards EVs, increasing the need for electricity. At the same time, the utility industry is transitioning towards an energy system containing a large share of renewable energy sources (Kempton & Tomić, 2005). With V2G, these two developments are starting to interact, in which electric vehicles can both consume from and deliver to the electricity grid (Lund & Kempton, 2008). The integration of EVs into the electricity grid, however, poses a challenge for ensuring the safety of the grid, such as the risk of overloading (Gonzalez Venegas et al., 2021). This requires additional technical specifications to ensure the stability and reliability of the grid. The EV charging industry is greatly relying on international technical standards, such as Open Charge Point Protocol (OCPP) and ISO 15118. Therefore, market players, such as EV supply equipment (EVSE) and EV manufacturers, are demanding clear guidelines for their products enabling bidirectional power flows (Kester et al., 2018; Neaimeh & Andersen, 2020). However, technical requirements for systems and products enabling V2G have not been specified yet for various elements (Gunkel et al., 2020). Moreover, non-harmonised requirements pose a significant burden for internationally oriented original equipment manufacturers (OEMs). These obstacles constrain the industry to develop and implement V2G technology, as grid operators seek solutions to mitigate grid congestion.

1.1 Research Objective

This study addresses knowledge gaps related to the necessity and implications of harmonising technical requirements specific to V2G. The study contributes to the existing literature by exploring barriers in the technical implementation and analysing their impact on V2G adoption. This comprehensive approach identifies the areas, reasons, and extent of the need for harmonisation, offering valuable insights for effective policy design. Moreover, this study establishes a foundation for understanding how technical specifications could influence the business models of V2G actors and how these actors could act upon the associated uncertainties. The study is guided by the following main research question:

How do institutional barriers in the technical implementation of vehicle-to-grid technology influence its adoption?

This study focuses on 'hard' requirements, i.e., essential requirements mandated by contracting authorities in public tenders. The requirements are associated specifically with the technical implementation and operation of V2G services. The primary geographical focus is the EU, with specific emphasis on the charging system in the Netherlands serving as a key reference. This is because of the dominant and leading position of the Netherlands in charging infrastructure (ChargeUp Europe, 2023).

1.2 Approach

This study exerts the grounded theory methodology, ensuring an open-minded approach to exploring stakeholder perspectives and needs. Data collection and analysis are guided by the following sub-questions:

SQ1: *What are the main barriers in the technical implementation of vehicle-to-grid technology obstructing its adoption?*

SQ2: *What underlying factors contribute to the emergence of the barriers identified?*

SQ3: *How do the barriers identified affect the key stakeholders in the vehicle-to-grid ecosystem?*

This qualitative study employs semi-structured interviews with ten industry experts from five key stakeholder groups, including CPOs, Distribution System Operators (DSOs), EV manufacturers, EVSE manufacturers, and regulators. The views of the participants shape emerging insights on the influence of institutional barriers on the adoption of V2G technology at their organisations. The emerging theory grounded in the empirical data provides the fundamental basis for identifying relationships between system failures and the diffusion of the V2G innovation. A comprehensive analysis integrating the Institutional Analysis & Development (IAD) framework and Multi-Level Perspective (MLP) provides a conceptual tool for understanding the dynamics observed in the empirical study. This novel approach presents a valuable tool for analysing niche innovations within complex institutional contexts, such as the EV charging system.

1.3 Complex Systems Engineering & Management in the V2G System

Various obstacles have to be overcome before V2G technology will be fully adopted in current energy infrastructures. The EV charging infrastructure is complex due to its embeddedness within the general power system, the interdependence between several actors, and the continuous change of its state. Therefore, this system is difficult to predict, complicating intervention in the system. This requires a socio-technical approach where the technical system, the institutional context, and social dimensions are well aligned. Methods and principles from the field of systems engineering are therefore applicable to the subject. For OEMs such as EVSE manufacturers, offering V2G technology with their products comes with technical challenges, such as standardisation of charge plugs, compatibility with the several types of electric vehicles, and compliance with national grid connection requirements (Horlings, 2022; Van de Weijer, 2022). However, technical specifications and regulations guiding the implementation of the technology are lacking, especially on an international level. This shows a clear interdependence between institutional frameworks and technological advancements. These interactions necessitate the alignment of various stakeholders to realise an efficient system, underscoring the importance of multi-actor coordination. Consequently, this shows the need for a multi-disciplinary approach to identify crucial obstacles hindering the adoption of V2G. This signifies a comprehensive approach to generating effective pathways to accelerating the development of V2G technology and the associated socio-technical transition.

1.4 Report Structure

This thesis is structured as follows. First, Chapter 2 elaborates on recent developments regarding requirements and technical standards specific to V2G. Furthermore, it presents a systematic literature review identifying knowledge gaps in the academic field of V2G. The knowledge gaps provide the basis for constructing the research objective and main research question guiding the study. Next, Chapter 3 introduces the grounded theory methodology and elaborates on the research methods applied. It presents sub-questions guiding the empirical study and analyses. In addition, it elaborates on the interview methodology and recruitment criteria, which are based on an initial stakeholder analysis. Furthermore, this chapter presents the coding phases following the grounded theory approach. Chapter 4 presents the theoretical framework consulted for interpreting the empirical data. It presents a comprehensive tool for analysis, integrating the IAD framework and MLP. The coherent framework serves as a theoretical lens assisting the interpretation and organisation of the results. Chapter 5 presents these results, maintaining an open-minded approach by preventing theoretical insights from affecting the analysis. Chapter 6 consults the theoretical framework to discuss the results and presents implications for the academic field and practitioners. Additionally, it outlines potential avenues for future research to contribute to knowledge development, to accelerate the advancement of V2G technology. Chapter 7 provides conclusions and recommendations.

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2 Harmonisation of V2G Requirements: Developments in Practice and Literature

Technical standards play a significant role in the electric vehicle (EV) charging industry. As explained in Chapter 1, vehicle-to-grid (V2G) adoption is lacking, which is expected to be caused partially by non-harmonised and undefined requirements and standards. Before delving into this problem, Section 2.1 presents commonly applied standards and protocols for EV charging and explores recent developments regarding requirements specific to V2G. Section 2.2 elaborates on the role of international standards in the EV charging industry in general to emphasise the significance of research in this field. Section 2.3 presents a systematic literature review exploring the state of the art and identifying knowledge gaps. It appears literature lacks knowledge on the extent to which harmonisation is needed and how the harmonisation process should be coordinated and governed. To identify where harmonisation is needed, why it is needed, and to what extent, this study aims to explore barriers in the technical implementation of V2G technology and understand how these affect the adoption by key actors. This chapter concludes with presenting the main research question constructed from the knowledge gaps identified in the literature review.

2.1 Recent Developments of V2G Requirements and Standards

EV charging infrastructures are complex and consist of various sub-systems, such as energy management, billing, power delivery, authentication, and data exchange. These sub-systems involve many actors with different roles, such as Charge Point Operators (CPOs) and e-Mobility Service Providers (eMSPs). EVs and EV supply equipment (EVSE) constitute the primary hardware components of EV charging. However, the realisation of charging sessions relies significantly on the underlying communication infrastructures between stakeholders and technical architectures. These elements play a critical role in facilitating reliable and efficient charging.

The establishment of technical requirements for EV charging infrastructure is imperative to ensure reliable and safe operation. These requirements serve as guidelines to guarantee interoperability among the various components of the charging ecosystem, such as EVs and EVSE. Technical requirements address crucial aspects, including communication protocols, power delivery specifications, and safety features. By adhering to these requirements, the industry ensures that charging stations are universally compatible with diverse EVs, fostering a seamless experience for EV users. Moreover, technical requirements play a pivotal role in mitigating safety risks and ensuring the overall reliability of EV charging systems. Due to the complexity of V2G and the complementary feature of bidirectional power, additional requirements are needed to ensure the safety and reliability of the underlying infrastructure and connected hardware. Moreover, V2G requires adaptation of communication infrastructures or even the creation of new ones. For example, information from electricity markets is required when operating V2G to optimise cash flows. On the contrary, information from grid operators on real-time grid loads is required when operating V2G to balance loads on the electricity grid. V2G, therefore, complicates the EV charging ecosystem even more.

Technical requirements specific to V2G (hereafter also referred to as V2G requirements, grid connection requirements, or vehicle-grid integration requirements) are developed continuously. At the moment, the industry is debating which requirements to set for V2G operations based on existing infrastructures and technology. Figure 2 depicts a simplified overview of the EV charging ecosystem. It presents the relationships between key actors and underlying communication infrastructures. The figure illustrates prevalent standards and protocols that are commonly applied, yet the practical adoption thereof diverges upon regional disparities and the specific actors involved. For the realisation of V2G power flows, the connections between the DSO, CPO, EV, and EVSE are mainly of interest. Bidirectional charging demands intervention in communication infrastructures, so protocols need to be adapted to facilitate communication between the actors and entities within the system (e.g., state-of-charge, user preferences, etc.). The figure excludes product-specific requirements for EVs and EVSE such as network codes and safety features, but are equally important. Some product requirements are related to communication protocols when, for example, the products need to be able to exchange specific data required by specific actors, such as charging profiles and state-of-charge information.

Figure 2 shows standards used commonly in EV charging infrastructures. It gives an overview of the relationships between actors key to enabling and managing charging sessions and showcases underlying communication infrastructures. A prevalent standard is ISO 15118, which is an international standard specifying data exchange between EVSE and EVs. A recent version, ISO 15118-20, enables data exchange required for bidirectional power flows (Mültin, 2020). However, this standard has not been widely adopted by EV and EVSE manufacturers yet, since it takes some time to fully integrate the standard into new products. Nonetheless, contracting authorities and the industry are increasingly embracing earlier versions, such as ISO 15118-2 enabling Plug & Charge (i.e., charging without authentication through a charge card). Moreover, industry players are debating on the communication protocol to use for data exchange between Distribution System Operators (DSOs) and charging infrastructure, since DSOs are expected to play a more active role for V2G purposes. OpenADR is such a protocol of interest. For data exchange between EVSE and CPOs, the open-source Open Charge Point Protocol (OCPP) is increasingly embraced in the industry. Especially in the Netherlands, where it has its roots, OCPP is the de facto standard. The founders of the protocol, in collaboration with the International Electrotechnical Commission (IEC), are aiming to publish OCPP as an international standard (Open Charge Alliance, 2023). These harmonisation attempts initiated from the market (i.e., 'bottom-up') are continuously enhancing interoperability within the EV charging ecosystem.

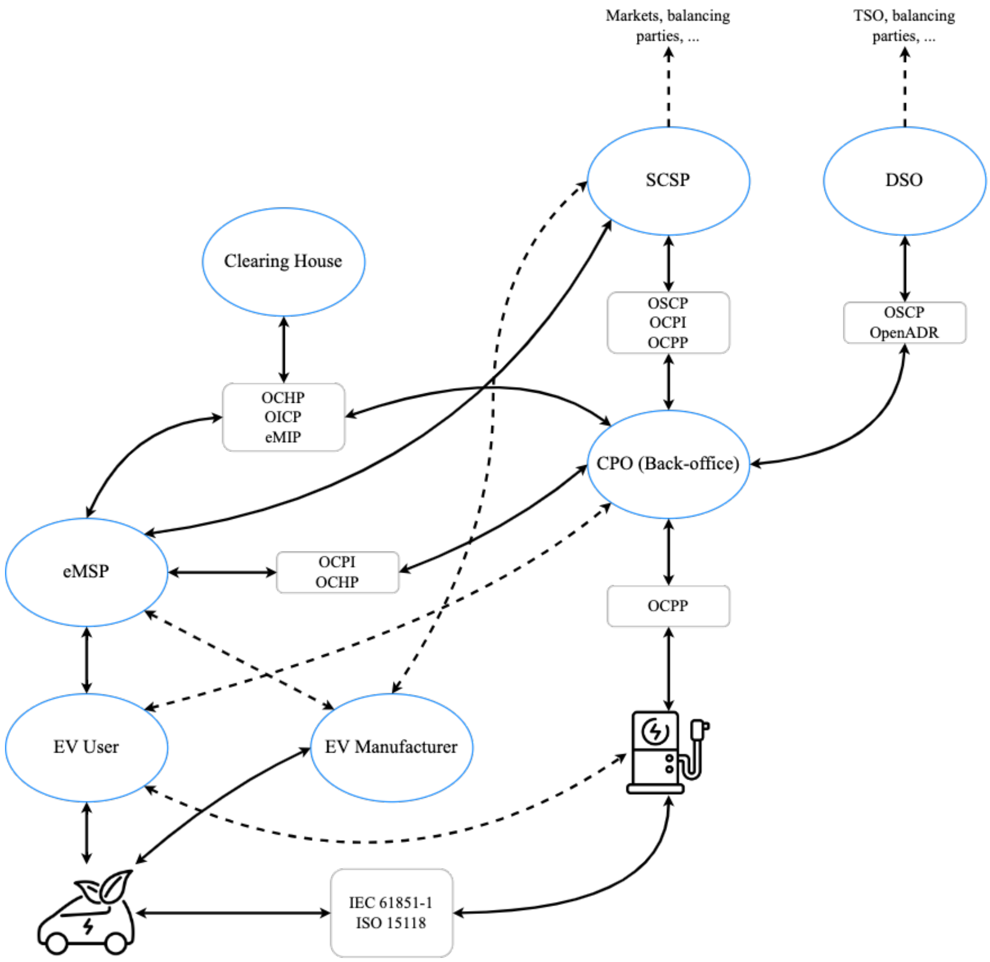

Figure 2: *Simplified Overview of EV Charging Ecosystem, underlying Communication Infrastructures, and Key Actors.*
Note. This overview presents standards and communication protocols used commonly in the EV charging ecosystem in the Netherlands. Key stakeholders potentially to be involved with V2G operations are considered. EVSE and EV icons retrieved from juicy_fish and kosonicon from Flaticon.com respectively. Dotted arrows indicate potential future connections due to developments in the industry. Connections without an affiliated protocol indicate non-standardised, proprietary communication. The figure is verified in consultation with industry experts for accuracy and relevance (as of January 2024). Open Clearhing House Protocol (OCHP), Open Smart Charging Protocol (OSCP), Open Charge Point Interface (OCPI), and e-Mobility Interoperation Protocol (eMIP) are less relevant to V2G, but included to give a complete overview.

2.2 The Role of International Standards

The European Union (EU) has set the objective to harmonise energy markets if this would lead to "a more competitive, customer-centred, flexible and non-discriminatory EU electricity and gas market with market-based supply prices" (Ciucci, 2023, p. 1). Harmonisation is the process in which "the effects of a type of transaction in one legal system are brought as close as possible to the effects of similar transactions under the laws of other countries" (Goldring, 1978, p. 289). With 'transaction', Goldring (1978) refers to the exchange of property rights on an asset or service, such as energy. In practice, harmonisation implies that laws or requirements in different countries are adjusted in such a way that the system of interest in essence performs similarly. This does not mean, however, that the countries implement the same laws, which is the case for unification where different laws are substituted by a single, unified law (Porcelli & Zhai, 2010). Harmonisation can take the form of maximum harmonisation or minimum harmonisation (Mańko, 2015). With maximum harmonisation, the EU establishes comprehensive regulations that the Member States must fully adhere to. This way, the Member States are not allowed to introduce additional regulations and are unable to set requirements that are more stringent than the EU has specified. On the other hand, with minimum harmonisation, the EU sets a minimum standard allowing Member States to go beyond the requirements specified. The choice between the two levels of harmonisation depends on the policy objectives of the EU and the current level of integration within the internal market of the system of interest.

Technical standards play a significant role in EV charging infrastructures. Standards are potential means of complying with specific requirements (e.g., laws and regulations) and include technical specifications and procedures (IEEE SA, 2021). These standards can be developed by international standardisation organisations, such as the International Organization for Standardization (ISO) or the International Electrotechnical Commission (IEC), or other organisations, such as regulatory bodies, industrial firms, or non-profit organisations, and are based on consensus. Technical standards are used to provide technical specifications aligning with successful practices and are recognised by the industry as a means of achieving certain objectives. European standards are indispensable for enhancing the internal market and discouraging the imposition of market barriers (Falvo et al., 2014). With the internal market, the EU has set the objective to, among others, allow the free movement of goods and services and strengthen integration (Ratcliff et al., 2023). Harmonisation is a possible instrument to achieve this. Particularly, harmonisation using product standards ensures interoperability, compatibility, and consistency across the Member States and reduces country-specific adaption costs for firms (Schmidt & Steingress, 2022). Harmonised standards are not always mandated, however. Compliance is voluntary, meaning firms are allowed to implement other solutions as long as they comply with the mandatory requirements set in specific regulations or laws. However, this could mean these firms would have to provide more details in their technical documentation, demonstrating compliance. The harmonised standards have the advantages of 'presumption of conformity', meaning adherence to harmonised standards ensures compliance with corresponding EU regulations (Your Europe, 2023).

In 2010, the European Commission issued a mandate to standardisation bodies to ensure interoperability within EV charging infrastructures in the EU (European Commission, 2010). Technical standards play an important role in the harmonised approach for enhancing interoperability. As stated by the Commission, "... harmonisation would allow users to use the same charger for a range of electric vehicles and it would ensure that chargers of electric vehicles can be connected and operated in all EU States" (European Commission, 2010, p. 2). Among others, this approach requires the harmonisation of physical connectors and software communications protocols. For example, Europe quickly settled to use only IEC 62196 Type 2 connectors, including the Combined Charging System (CCS) for fast charging (Lesage, 2013).

By Greenstein and David (1990), standards are commonly categorised as either de facto or de jure. De facto standards emerge from market dynamics and technology diffusion. They are often adopted as a result of high acceptance by consumers or other market players (Katz & Shapiro, 1986). De jure standards, on the other hand, are governmental and developed through formal stakeholder engagement, such as through recognised standardisation organisations such as CEN and ACER. Standards such as OCPP, OCPI, and OpenADR, however, are conceptualised as *open standards*. Such standards are developed by open alliances or public standardisation organisations, adopted voluntarily by industrial players, and can be accessed by anyone (Neaimeh & Andersen, 2020). Initially, they are not considered to be either de facto or de jure. However, after formal endorsement, they can become de jure; or, after voluntary, widespread adoption by the industry they become de facto. Proprietary standards, on the other hand, are created by private entities and may have restrictions on use imposed by the owner. Again, the adoption of these standards is voluntary. Open standards, however, are prevalent in the EV charging industry, as shown in Figure 2.

In support of EU regulatory objectives, voluntary standards such as open standards can play a role in many innovative industries instead of or complementary to harmonisation as initiated by the European Commission (EC) (Schmidt & Steingress, 2022). When successful in practice, the EU may formally recognise open standards as a means of achieving specific policy goals. Compliance with these standards can then help firms meet EU regulatory requirements more easily. Formal endorsement of open standards can provide a basis for achieving compatibility and consistency across the EU market. This supports the EU competence in creating a single internal market with harmonised technical specifications. Therefore, open standardisation and EU competencies can work in tandem to create a more efficient and harmonised EU market.

2.3 Systematic Literature Review

Original equipment manufacturers (OEMs), such as EVSE manufacturers and EV manufacturers, are demanding more harmonised regulations and standards for V2G-enabling products to ensure clarity concerning product requirements and limit complexity. For example, network codes are local rules, meaning they can vary from one system operator to the other (Mohseni & Islam, 2012). This could indicate disparities in product requirements throughout markets, complicating the roll-out of V2G-compatible products by international OEMs. This section presents a systematic literature review exploring the scientific developments regarding the harmonisation of technical requirements specific to integrating EVs into electricity grids and offers an overview of remaining barriers and knowledge gaps. Conducting a literature review helps identify these knowledge gaps, which serve as the starting points for new research (Van Wee & Banister, 2016; Webster & Watson, 2002). The review has been conducted in May 2023.

2.3.1 Literature Search Strategy

Figure 3 depicts the search strategy applied in the literature review. Scopus was selected as the only source for the literature search because of its extensive, reliable, and user-friendly database. On Scopus, a search string was applied, which consists of the elements presented in Table 2. Elements in the same column are combined with the OR operator. The resulting three parts are combined with the AND operator, resulting in the complete search string.

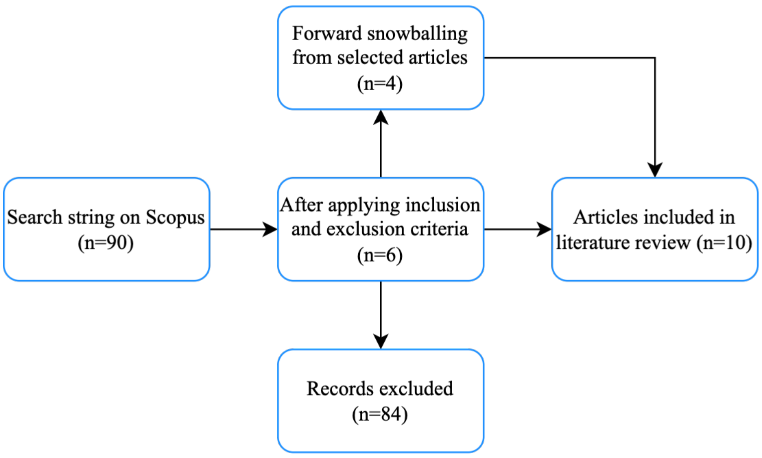

Figure 3: *Search Strategy.*

On Scopus, the search string was applied to article titles, abstracts, and keywords. An article is included in the review if it meets all inclusion criteria and none of the exclusion criteria. Table 3 presents the inclusion and exclusion criteria used. In addition, forward snowballing has been applied to ensure a sufficient number of articles are included in the review.

Table 2: *Search String Components.*

Vehicle-to-grid	Grid connection requirements	Harmoni*
vgi	grid code*	standardi*
vehicle-to-everything	communication protocols	coordination
v2g	policy	normali*
v2x	grid requirements	
bidirectional charging	grid standards	
vehicle-to-anything	grid compliance	
v2h	network code*	
vehicle-to-home	network standards	

Note. * indicates any possible suffix.

Table 3: *Inclusion and Exclusion Criteria.*

Inclusion	Exclusion
Discusses the potential and/or shortcomings of harmonisation in V2G infrastructures	Not in English nor Dutch
Discusses the dependence between at least two entities within the V2G infrastructure (e.g., between grid and EV)	Does not elaborate on V2G technology
	Does not discuss any aspect of harmonisation for V2G rollout

2.3.2 Identifying Knowledge Gaps

Ten articles were reviewed. Table 4 gives an overview of these articles. It also elaborates on the need for harmonisation of a specific aspect of the EV charging ecosystem mentioned in the articles, as well as the affiliated uncertainties and potential barriers. The articles differ in the extent to which harmonisation is discussed. However, for each article, a coherent need can be specified. Harmonisation of V2G requirements, however, involves several uncertainties and challenges. The third column of Table 4 elaborates on the knowledge gaps identified in the articles as well as the potential barriers and shortcomings of harmonising the specific aspect of the charging ecosystem.

Table 4: *Literature Overview Resulting from the Literature Search.*

Reference	Need for harmonisation	Barriers and uncertainties
Gonzalez Venegas et al. (2021)	Standardisation of interconnection requirements to ensure system safety and easing administrative procedures (e.g., taxation). Simplification and standardisation of connection procedures and adapted metering options for EVs to support the provision of flexibility.	How to coordinate EVs providing ancillary services to the Transmission System Operator and DSO (such as V2G). National network codes might pose a barrier for international deployment of V2G. Characterisation of technical flexibility requirements for distribution grids.
Neaimeh and Andersen (2020)	Standardising open communication protocols to facilitate compatibility and communication between different entities and equipment, which are key to ensure universal support for grid integration, thereby minimising grid reinforcement costs and facilitating integration of renewables.	Whether legislation ensures that the industry will adopt V2G more quickly, and whether governmental intervention is even required.
Sovacool et al. (2017)	"Absence of needed laws, regulations, and standards could slow a VGI [(vehicle-grid integration)] transition." "Varying design standards for EVSE (recharging equipment) could lead to limited access for VGI services[, such as V2G]."	Elaboration on the need for institutional capacity and cross-sectoral policy coordination.
Gunkel et al. (2020)	Not adapted technical standards limit EVs in offering their flexibility service to the market, therefore requiring standardisation.	Unknown what the most successful business case is for technologies serving flexibility, such as V2G.
Mojumder et al. (2022)	Lack of standardisation becomes barrier for business models to be successful, limiting V2G adoption (especially on international level).	Which standards should be used? What reforms are necessary for a profitable business model? Current literature lacking in devising a proper V2G business model.
Tirunagari et al. (2017)	Standardisation of the communication protocols used in EV charging for interoperability of charging control systems and charging stations. Necessary to effectively integrate EVs into power grid.	More standardisation work required to enhance interoperability, as well as to ensure software and hardware compatibility with infrastructures. Suitable policies to mandate the interoperable communication protocols which offer V2G functionalities are needed.
Kester et al. (2018)	The industry has the need for technical guidelines and standards.	Uncertain how standardisation can be realised, and to what extent. Also, uncertain what the role of the government should be.
Ferwerda et al. (2018)	Need for single protocol (e.g., OCPI) to connect both charge point operators and service providers via hubs and peer-to-peer.	How a theoretical framework would look like for comparative analysis between the different e-roaming protocols, providing recommendations for harmonisation and future convergence.
Habib et al. (2018)	Standards and codes required for effective and safe vehicle-grid integration.	Many groups working on standards and codes, but which ones will be widely accepted? How to harmonise this process?
Sovacool et al. (2020)	Need for security and privacy standards of V2G. Need for V2G standardisation in electric vehicles to encourage full adoption.	"VGI technology is in its infancy with lack of uniformity in communication protocols, standards, and commercial applications."

Note. This table showcases the need for harmonisation mentioned in the articles and the affiliated knowledge gaps and potential barriers.

Table 5 shows a synthesis of the results. Two main knowledge gaps can be identified:

- It is unknown to what extent harmonisation of technical requirements in the V2G system is needed, and how this is achieved.
- It is unknown what reforms of business cases are needed as a result of the harmonisation of technical requirements in the V2G system.

Articles discussing the first knowledge gap vary in scope. Either harmonisation of the data communication protocols, technical requirements for grid integration, the infrastructure in general, or a combination of these was discussed. The three perspectives affect the extent to which harmonisation can be performed. However, all actors are affected by the harmonisation of either of the aspects. Communication protocols, for example, are part of the general infrastructure and are often related to a technical standard at the same time. They cover the communication between entities within the infrastructure, such as the charging station, the EV, the grid operators, and the CPO. Harmonisation of communication protocols is necessary to facilitate universal support for grid integration to offer flexibility services (Gonzalez Venegas et al., 2021; Gunkel et al., 2020). At the moment, uniformity is lacking (Sovacool et al., 2020). Neaimeh and Andersen (2020) and Kester et al. (2018) state, however, it is unsure whether governmental intervention is required to facilitate harmonisation, and whether legislation would ensure faster adoption of V2G technology. On the other hand, Tirunagari et al. (2017) and Sovacool et al. (2017) state suitable policies are needed. Candidate standards for communication protocols, such as OCPP, are already in development, but the extent to which this protocol has been embraced differs on a regional level (Ferwerda et al., 2018; Habib et al., 2018). Therefore, there is a need for a clear harmonisation process: does open standardisation by industry players suffice, or do we need the European Union to step in?

It is clear literature is lacking knowledge on what are potential steps towards a harmonised system expected to increase the V2G adoption rate internationally. It is unclear to what extent harmonisation is needed, how the harmonisation process should be coordinated and governed, and what reforms to business models are necessary as a result of harmonisation.

Table 5: *Literature Synthesis.*

Knowledge Gap	Scope	References
Unknown to what extent harmonisation of technical requirements in the V2G system is needed, and how this is achieved.	Data exchange protocols	Gonzalez Venegas et al. (2021), Neaimeh and Andersen (2020), Tirunagari et al. (2017), Ferwerda et al. (2018), Sovacool et al. (2020)
	Technical requirements	Kester et al. (2018), Gonzalez Venegas et al. (2021), Sovacool et al. (2017)
	General	Sovacool et al. (2017), Sovacool et al. (2020), Habib et al. (2018)
Unknown what reforms of business models are needed as a result of harmonisation of technical requirements in the V2G system.		Gunkel et al. (2020), Mojumder et al. (2022), Sovacool et al. (2020)

2.4 Main Research Question

A coherent research question is constructed primarily from the first knowledge gap presented earlier. This study aims to identify barriers in the technical implementation of V2G technology and understand how these affect the adoption by key actors. It focuses on the technical specifications necessary to realise implementation. This study helps to identify where harmonisation is needed, why it is needed, and to what extent. This study captures barriers arising from non-harmonised requirements and (yet) undefined requirements specific to V2G to ensure a comprehensive approach. This way, the study provides a basis for policy design and understanding the effects of technical requirements on business models. Because of the latter, this study also contributes to the second knowledge gap. However, this is not the primary objective. The main research question of this thesis project is stated as follows:

How do institutional barriers in the technical implementation of vehicle-to-grid technology influence its adoption?

Technical implementation refers to the technical requirements essential to the integration of EVs into the electricity grid, enabling bidirectional power flows. For example, this includes product requirements related to bidirectional power delivery, safety features, or data exchange. This study focuses on 'hard' requirements, i.e., essential requirements mandated by significant customers and contracting authorities. The knowledge gaps demand exploration of the need for harmonisation of technical requirements based on the influence of non-harmonised and undefined requirements on the adoption of V2G in practice. For many of the actors of the EV charging system, such as EVSE manufacturers, there is uncertainty regarding the technical requirements for offering V2G technology with their products (Gunkel et al., 2020; Kester et al., 2018). There is the presumption that the absence of standardised requirements, on an international level, will slow and even limit the integration of vehicles into the electricity grid (Sovacool et al., 2017). This also affects the adoption of V2G technology in business models for industry players (Gunkel et al., 2020; Mojumder et al., 2022). Even when national requirements are known in some countries, differences between countries affect the international deployment of V2G technology (Gonzalez Venegas et al., 2021). Therefore, this study delves into the barriers observed obstructing key stakeholders to enable V2G. Chapter 4 elaborates on the institutional nature of this study and the effect of this on the diffusion of V2G technology. This way, this study aims to support the development of effective policy, regulatory frameworks, and business models related to V2G. Chapter 3 presents the research approach exerted to achieve this objective, guided by the main research question.

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3 The Grounded Theory Approach

Chapter 2 presented the main research question aimed at filling the knowledge gaps identified. This chapter elaborates on the grounded theory research approach. Section 3.1 presents the sub-questions guiding the research activities. Section 3.2 presents the fundamentals of the research approach and elaborates on the methods applied for data collection and analysis. Section 3.3 presents the interview approach for data collection purposes, including an initial stakeholder analysis for identifying relevant stakeholders to recruit. The chapter concludes by presenting the research participants.

3.1 Research Questions

As identified in Chapter 2, the main research question is stated as follows:

How do institutional barriers in the technical implementation of vehicle-to-grid technology influence its adoption?

To develop an answer to this question, sub-questions are constructed to guide the research activities. The sub-questions, SQ1, SQ2, and SQ3 respectively, are stated as follows:

SQ1: *What are the main barriers in the technical implementation of vehicle-to-grid technology obstructing its adoption?*

SQ2: *What underlying factors contribute to the emergence of the barriers identified?*

SQ3: *How do the barriers identified affect the key stakeholders in the vehicle-to-grid ecosystem?*

The primary objective of the first research question is to explore the nature of the problem under study. Specifically, it focuses on identifying the primary obstacles stemming from the technical requirements specific to vehicle-to-grid (V2G). This establishes a basis for addressing the main research question and steers subsequent analyses. The second research question delves into the origins of the barriers identified in the initial phase. Its focus lies in creating an understanding of the causes of the barriers. The third research question focuses on the perceived consequences of the barriers identified. This contributes to an understanding of how stakeholders are affected by these barriers and the hesitancy in V2G adoption among these actors. The three sub-questions guide the analytical process towards formulating a comprehensive answer to the main research question. The next section presents the grounded theory approach used to find answers to the research questions. Figure A1 in Appendix A presents the research flow diagram.

3.2 What is Grounded Theory Research?

This study exerts the grounded theory approach. This qualitative research approach focuses on developing a theory through the analysis of empirical data (Johannesson & Perjons, 2014). The emerging theory providing insight into a specific phenomenon under study is 'grounded' in the data (Corbin & Strauss, 1990). Grounded theory research does not start with a hypothesis. The empirical data is the starting point and guides the research activities. A theory is developed rather than tested (Turner & Astin, 2021). This requires an open-minded approach.

This study explores barriers obstructing the adoption of V2G. Grounded theory is useful for such exploratory studies where little is known about a specific phenomenon (Chun Tie et al., 2019; Johannesson & Perjons, 2014). Therefore, it is a suitable approach for this study. This study employs interviews to discover stakeholder perspectives and identify key obstacles. The views of the participants shape the emerging theory and help understand the phenomenon based on their perspectives (Turner & Astin, 2021). Grounded theory has proven before to be a valuable approach in the electric vehicle (EV) and EV charging domains to explore perspectives and identify barriers to technology diffusion (Mohamed et al., 2018; Roemer & Henseler, 2022; Wu & Chang, 2013).

In a grounded theory study, data analysis and sampling happen simultaneously, facilitating theoretical sampling (Chun Tie et al., 2019). With theoretical sampling, participants are purposefully selected based on preliminary results obtained through data collection and analysis so far. Sampling stops when theoretical saturation is reached, i.e., when no new data is needed to understand concepts and form a theory (Turner & Astin, 2021). However, due to time constraints, this study does not exert iterative sampling. Interviews are employed with a predetermined number of participants. Nonetheless, the topic guide is refined continuously based on the interviews performed and analysed so far and data saturation is tracked.

The empirical data is analysed through qualitative coding, in which recurring concepts and overarching categories are constructed (Chun Tie et al., 2019). For this purpose, this study employs ATLAS.ti and its data analysis tools. The coding process consists of three phases: open coding, axial coding, and selective coding (Johannesson & Perjons, 2014). Open coding refers to identifying recurring concepts. The empirical data are broken down into discrete excerpts subject to evolve in later coding stages. Axial coding refers to the interconnection of the most important concepts and the development of categories. Selective coding refers to the procedure of building a coherent, unified category by connecting axial codes and identifying relationships between these. Selective coding represents the phenomenon under study and provides a basis for theory development (Chun Tie et al., 2019; Johannesson & Perjons, 2014). Constant comparative analysis supports coding and category development by stimulating continuous comparison of codes (Corbin & Strauss, 1990). This way, differences and similarities between codes are identified structurally. In addition, memoing is exerted to support data analysis. With memoing, the researcher keeps track of emerging concepts, categories, and insights (Chametzky, 2023). Examples of memos of this study are shown in Table 6. In addition, the study applies quantitative methods to analyse the groundedness of codes, representing the degree to which codes reoccur in the data.

Table 6: *Examples of Memos.*

Date	Topic	Memo	Follow-up
03-11-2023	Who is in control	Interviewee (Regulator 1) acknowledges the debate between the stakeholders about who is in control of V2G services. I will focus more on this with the other interviewees and explore their views.	Focus more on debate 'who is in control' with other participants.
09-11-2023	Interview CPO2	Again, unclear what "V2G-ready" actually means. Many of the same problems addressed as with other CPO. Provided more examples of contracting authorities not knowing what they are demanding from the economic operators.	Ask DSO 2 how network code compliance is organised with their pilot. Ask EVSE Manufacturer 2 what a V2G-ready charger entails. Think about contacting a contracting authority regarding the V2G requirements in tenders, and ask about their reasoning.
13-12-2023	Open coding CPO2	V2G-readiness as main point of discussion so far. Main concerns of CPO is the financial risk of changing and unknown requirements, especially when hardware changes are required. Need for good agreements with contracting authorities. The current field of chargers does not seem to be ready for V2G. Big part of the problem is the lack of knowledge at contracting authorities and policymakers.	

A major challenge of grounded theory research is to maintain an open mind (Johannesson & Perjons, 2014). Every researcher has a specific background and knowledge that could affect the interpretation of empirical data. Therefore, the key to grounded theory is verification and reflexivity, especially in the latter stages of coding (Corbin & Strauss, 1990). To ensure verified insights and prevent bias, this study actively involves experts from the field of EV charging and experienced researchers to test concepts and suggested relationships. However, one should be careful with the generalisation of the theory to be developed, since the conditions of the study can be different from practice. By ensuring a reproducible approach, verification, and data saturation, the generalisability of the theory is enhanced (Corbin & Strauss, 1990).

Another point of discussion related to grounded theory research is the role and timing of reviewing published theories. Classic grounded theorists recommend that published literature should not be reviewed before a theory is developed (Turner & Astin, 2021). This is believed to ensure the open-mindedness of the researcher by avoiding forcing data into preconceived ideas. Therefore, this study only engages the theoretical framework after data analysis and theory development (see Chapter 6). The framework, presented in Chapter 4, is constructed concurrently with data collection and analysis. It aids in the interpretation of the empirical data rather than guiding data collection and analysis. Before data collection, a literature review is conducted, but only to identify knowledge gaps in the field as presented in Chapter 2.

3.3 Interview Approach

Individual in-depth interviews are employed to collect data for this study, allowing a deep understanding of stakeholder perspectives. In particular, semi-structured interviews are conducted, organised around a coherent set of predetermined open questions and maintaining room for emerging follow-up questions (DiCicco-Bloom & Crabtree, 2006). Both face-to-face and digital interviews are conducted. Semi-structured interviews are well suited for grounded theory research to remain open-minded, leaving room for the interviewer to steer the conversation based on emergent concepts (Foley et al., 2021). However, the interviewer should not steer the interview based on published literature and theories, as explained earlier, or their views on the matter. This is achieved by preventing suggesting solutions, using open questions only, and maintaining a neutral position in discussions (Johannesson & Perjons, 2014; Myers & Newman, 2007). Appendix B presents the topic guide used during the interviews. A topic guide includes predetermined, open-ended questions leaving room to be discussed in flexible order (Gill & Baillie, 2018). Interviews are automatically transcribed using Microsoft Teams. Summaries are constructed based on the interview transcripts and approved by the participants within two weeks after receiving the particular summary digitally. Figure 4 visualises the interview approach.

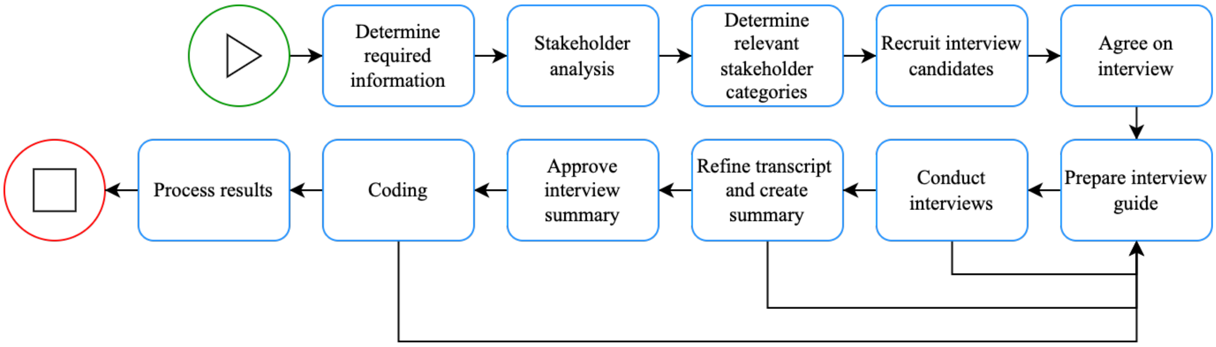

Figure 4: *Interview Approach.*

Participants are sampled through a purposeful selection of people from organisations relevant to the phenomenon under study (Chun Tie et al., 2019). Therefore, the next section presents a stakeholder analysis, identifying the key stakeholders to consider interviewing. The stakeholder analysis provides a basis for recruiting the participants, who are presented in Section 3.3.2.

3.3.1 Stakeholder Analysis

Performing a stakeholder analysis before recruiting participants is crucial to ensure key actors are involved in the study. These actors should have a vested interest in the research topic and represent a vital role in the system under study. Figure 2 in Chapter 2 showcases relevant actors in the EV charging ecosystem based on communication infrastructures. It reveals key stakeholders of the system, i.e., organisations that are potentially affected by intervention in the system (Johannesson & Perjons, 2014). The actors are interdependent, demanding an understanding of their objectives and interests (Enserink et al., 2022). Figure 5 complements the analysis by arraying stakeholders on a power versus interest matrix, known as a power-interest grid (Bryson, 2004). It organises stakeholders based on their power and interests related to the research topic. In this case, key stakeholders, identified from Figure 2, are organised based on their power and interest related to the technical specifications of V2G system elements. In particular, to what extent the stakeholders could exert power on defining the technical requirements specific to V2G and to what extent they are interested in the specifications.

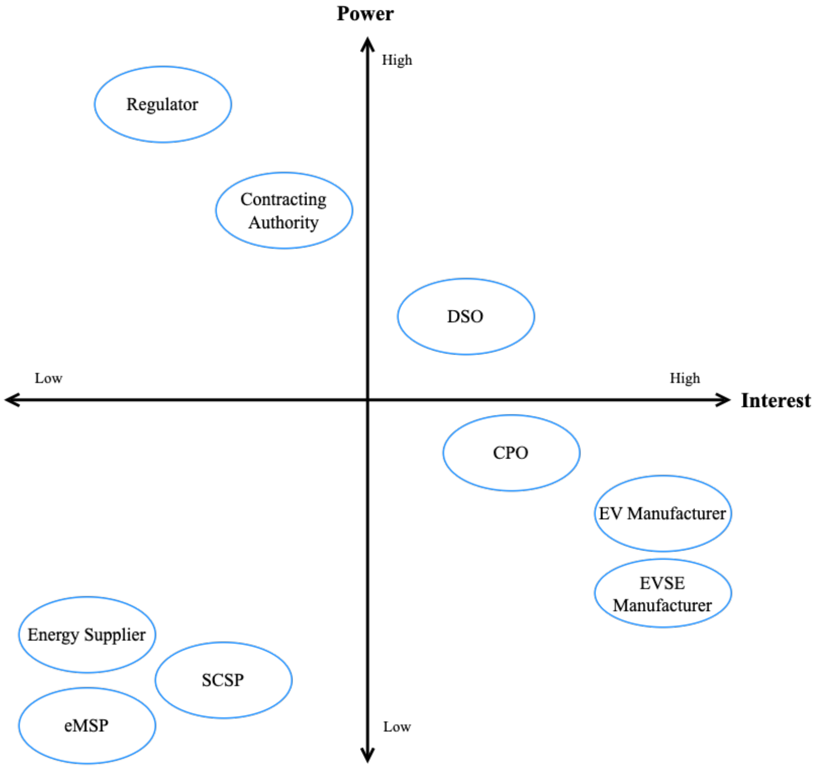

Figure 5: *Power-Interest Grid with Key Stakeholders.*

Five key stakeholder categories are identified based on the power-interest grid, namely the regulator, EV supply equipment EVSE manufacturer, Charge Point Operator (CPO), EV manufacturer, and Distribution System Operator (DSO). These stakeholder groups are considered most relevant to the development of technical requirements specific to the integration of EVs into the electricity grid for V2G purposes. The stakeholders are either involved with defining the requirements (i.e., high power) or implementation of the requirements (i.e., high interest), or both. The regulator is mainly involved with the first and is therefore considered relevant to this study. However, both national and international regulators should be involved due to the international scope of this study. DSOs are also involved with defining requirements, especially concerning grid connection. Moreover, as shown in Figure 2, DSOs need to be actively involved in the V2G system and need to develop a digital infrastructure to communicate with the other actors. Therefore, technical requirements, such as communication protocols, are relevant to this actor, next to the safe physical connection of V2G hardware to their grid. CPOs, especially in the Netherlands, are also key actors in the EV charging ecosystem. They are responsible for technical operation and maintenance of EVSE in public spaces. They are also financially at risk. CPOs acquire energy contracts for the power delivery. Therefore, they need to maximise transactions and offer additional services to maximise utilisation. They purchase EVSE at original equipment manufacturers (OEMs) and are responsible for compliance with regional regulations and industry standards. In addition, they are needed to configure EVSE correctly to enable charging services, such as V2G, and support the latest communication protocols. Therefore, CPOs are considered relevant to this study. Obviously, EVSE and EV manufacturers need to be involved too. These organisations offer the required hardware for V2G operations and must adhere to the technical specifications required for V2G-enabling products.

Other actors, such as the e-Mobility Service Provider (eMSP), Smart Charging Service Provider (SCSP), and energy supplier, are not considered for this study, since they are not directly related to the physical infrastructure required for V2G services and the implementation of underlying technical requirements. Contracting authorities are also left out of scope. These governmental organisations are primarily responsible for evaluating the bids in tenders for public charging infrastructure and therefore determine which technical standards and protocols must be applied in general. However, they are highly influenced by national policies and regulations. Therefore, involving both regulators and contracting authorities is considered redundant.

3.3.2 Participants

Table 7 presents the participants of this study, consisting of ten organisations represented by a total of twelve participants. A total of ten organisations, two of each stakeholder category, is considered sufficient due to the size of this study and time limitations. Ideally, as explained earlier, data saturation is achieved. However, this cannot be ensured with the limited number of participants and the available time of this study. Nonetheless, data saturation is monitored continuously. This study remains to provide a relevant basis for further research if data saturation is not achieved.

Table 7: *Profiles of Participants.*

Type of Organisation	Position	Professional Experience (Years)		Geographical Focus
		EV Charging	V2G	
Regulator 1	Policy Officer Electromobility & EU	11	5	National
Regulator 2	Team Leader	4	1	International
EVSE Manufacturer 1	Product Manager Public Charging	1	1	International
EVSE Manufacturer 2	Head of Strategic Enablement	6	1	International
	Product Manager Smart Charging	3	1	
CPO 1	Product Manager E-Mobility	6	3	National
	Product Owner Smart Charging	3	2	
CPO 2	Energy Development Manager	13	6	National
EV Manufacturer 1	Manager New Business & Mobility	5	2	International
EV Manufacturer 2	Business Development Manager	6	4	International
DSO 1	Innovation Manager Electric Mobility	15	5	National
DSO 2	Senior Advisor Electric Mobility	15	12	National

The participants, Regulator 1, Regulator 2, EVSE Manufacturer 1, EVSE Manufacturer 2, CPO 1, CPO 2, EV Manufacturer 1, EV Manufacturer 2, DSO 1, and DSO 2 are for the remaining of this thesis referred to as R1, R2, EVSE1, EVSE2, CPO1, CPO2, EV1, EV2, DSO1, and DSO2 respectively. The selection of interviewees is structured deliberately to ensure the representation of key stakeholders who held pivotal roles in shaping and overseeing V2G developments within their respective organisations. Each participant is identified as one of the primary individuals responsible for V2G initiatives within their organisation. This selection criterion aims to capture insights from individuals possessing comprehensive knowledge and decision-making capabilities related to V2G strategies. In addition, OEMs were selected only if their geographical focus for economic activity was internationally oriented to capture related challenges. CPOs and DSOs are commonly only operational within one country, so organisations with only a national geographical focus were reached. Moreover, both a national and international regulator were reached to explore both perspectives since both national and international regulations apply to the EV charging system.

The participants were reached through professional networks and LinkedIn. In addition, to reach relevant potential participants, several events attracting experts from the field were visited, as shown in Table F1 in Appendix F. This way, multiple participants were recruited at the events.

The participants were required to sign an informed consent form to ensure autonomy and data privacy, but participation remains voluntary (Gill & Baillie, 2018). In addition, mandatory approval from the TU Delft ethics committee is obtained.

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4 Institutions and Socio-Technical Change: A Theoretical Lens

This chapter presents a theoretical framework that will assist in interpreting the research findings by providing a theoretical lens and conceptual foundation for analyses. As explained in Chapter 3, this lens aids in deriving meaning and implications from research data rather than guiding data collection and analysis. It helps to understand why the adoption of vehicle-to-grid (V2G) technology is obstructed while maintaining the inductive nature of a grounded theory approach. This study merges the Institutional Analysis and Development (IAD) framework presented by Ostrom (2005), which identifies micro-level institutional interactions, with the Multi-Level Perspective (MLP) presented by Geels (2002), which explores macro-level transitions in socio-technical systems. Integrating these frameworks provides a comprehensive lens to analyse the adoption of V2G technology. The IAD framework focuses on institutions and actor interactions, while the MLP delves into socio-technical transitions among conceptual niches, regimes, and landscapes. This integrated approach aids in identifying and understanding the interplay between institutional arrangements and V2G technology adoption dynamics.

4.1 Institutional Analysis & Development Framework

Hodgson (2006, p. 2) presented institutions as "durable social rules and procedures, formal or informal, which structure the social, economic and political relations and interactions of those affected by them". Formal institutions are established by binding laws or regulations, while informal institutions could be constituted by norms and values and are embedded in traditional social practices. They can be seen as mechanisms for coordinating and adjusting behaviour between two or more individuals or groups of individuals (Polski & Ostrom, 2017). For example, technical requirements and standards for V2G are considered institutions, since these rules, either formal or informal, structure the interactions between actors and entities within the ecosystem. In particular, the interactions between the electric vehicle (EV) user and the Charge Point Operator (CPO) are shaped by the technical specifications and data exchange protocols applied by the EV, EV supply equipment EVSE, and other related technology. These define the type of information shared among the actors. Since this study aims at identifying substantial barriers arising from technical requirements for V2G systems, this thesis adopts the definition presented by Hodgson.

In this study, the IAD framework developed by Ostrom (Ostrom, 2005) is applied to understand how (the lack of) institutions affects the social, economic and political interactions between key actors of the system. Figure 6 depicts the framework. By applying the IAD framework, this study aims to provide a systematic analysis of how rules (i.e., technical requirements, standards, regulations, etc.) affect the actors and their interactions. It also aims to provide a basis for future policy design to improve the system. V2G requires collective action, meaning the key actors in the system collaborate to collectively tackle a common challenge, namely the need for flexibility services in the electricity grid. Collective action problems are a suitable application for the IAD framework, where the framework serves as a diagnostic tool to identify the key elements of a policy issue to consider when analysing existing policies or designing new policies (Heikkila & Andersson, 2018). While the framework has its roots in the study of common-pool resources, its adaptable nature allows for broader applicability across different contexts (Ostrom, 2011).

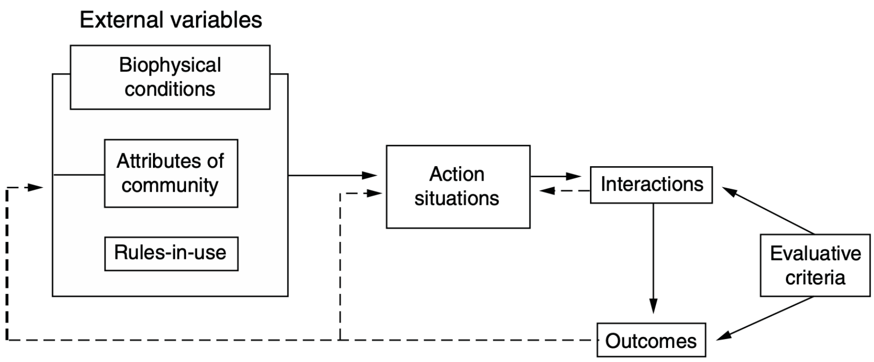

Figure 6: *IAD Framework Visualised (Ostrom, 2010).*

4.1.1 A Policy Issue

The IAD framework is a manageable framework for comprehending complex systems. It is believed to avoid oversights and simplifications that could lead to policy failures (Polski & Ostrom, 2017). The focus of the analysis is on the action arena, which includes an action situation and the actors involved in the situation. The aim is to identify the influence of biophysical conditions, community attributes, and rules-in-use on the behaviour of the actors in the action situation. The framework also aims to identify and assess the connections between patterns of interaction occurring in the action arena and the resulting outcomes (Polski & Ostrom, 2017). Applying the framework starts with isolating a policy issue or objective, forming the basis for the remaining analysis. The coordination of grid compliance of V2G-enabling products is an example of such policy issues, as acknowledged by Gonzalez Venegas et al. (2021) and Habib et al. (2018). The next sections present the key components of the framework.

4.1.2 Action Situation and Actor Interactions

As Polski and Ostrom (2017, p. 28) described, the action arena is the "conceptual space in which actors inform themselves, consider alternative courses of action, make decisions, take action, and experience the consequences of these actions". The action arena consists of the action situation and the actors who interact in the action situation. Figure 7 depicts the action situation and its elements. It consists of the characteristics of the actors, the positions (or roles) the actors hold, the set of actions that actors can take and their connection to the outcomes, the amount of information available to the actors, the level of control of the actors over actions in the situation, the potential outcomes, and the costs and benefits the actors incur when they take action. In addition, the decision-making capabilities of the actors must be understood, since these affect their choices. Their available resources, valuations or preferences, information processing capabilities, and the selection criteria they use to evaluate actions must be considered (Ostrom, 2011; Polski & Ostrom, 2017).

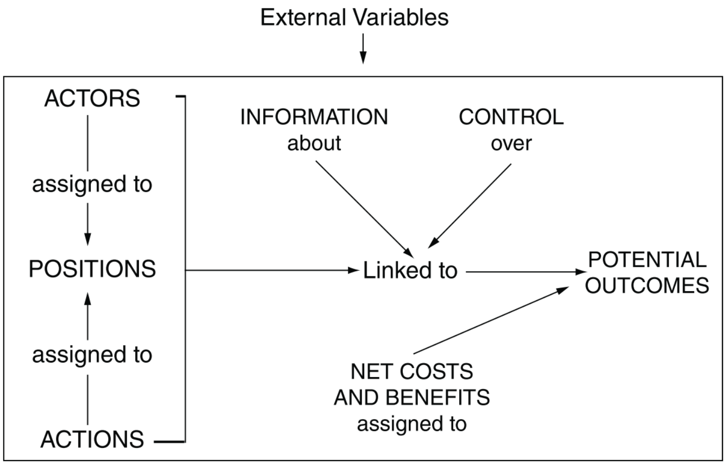

Figure 7: *Internal Elements of the Action Situation (Ostrom, 2010).*

Patterns of interaction are the conduct of the actors resulting from the structure of the action situation. They present the relationships among the actors, rules, and other external variables. The interactions result in particular outcomes and therefore represent the performance of the policy system.

4.1.3 External Variables

Ostrom identified three external variables affecting the structure of an action arena leading to particular interactions and outcomes. The IAD framework treats these variables as fixed (Ostrom, 2005). The external variables consist of the biophysical conditions of the system, attributes of the community within which the arena occurs, and the rules actors use to order their relationships. The biophysical conditions of the system refer to material and human resources and capabilities related to providing goods and services (Polski & Ostrom, 2017). The economic nature of the good or service is defined based on two attributes, namely excludability and subtractability. Excludability is the extent to which access to consumption of the good can be controlled or the difficulty of excluding potential beneficiaries. Subtractability is described by the extent to which one's consumption reduces the supply available to another. Figure 8 presents the resulting four types of goods. Next to identifying the type of good of interest, one should identify and distinguish associated production and provision activities (Polski & Ostrom, 2017). Production refers to the activities related to transforming inputs into outputs. Provision refers to the activities related to financing and distribution. The analysis of the economic nature of the good or service and its associated production and provision activities serves to provide a basis for understanding the impact of the biophysical conditions on the structure of the action situation and the resulting interactions (Ostrom, 2005).

		Subtractability of Use	
		High	Low
Difficulty of excluding potential beneficiaries	High	*Common-pool resources*: groundwater basins, lakes, irrigation systems, fisheries, forests, etc.	*Public goods*: peace and security of a community, national defense, knowledge, fire protection, weather forecasts, etc.
	Low	*Private goods*: food, clothing, automobiles, etc.	*Toll goods*: theaters, private clubs, daycare centers

Figure 8: *Types of Goods (Ostrom, 2010).*

The second set of external variables of interest is the attributes of the community. These attributes relate to the actors impacted by the policy issue. The community can be described by identifying their values, norms, and beliefs related to the policy issue (Polski & Ostrom, 2017). It is imperative to understand the cultural context of the actors since this could clarify potential conflicting interests of the actors, affecting the interactions and outcomes observed. Environmental challenges such as the energy transition require social norms and values to be adapted (or developed) to stimulate desirable, pro-environmental behaviour (Heikkila & Andersson, 2018; Kinzig et al., 2013). Therefore, social norms and values are essential elements to consider in institutional analysis.

The third set of external variables comprises the rules in use. These are the "minimal but necessary set of rules that are needed to explain policy-related actions, interactions, and outcomes" (Polski & Ostrom, 2017, p. 11). This recalls the goal of the analysis to understand how rules, either formal or informal, affect behaviour in the action arena, or the other way around. These dynamics are the core of this study since technical requirements and specifications (e.g., product standards, protocols, etc.) are the types of rules applicable to the policy issue related to V2G. These rules can limit or stimulate certain behaviours, affecting actor interactions. Simultaneously, these interactions and affiliated outcomes could affect the applicable rules. Figure 9 depicts the seven types of rules corresponding with specific elements of the action situation. As presented by Ostrom (2010), the seven rules are the following:

- Boundary rules: specify how actors are chosen to enter or leave their position;
- Position rules: specify a set of positions or roles and how many actors hold each one;
- Choice rules (or authority rules): specify which actions an actor in a given position may take (Polski & Ostrom, 2017);
- Information rules: specify channels of communication among actors and what information must, may, or must not be shared;
- Aggregation rules: specify how the decisions of actors are translated into intermediate or final outcomes;
- Scope rules: specify the outcomes that could be affected;
- Payoff rules: specify how benefits and costs are distributed to actors in positions.

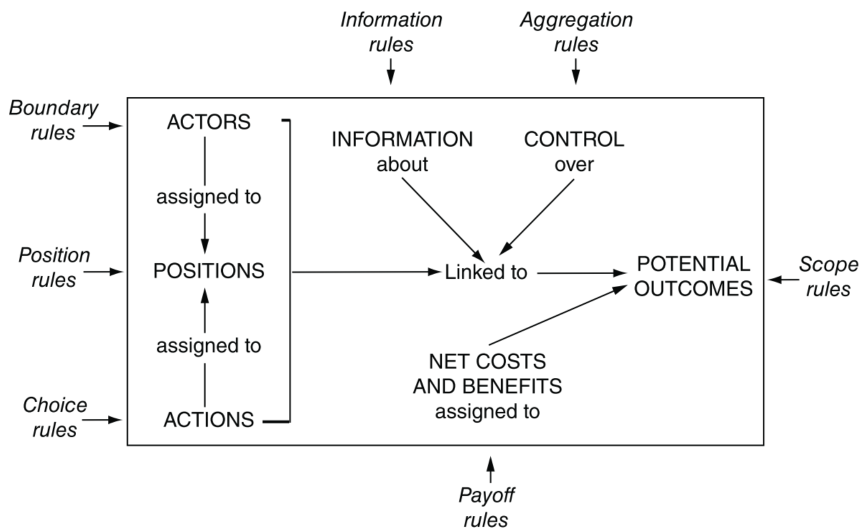

Figure 9: *Relationship between Rules-in-Use and the Action Situation (Ostrom, 2010).*

Rules are nested in other sets of rules (Polski & Ostrom, 2017). To analyse the rules affecting the actors on a day-to-day basis (i.e., operating rules), the higher-level rules must be understood. These levels are the collective-choice rules and constitutional rules. The collective-choice level consists of the rules determining who may participate in an activity affecting the operating level and how operating rules may be changed. Constitutional rules determine who may participate in developing collective-choice rules and how these rules may be changed. Understanding the interplay between the three levels aids in analysing policy issues.

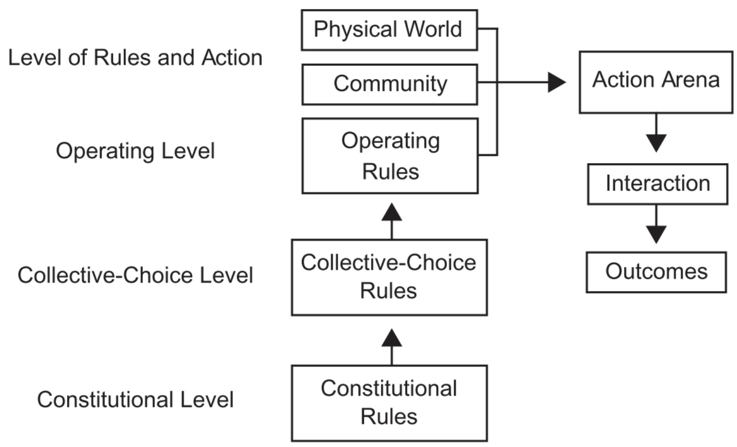

Figure 10: *The Levels of Rules related to Other Elements of the IAD Framework (Polski & Ostrom, 2017).*

4.1.4 Outcomes and Evaluative Criteria

The outcomes of the actor interactions represent the performance of the system (Ostrom, 2010). To assess this performance and compare alternative policy interventions, evaluative criteria must be specified. Examples of evaluative criteria are sustainability, adaptability, accountability, efficiency, and effectiveness, but many alternatives are possible depending on the policy issue. As Polski and Ostrom (2017) propose, one could consider assessing the outcomes based on the extent to which the policy context stimulates innovation for sustainability purposes, which could be relevant for this study. Evaluative criteria are also applied to the processes and interactions achieving the outcomes. This contributes to a comprehensive analysis of the performance of the policy system.

4.1.5 Limitations

In general, frameworks should not be used to explain or predict system behaviour (Enserink et al., 2022). Frameworks should be used for a mere description of the behaviour, meaning they attempt to identify relevant elements and interrelations one should consider for their analysis to clarify phenomena (Ostrom, 2005). They offer a lens through which phenomena can be analysed but do not explain explicitly why things happen as they do. Frameworks lack the depth and predictive capacity to offer explanations for why these behaviours occur or predict future outcomes reliably based solely on the frameworks themselves. For this study, this implies that the IAD framework serves merely as a tool to organise system behaviour and guides analysts to identify interesting patterns (Heikkila & Andersson, 2018).

One must recognise there is no single framework that captures everything necessary to consider for policy design (Heikkila & Andersson, 2018). However, the IAD framework offers a rich and often employed approach for analysing institutional arrangements. The framework enables an effective analysis of collective action problems, but analysts must take caution when translating the analysis to legislative decisions or rule-making (Heikkila & Andersson, 2018). Furthermore, institutional analysis will not generate a single best solution for policy intervention. Because of the changing nature of economic, social, and political settings, no specific set of rules will produce a fully predictable improvement of the system (Ostrom, 2005). As with any complex system, the performance of policy systems and the effect of policy interventions cannot be predicted easily due to possible emergent and chaotic behaviour (Bouwmans, 2018).

4.2 Multi-Level Perspective on Socio-Technical Transitions

The MLP on socio-technical transitions has been introduced by Geels (2002), in which insights from evolutionary economics and technology studies are combined to analyse socio-technical systems. It provides a lens to comprehend how technological advancements and innovations interact with existing regimes and the broad societal context. Analysing socio-technical systems using the MLP helps identify barriers and opportunities for the adoption of innovative technology, such as V2G, within the broader system.

The MLP consists of three levels, as Figure 11 depicts: technological niche, socio-technical regime, and landscape development. The three levels represent analytical concepts for understanding complex dynamics of socio-technical change (Geels, 2002). The technological niche level represents the environment in which radical innovations emerge. These novelties challenge existing regimes and conventional practices and provide the basis for technological transitions and co-evolutionary change. The emergence and adoption of novel technologies, however, are also influenced by developments at the regime and landscape levels. The MLP, therefore, offers an analytical perspective to understand how innovations depend on processes on the regime and landscape levels, affecting technological transitions. This socio-technical approach involves many different actors and social groups, which are often neglected in other approaches focusing on limited dimensions of sustainability (Geels, 2012). Therefore, the MLP incorporates a multi-dimensional approach and focuses on interactions between many dimensions, such as industry, markets, policy, and technology.

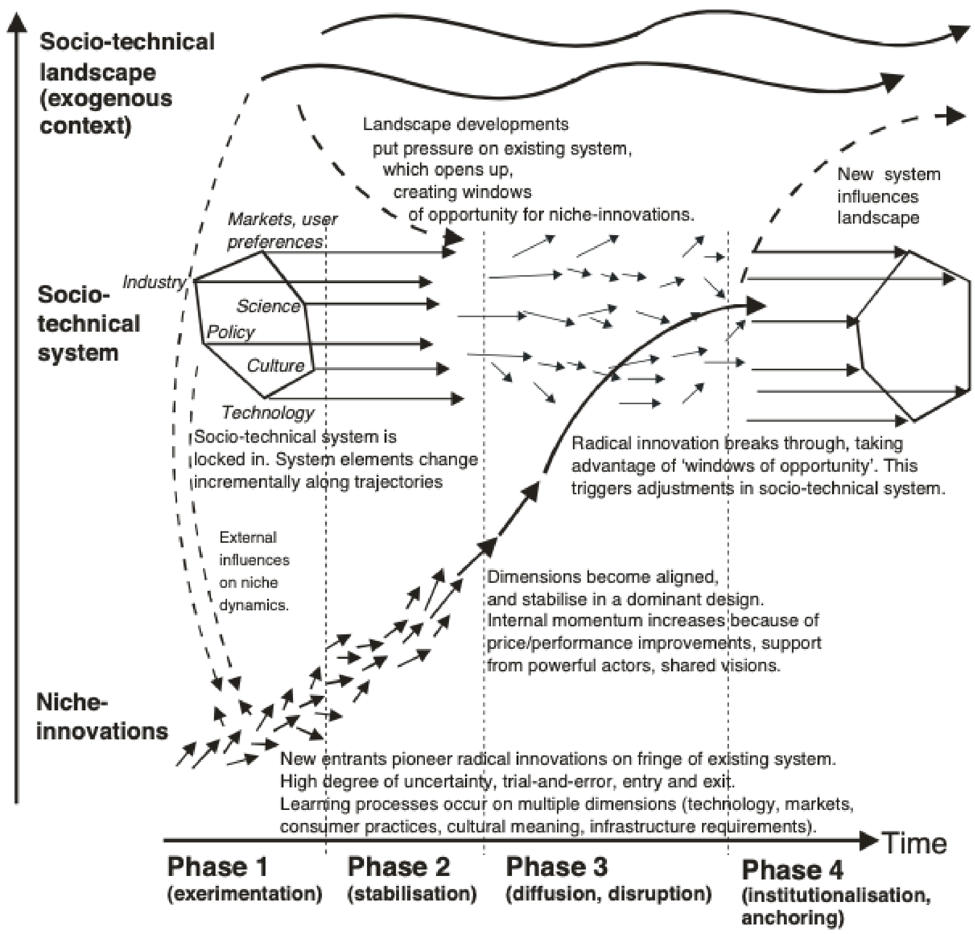

Figure 11: *The Multi-Level Perspective on Socio-Technical Transitions (Geels, 2019).*

4.2.1 From Radical Innovation to a New Regime

The landscape level provides a broad context shaping the regime and niches, such as societal values, governmental policies, and macro-level changes. Environmental challenges are an example of external developments putting pressure on the landscape level, pushing governments to implement and adapt environmental policy. Besides the niche level, innovation also occurs in the socio-technical regime, but more incrementally due to the stability of the regime. Smith and Raven (2012) present six dimensions which can show internal dynamics in the regime as a result of selection pressures. The dimensions are the following:

- Industry: established structures and decision-making mechanisms within industries, encompassing platforms and procedures that dictate resource allocation (e.g., legacy energy corporations);
- Technologies and infrastructures: technical standards and arrangements forming the backbone of infrastructures associated with specific technologies (e.g., conventional power grid and gas network);
- Science: knowledge base comprising guiding principles and socio-cognitive processes (e.g., common scientific beliefs);
- Markets and user preferences; stabilized market and supply mechanisms and dominant user behaviours influencing consumption patterns (e.g., reliance on fossil-fuel powered products);
- Policy: public policies, regulatory frameworks, and associated political power structures shaping technological transitions (e.g., fossil fuel subsidies (NOS Nieuws, 2023a));
- Culture: cultural significance and symbolic representations of the regime (e.g., societal perceptions favouring conventional energy sources, rooted in cultural beliefs).

The elements of these dimensions change incrementally along technological trajectories, meaning they follow a stable path of innovation and improvement. The internal dynamics, in addition to pressure from changes in the socio-technical landscape, could result in tensions in the regime, as visualised in Figure 11. These tensions could enable radical innovations to break out of the niche level and trigger changes in trajectories, once these innovations are more stabilised into dominant designs.

Novelties emerge in niches, which could be small markets with special demands. The actors in this level aim to stimulate the adoption of their innovations at the regime level or replace existing technologies (Geels, 2012). This way, the niche level puts pressure on the socio-technical regime. Niche innovations are unstable, but could develop into dominant designs, for example by linking multiple technologies. This is also known as co-evolution of technologies (Geels, 2005). A great example is the hybrid-electric vehicle, combining the conventional combustion engine with an electric motor. However, radical innovations do not enter the regime immediately; this happens gradually. This is known as niche accumulation, where radical innovations are used in subsequent market niches (i.e., application domains) (Geels, 2005; Geels, 2002). The diffusion of radical innovations is also driven by actor-related patterns, entailing support and involvement of relevant actors (Geels, 2005).

For niche innovations to realise socio-technical transitions, four phases are identified (Geels, 2019), as shown in Figure 11. In the first phase, niche actors engage in experimentation, in which learning is key. Niche actors confront uncertainty regarding, for example, technical performance, costs, market demand, user preferences, and social acceptance. Small-scale projects are initiated to test these uncertainties, preventing radical innovations from becoming isolated from established technologies and markets. Simultaneously, the landscape and regime exert influence, setting boundaries and influencing niche dynamics. In the second phase, niche innovations reach a more stable state, characterised by the establishment of a dominant design. This involves the exchange of experiences and aggregation of product specifications, standardised design guidelines, and best practices. Consumers become more familiar with the innovation (Geels, 2019). These developments create more stable innovation trajectories. Having achieved a stable state, the niche innovation moves into the diffusion phase. Landscape developments and niche innovations destabilise the regime, creating windows of opportunity for niche innovations to diffuse. These innovations, however, need sufficient momentum to exploit the windows of opportunity effectively and prevent incumbent actors from counteracting. Successful diffusion leads to the emergence of a new socio-technical system, embedding radical innovations within the socio-technical landscape. The seven dimensions of the regime are adapted to the emerging innovation. For example, new institutions, policies, and regulations are formed and new infrastructures are created. The new regime continues to exert pressure on the landscape, sustaining the cycle of socio-technical change.

4.2.2 Limitations and Alternatives

As explained earlier, frameworks alone should not be used to explain or predict system behaviour. The MLP is generally seen as a framework but is also a so-called 'middle-range theory' (Geels, 2011). A middle-range theory is a type of theory that aims to explain specific aspects of phenomena within a limited scope, falling between broad, overarching theories and specific empirical observations (Merton, 1949). It is more focused than 'grand theories', but broader than hypotheses. Middle-range theories often provide explanations for certain observed patterns within a particular discipline, without being overly broad or contextually limiting. Overall, the MLP serves as both a framework and a middle-range theory by providing a structured approach to analysing and understanding transitions within socio-technical systems, focusing on the dynamics between niches, regimes, and landscapes. Interpretive creativity, domain knowledge, and theoretical sensitivity are required for explanation or prediction beyond what the MLP framework provides (Geels, 2012).

The present literature uses several alternative approaches to analysing technological innovations. The Innovation System (IS) approach is an alternative to analysing the emergence of innovations and focuses on the collective action to innovation. An IS is defined as "all institutions and economic structures that affect both rate and direction of technological change in society" (Hekkert et al., 2007, p. 415). Bergek et al. (2008) introduced the Technological Innovation System (TIS) within the IS, which is a more technology specific approach. This approach is valuable in understanding the dynamics surrounding the innovation processes of specific technologies. However, it does not offer the comprehensive analytical tools required to fully grasp transitions in technological systems or socio-technical regimes. It does not focus on the position of the niche innovation related to the regime and landscape, nor on the underlying interplay, which the MLP does offer (Hekkert et al., 2007; Weber & Rohracher, 2012). Additionally, the Diffusion of Innovations (DOI) theory is a common approach to studying technological innovations (Rogers et al., 2009). While DOI theory primarily explores how innovations spread among individuals or groups within a social system, the MLP considers broader socio-technical transitions and innovation dynamics across multiple levels, including societal, technological, and institutional dimensions.

This study aims to identify system failures. Weber and Rohracher (2012) presented four transformational system failures in addition to market failures and structural system failures. These transformational system failures aid in rationalising the need for policy interventions in transformative change processes, such as socio-technical transitions. They serve as guidelines for the justification of policy intervention. Weber and Rohracher (2012) build on the MLP and extend its application to innovation policy studies to put pressure on the currently dominant perspective offered by the IS approach. Therefore, this study applies these concepts to the analysis of the V2G system.

4.3 An Integrated Approach

As shown earlier, the IAD framework primarily focuses on micro-level interactions based on rules, actors, and resources within specific action situations. However, it lacks a view of the influence of the broader societal context, does not capture the long-term implications of institutional barriers, and, as a framework, is not suitable to explain and predict phenomena. On the other hand, the MLP might overlook the complexity and influence of micro-level interactions and institutional arrangements shaping the behaviour of niche actors within a socio-technical regime. Applying the IAD framework aids in describing and analysing the rules and actor interactions within the regime, which influence the acceptance of or resistance to niche innovations. Combining the IAD framework and MLP offers a more holistic view of the socio-technical system and the diffusion of V2G technology. An integrated approach provides a bridge between micro-level interactions (IAD) and macro-level contextual influences (MLP), offering a comprehensive understanding of how institutional arrangements within the socio-technical regime affect niche actors and the adoption of V2G.

The integrated approach focuses primarily on the left half of Figure 11, representing the first two phases of socio-technical transitions. V2G technology represents the radical innovation and technological niche. The established electric power system, currently encompassing largely of conventional supply and flexibility services offered by fossil fuel power plants, serves as the socio-technical regime. The main components of this regime are power generators, transformers, and transmission and distribution networks (Banerjee et al., 2016). The IAD framework aids in describing interactions between the emerging niche innovation and the established regime, as well as the influence of landscape developments on the regime and, albeit indirectly, the niche innovation. The MLP, therefore, serves as the conceptual context of the institutional analysis on the emergence of V2G technology. The analysis identifies institutional failures within the six dimensions of the regime and the socio-technical landscape, providing a basis for understanding relations between the three levels constraining the diffusion of V2G.

5 Empirical Results

In accordance with the interview approach outlined in Section 3.3, semi-structured interviews were conducted with ten organisations representing five key stakeholder groups. The participants were selected based on their affiliation with V2G in their position in the organisation. The organisations were selected based on their power and interest in V2G developments. The interviews were organised around a set of predetermined open questions and maintained room for emerging follow-up questions. Ethical considerations, including informed consent and data anonymity, were strictly adhered to throughout the interview process. The principles of the three coding phases of the grounded theory approach are applied to analyse the empirical data.

This chapter covers the insights derived from the three coding phases: open coding, axial coding, and selective coding. In the open coding phase, the empirical data retrieved from the interviews are broken down into discrete components to uncover emergent themes. Consequently, axial coding interconnects open codes, revealing recurring patterns and relationships that underlie the complexities of vehicle-to-grid (V2G). The selective coding phase organises the preceding phases, connecting axial codes to construct a coherent theme. This core theme guides the study towards developing a theory for the phenomena observed in the dataset before engaging the theoretical framework presented in Chapter 4.

Firstly, Section 5.1 addresses data saturation. The succeeding sections present the results emerging from the three coding phases.

5.1 Data Saturation

Figure 12 shows the number of insights gained throughout the data collection phase. The number of insights represents the open codes emerging in the data and were tracked after the interviews were performed. As shown, after six interviews, little new insights were observed. This implies data saturation is reached, referring to "the point in data collection when no additional issues or insights are identified and data begin to repeat so that further data collection is redundant, signifying that an adequate sample size is reached" (Hennink & Kaiser, 2022, p. 2). Figure 12 shows that interviews EVSE1 and CPO1 were significant contributors to the total number of insights, meaning little insights were gained at the subsequent interviews. Therefore, a sufficient sample size was reached.

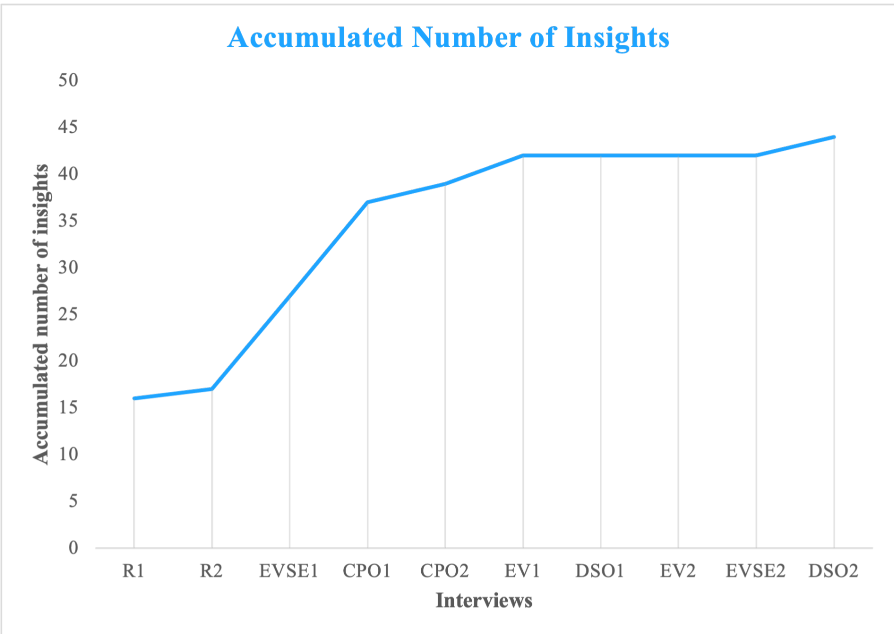

Figure 12: *Data Saturation Visualised.*
Note. This figure presents the accumulated number of insights (i.e, open codes) after each interview. The data are presented chronologically.

5.2 Open Coding

Table D1 lists all codes emerging from the interview data. In total, 44 codes were identified among the ten interviews. Table 8 presents the open codes emerging the most. Tables D2 to D11 from Appendix D present the open codes for each participant. By applying the constant comparison method, the total number of open codes could be limited to a manageable quantity. The open codes present barriers to V2G implementation and related causes and effects. This ensures the relevance of the open codes while maintaining a manageable overview. The open codes lay the foundation for the axial coding phase.

Table 8: *Most Emerging Open Codes.*

Open Code	Groundedness	Participants
call for standardisation in general	9	CPO1, CPO2, DSO1, DSO2, EV1, EV2, EVSE1, EVSE2, R1
need for common standard across Europe	8	DSO1, DSO2, EV1, EV2, EVSE1, EVSE2, R1, R2
charging standard ambiguity (AC or DC)	7	CPO1, CPO2, DSO1, EV1, EV2, EVSE1, EVSE2
network codes requirements ambiguity	7	CPO1, CPO2, DSO1, EV1, EV2, EVSE1, R2
ambiguity in future protocol requirements	6	CPO1, CPO2, DSO2, EV1, EVSE1, EVSE2
DSO-CPO communication standard ambiguity	6	CPO1, CPO2, DSO1, EVSE1, EVSE2, R1
hardware requirements specific to V2G are unknown	6	CPO1, CPO2, DSO1, EV1, EV2, EVSE2
lack of DSO-CPO communication infrastructure	6	CPO1, CPO2, DSO1, EVSE1, EVSE2, R1
lack of V2G EVs as limiting factor	6	CPO1, CPO2, DSO1, EV2, EVSE2, R1
process of standardisation is slow	6	DSO1, DSO2, EV2, EVSE2, R1, R2
risk of market fragmentation Europe	6	CPO2, DSO1, EV1, EV2, EVSE1, EVSE2
who should be in control V2G session	6	CPO1, CPO2, DSO2, EV1, EV2, R1

Note. This table presents the open codes emerging more than five times in all interview data. Open codes are in order of groundedness, i.e., the total number of times the particular code emerges in the dataset. The third column presents the interviews in which the open codes emerge.

5.2.1 Regulators

As shown in Table 9, standardisation is a central theme in both interviews with regulators. Both mention the need for common standards across Europe in favour of national standards. R1 sees standardisation as the way to make big steps in the implementation of V2G (see Appendix C.1). However, the participant realises that standards are usually defined on a European level, meaning the Netherlands is relying on European developments. Both participants acknowledge that European standardisation is a slow process, but also that it is needed to accelerate the implementation of V2G on a large scale. Both mention several aspects of the V2G ecosystem to which standards are needed, such as communication infrastructures between the various actors. R1 supports the application of the Open Charge Point Protocol (OCPP) protocol, which is currently the de facto standard in the Netherlands. However, the participant mentions resistance by some Member States is observed, obstructing European adoption of the standard. This emphasizes the observation of both participants of various actors having a strong influence on standard-setting processes. In particular, some actors exert influence due to the threat of specific standards to affect their business model (or opportunity, in case of a positive effect on the business model). For example, according to R1, ISO 15118 is believed to give electric vehicle (EV) manufacturers too much influence in the V2G ecosystem. Moreover, while R1 condemns resistance to OCPP, the participant appreciates that competing standards enable a competitive market. However, the Netherlands is seen as a pioneer in terms of EV charging (see R1, CPO1, EV1, and DSO2). Therefore, OCPP is gaining much support from Dutch regulators, such as R1.

R2 elaborates merely on the harmonisation of network codes, since the network codes are currently inadequate for V2G applications and non-harmonised among the Member States of the European Union (EU) (see Appendix C.2). The participant elaborates on harmonisation attempts. Moreover, the participant also states standards are too prescriptive, meaning the network codes are not intended to mandate the application of specific standards. Therefore, R2 is not related to the open code 'call for standardisation in general', as shown in Table 8. However, R2 acknowledges the negative effects of non-harmonised network codes. For example, the participant mentions concerns from original equipment manufacturers (OEMs), i.e., EV and EV supply equipment (EVSE) manufacturers, due to diverging requirements within the EU. The participant acknowledges that non-harmonised network codes are a hurdle to electric mobility at the moment. In contrast, R1 states the network codes are no obstacle to V2G implementation, as shown in Table D13 in Appendix D.6.

Table 9: *Open Codes Regulators (Consolidated).*

Regulators	
Open Code	**Groundedness**
need for common standard across Europe	8
process of standardisation is slow	6
network codes disparities Europe create uncertainty	5
influence of actors on setting standards	3

Note. This table presents the open codes emerging in both interviews with regulators. Open codes are in descending order of groundedness.

5.2.2 EVSE Manufacturers

The EVSE manufacturers delve deeper into the technical requirements for V2G-enabling products (see Tables D4, D5, and 10). Both interviewees elaborate on their concern about whether alternating current (AC) or direct current (DC) will become the charging standard for V2G. They both state there is a risk of EVSE currently operational needing to be replaced when DC becomes the standard since most operational chargers are operating on AC and are therefore lacking the hardware to enable DC V2G (e.g., an inverter). Next to the charging standard ambiguity, both participants are worried about possible market fragmentation and segmentation within Europe due to technical requirements disparities. Market fragmentation is observed when each country exerts different requirements for public chargers, resulting in EVSE manufacturers producing different products for each regional market. This results in chargers becoming more expensive, as stated by EVSE2 (see Appendix C.4). Market segmentation, on the other hand, is observed when only a specific set of EVs can be used with a specific set of EVSE. EVSE1, for example, mentions the risk of non-harmonised network codes to negatively affect interoperability of EVSE and EVs (see Appendix C.3). Because of these concerns, both interviewees pledge to European standards and guidelines. According to the two participants, another important aspect of the V2G ecosystem requiring a technical standard, is the communication infrastructure between Distribution System Operators (DSOs) and Charge Point Operators (CPOs). They both acknowledge that the DSO should be integrated into the EV charging ecosystem, creating an active role for DSOs. This requires, however, a communication infrastructure with which specific data can be exchanged. OpenADR is one of such communication protocols, but, according to EVSE1, OCPP is seen as the preferred alternative. However, if OCPP would indeed enable such communications, an updated version is required. The interviewees are both concerned future protocol versions affect the hardware requirements for their products, again implying a possibility of public chargers needing to be replaced or adapted.

As shown in Table D12, EVSE2 and four other participants state the ISO 15118 protocol does not support data exchange regarding network codes. As explained earlier, network codes can diverge within the EU. This requires EVs, when crossing borders, to know which network code applies when performing V2G. Therefore, the commonly applied protocol ISO 15118 should support the exchange of such data. In contrast, EVSE1 states this is possible with the ISO 15118 protocol. In addition, as shown in Table D15, EVSE1 states the hardware requirements for V2G-compatible chargers are known, contrary to statements by six other interviewees.

Table 10: *Open Codes EVSE Manufacturers (Consolidated).*

EVSE Manufacturers	
Open Code	**Groundedness**
call for standardisation in general	9
need for common standard across Europe	8
charging standard ambiguity (AC or DC)	7
DSO-CPO communication standard ambiguity	6
lack of DSO-CPO communication infrastructure	6
risk of market fragmentation Europe	6
ambiguity in future protocol requirements	6
risk of market segmentation Europe	5
EVSE adaptation risk	4

Note. This table presents the open codes emerging in both interviews with EVSE manufacturers. Open codes are in descending order of groundedness.

5.2.3 CPOs

The two CPOs are very much aligned concerning their concerns regarding V2G implementation (see Tables D6, D7, and 11). Again, the risk of EVSE to be replaced due to new hardware requirements is mentioned. Both participants state CPOs have a significant financial risk when EVSE need to be replaced since they are the owners. In the Netherlands, when a municipality decides to offer V2G services in a specific region, they want the public chargers to support this functionality. However, if the chargers currently in the field do not suffice, the CPO will need to provide an alternative charger or the concession might be lost to another operator. The participants observe a lack of knowledge of contracting authorities. According to CPO1, consultants are frequently involved in drawing up tenders for the municipalities (see Appendix C.5). They hear about standards such as ISO 15118 and other technical requirements and then include them in the tender, but they are not fully aware of the implications for the manufacturers and CPOs. CPO2 also states contracting authorities often do not know the answer to why they are demanding some of the requirements. The CPOs observe unrealistic and very demanding requirements, often unnecessary for the applicable situation. For example, they are demanding compliance with future versions of certain protocols, without knowing the hardware requirements for these future versions. Therefore, both CPOs are also doubting some OEMs already claiming their products are V2G-ready. The CPOs are also uncertain about the requirements related to the network codes and are demanding clarity from the grid operators, who currently fail to do so. According to the CPOs, it is unknown what the requirements are, who must comply with the network code, and how the network code should be communicated. In general, according to the CPOs, it is unknown what "V2G-ready" actually entails.

The CPOs are also questioning who should control the V2G sessions. With this, they mean, for example, who should decide the discharging speeds and schedule. CPOs are afraid to lose control since they have financial risk. The CPO wants to remain in control because they purchase the energy, and that must match the energy sold. They must therefore be able to accurately predict at what time how much energy is consumed. If another entity controls and influences the charging process, the predictions will deviate more from reality, and the CPO will run financial risk, possibly resulting in fines. Therefore, as CPO2 states, CPOs are expecting a reward for discharging services when their regular revenue streams are affected (see Appendix C.6). Next to their concerns regarding who should be in control, both CPOs question whether AC or DC will be the charging standard, same as the EVSE manufacturers. In addition, they are elaborating on the lack of communication infrastructure between DSOs and CPOs, and are demanding clarity for standards to implement. Nonetheless, since these CPOs are not operational internationally, they do not express any clear preference regarding European standards instead of national standards. Therefore, CPO1 and CPO2 are not related to the most emerging open code 'need for common standard across Europe', as shown in Table 8. However, CPO2 states technical requirements disparities within Europe would limit their number of alternative suppliers. In particular, the CPO could only select EVSE suppliers offering products complying with the requirements applicable to their region. Next the these uncertainties, the CPOs are elaborating on the currently lacking environment for pilot projects to experiment with V2G services. The pilot environment refers to the context or setting in which the pilot project takes place. It presents the conditions that surround the implementation of the project. The CPOs mainly blame the lack of V2G-compatible EVs and realistic requirements and standards for the lacking pilot conditions.

Table 11: *Open Codes CPOs (Consolidated).*

CPOs	
Open Code	**Groundedness**
call for standardisation in general	9
charging standard ambiguity (AC or DC)	7
network codes requirements ambiguity	7
DSO-CPO communication standard ambiguity	6
hardware requirements specific to V2G are unknown	6
lack of DSO-CPO communication infrastructure	6
lack of V2G EVs as limiting factor	6
ambiguity in future protocol requirements	6
who should be in control V2G session	6
doubtful claims V2G-readiness	5
lack of knowledge contracting authority	5
influence of actors on setting requirements	4
financial risk V2G activity	4
financial risk EVSE replacement	3
unrealistic pilot environment	3
who must comply with network code	3
grid operator to specify network code communication	2

Note. This table presents the open codes emerging in both interviews with CPOs. Open codes are in descending order of groundedness.

5.2.4 EV Manufacturers

The EV manufacturers state similar issues as the CPOs and EVSE manufacturers (see Tables D8, D9, and 12). EV manufacturers are stating they run financial risk with V2G services, opposed to CPOs. As EV1 states, with V2G, there is also a revenue model, which in the public domain is observed for one party, the CPO, but not for the EV manufacturer (see Appendix C.7). That one party may have all the advantages, but not the disadvantages as is the case for EV manufacturers, such as possible battery degradation and therefore warranty claims. As EV2 also states, the car manufacturer also bears high development costs but receives nothing in return (see Appendix C.8). Therefore, EV manufacturers are also questioning who should be in control of V2G sessions. With current protocols, EVSE cannot acquire all necessary information from EVs to enable bidirectional charging. This concerns, for example, state-of-charge information. The charging station and the car must not conflict with the charging profile they want to apply, as stated by EV2. A charging station must therefore be able to view more information from the car, or the car must have more control over the charging station. However, as explained earlier, EV manufacturers are afraid to lose control over charging sessions, therefore there is a possibility they will not open up their system for third parties.

Table 12: *Open Codes EV Manufacturers (Consolidated).*

EV Manufacturers	
Open Code	**Groundedness**
call for standardisation in general	9
need for common standard across Europe	8
charging standard ambiguity (AC or DC)	7
network codes requirements ambiguity	7
hardware requirements specific to V2G are unknown	6
risk of market fragmentation Europe	6
who should be in control V2G session	6
risk of market segmentation Europe	5
doubtful claims V2G-readiness	5
unable to communicate network code to EV/EVSE	5
financial risk V2G activity	4
impact on EV battery health	3
EVSE lack data from EV	3
pilots require diverse actors	3

Note. This table presents the open codes emerging in both interviews with EV manufacturers. Open codes are in descending order of groundedness.

As shown earlier, EVSE1 and EVSE2 are stating the opposite regarding the possibility of communicating network code information between EVSE and EVs. EV1 and EV2 also state the current protocol does not support this type of data exchange. The four OEMs, however, are agreeing on other topics. As shown in Table 13, the four participants are all questioning whether AC or DC will be the charging standards, as this affects their product designs. They are afraid of market fragmentation and market segmentation, therefore pledging to European standards.

Table 13: *Open Codes OEMs (Consolidated).*

OEMs	
Open Code	**Groundedness**
call for standardisation in general	9
need for common standard across Europe	8
charging standard ambiguity (AC or DC)	7
risk of market fragmentation Europe	6
risk of market segmentation Europe	5

Note. This table presents the open codes emerging in all interviews with EV and EVSE manufacturers. Open codes are in descending order of groundedness.

5.2.5 DSOs

Standardisation was also a central theme in the interviews with DSO1 and DSO2, as shown in Table 14. DSO2, however, believes competing standards enable a competitive market (see Table D16). Setting a standard too quickly can greatly hinder innovation (see Appendix C.10). Both participants are in favour of standardisation on a European scale but acknowledge that these processes are slow. DSO2, therefore, argues against the need for solely European standards. The participant is convinced not everything should be solved on a European level, since this takes time. The Netherlands cannot wait for time-consuming standardisation, since grid congestion demands action in the short term. DSO1, therefore, mentions that the participant would be satisfied if there would be a national standard for communication between the CPO and DSO, which is now lacking (see Appendix C.9). However, with the integration of DSOs into the V2G ecosystem, DSO1 is concerned the DSOs will not be quick to set up their systems to control charging stations. DSOs are expected to have a more active role, as stated by EVSE1 and EVSE2, but DSO1 does not necessarily demand this. According to DSO1, it is mainly important for the grid operator that V2G activities are done safely and following the applicable rules.

Interestingly, as shown in Table D14 and D15, DSO2 states the hardware requirements for V2G products are clear and that the grid operator already provides these requirements. However, DSO2 also acknowledges that requirements for future protocols are unknown, which could mean public chargers need to be replaced. However, as shown in Table D17, the participant sees this as a negligible risk, since these chargers are visited by service engineers either way. The participant, therefore, suggests EVSE manufacturers should add hardware to their chargers now and make the chargers modular to more easily adapt to future requirements.

Table 14: *Open Codes DSOs (Consolidated).*

DSOs	
Open Code	**Groundedness**
call for standardisation in general	9
need for common standard across Europe	8
process of standardisation is slow	6

Note. This table presents the open codes emerging in both interviews with DSOs. Open codes are in descending order of groundedness.

5.3 Axial Coding

This section presents the axial codes identified based on the open codes. Axial codes are overarching themes, connecting open codes related to a specific theme. In total, eight axial codes are identified. Table 15 presents the axial codes with a brief description of the code, an example from the empirical data, and its size. The size represents the number of open codes related to the axial code. Tables E1 to E8 in Appendix E show the underlying open codes for each axial code. The axial codes lay the foundation for the selective coding phase, in which an overarching theory is proposed by identifying connections between the axial codes. The axial codes emerged following the constant comparison method in which data were constantly compared to discover similarities and differences. This way, axial codes were defined and refined iteratively.

Table 15: *Description of the Axial Codes, including Examples and Size.*

Axial Code	Description	Example from data	Size
charging standard ambiguity	Codes related to the ambiguity of whether AC or DC will be the standard for bidirectional charging.	*...will it be AC or DC? The choice is mainly determined by the car manufacturers, and not top-down. (DSO1)*	7
control authority V2G sessions	Codes related to the actor to be in control of V2G charging sessions.	*The EV manufacturer is particularly afraid of losing control with V2G, in the public domain... (EV1)*	8
DSO integration	Codes related to integrating DSOs into the charging ecosystem and infrastructures.	*There is still uncertainty about how the grid operator will communicate about local grid congestion, ... (CPO2)*	4
pilot conditions	Codes related to the lacking conditions for pilot projects and testing.	*... They learn not much from pilots with old protocols... (EV1)*	9
network codes	Codes related to the network codes applicable to the V2G ecosystem.	*It is still unclear who must comply with the network code. The car or the charging station? (CPO1)*	11
technical requirements deficiency	Codes related to missing, inadequate, or incomplete technical requirements.	*Want to prevent the charging stations in the field from having to be visited in an X number of years for new hardware due to new grid codes. (EVSE1)*	17
technical requirements disparities	Codes related to inconsistent or divergent technical requirements across geographical regions.	*... Every country has different requirements, which translates into different hardware. (EVSE2)*	7
standardisation	Codes related to technical standards and the development of standards.	*Standardisation is the way to make big steps. (R1)*	8

Note. The fourth column presents the size of each category, i.e., the number of open codes. Axial codes are in alphabetical order.

5.3.1 Emergent Patterns

The first axial code, outlined in Table E1, establishes connections among open codes concerning the ambiguity surrounding charging standards. This code encompasses discussions on the merits and drawbacks of the two distinct charging standards, along with considerations of the consequences for various actors and their preferences. It includes codes addressing concerns such as the potential need to replace public chargers if DC becomes the prevailing standard for V2G, as identified by EVSE1, EVSE2, CPO1, and DSO1. Additionally, it explores the implications for specific stakeholders if either DC or AC emerges as the standard. For instance, with DC adoption, electric vehicles would necessitate less hardware for V2G applications, as stated by EV1. However, if AC becomes the standard in a particular EU country, EV manufacturers might need to create a separate version of the vehicle tailored for the European market to support AC V2G. Therefore, EV1, EV2, EVSE1, and EVSE2, among others, fear the absence of a unified decision across Europe will result in market fragmentation within the EU.

The second axial code, detailed in Table E2, establishes connections among codes surrounding the entity to be responsible for managing V2G charging sessions. Once again, this code delves into the outcomes for and preferences of various stakeholders, with a primary focus on CPOs and EV manufacturers. The implications extend beyond individual issues, touching upon additional insights. The decision regarding control authority significantly impacts business models, potentially leading to a loss of influence and revenues for actors such as CPOs, as stated by CPO1 and CPO2. Consequently, achieving a unified decision on this matter across Europe becomes imperative for most participants.

The third axial code, showcased in Table E3, highlights the integration of the DSO into the V2G ecosystem. This code predominantly connects open codes associated with the communication infrastructure between CPOs and DSOs, which is presently lacking. The open codes delve into proposed standards and the preferences of different stakeholders regarding these standards. For example, CPO1 indicates OpenADR, a possible protocol for such communication, is outdated, while DSO1 marks OpenADR as the preferred standard. Again, the implementation of a European standard would benefit many actors but could slow the process.

The fourth axial code, shown in Table E4, addresses the inadequacy of pilot conditions. This encompasses open codes that portray the challenges faced by actors in initiating pilot projects. Specifically, OEMs and CPOs highlight either the absence of V2G-enabled EVs or the absence of V2G-enabled EVSE as limiting factors. This reveals a classic chicken-and-egg dilemma, where actors await each other to introduce V2G products. Nevertheless, there is a shared acknowledgement among actors that diverse collaboration is essential to realise V2G through pilot projects. However, the current protocols and standards in use are not fully prepared for V2G, restricting research & development (R&D) initiatives, as indicated by EV1. Consequently, there is a pressing need for technical standards to facilitate V2G, ideally on a European scale.

The fifth axial code, outlined in Table E5, establishes connections among open codes concerning network codes relevant to V2G. This incorporates discussions regarding the content of the network codes, which presently lack adaptation for V2G, causing uncertainty among various stakeholders. Additionally, there is ambiguity for certain actors regarding who is responsible for complying with the network codes (the EV or EVSE), the procedures for verifying compliance, and how the network codes are communicated and implemented.

The sixth axial code, detailed in Table E6, establishes connections among open codes related to technical requirements deficiency. The term 'technical requirements' refers to the technical product requirements for V2G-enabling products, which mainly entails EVs and EVSE and underlying infrastructures such as communication protocols. Unlike the previously discussed axial codes, this code has a more general scope by encompassing numerous open codes also linked to other axial codes. Nevertheless, it emerges as a recurring theme in the dataset. It includes open codes addressing the absence, inadequacy, or incompleteness of technical requirements. Many participants state they do not know what "V2G-ready" actually entails, among which CPO1, CPO2, EV1, EV2, and EVSE2. The axial code encompasses requirements related to network codes and V2G-specific hardware. The code also encompasses considerations of the consequences of technical requirements deficiency for various stakeholders, such as the potential future replacement of public chargers. Standardisation is recognised consistently as a crucial mechanism to enhance clarity. Furthermore, grid operators are perceived as the entities responsible for ensuring this clarity, a responsibility that, according to some participants, they currently fall short of fulfilling.

The seventh axial code, outlined in Table E7, also takes a broader perspective, focusing on requirements disparities. This encompasses open codes related to inconsistent or divergent technical requirements across different geographical regions. Recognising that technical requirements disparities could lead to market segmentation and fragmentation, as discussed previously, several participants emphasise the need for common standards across Europe as a necessary means to prevent such outcomes.

The concluding axial code, highlighted in Table E8, delves into the recurring theme of standardisation. This code focuses on the perspectives of the participants regarding the advantages and disadvantages associated with standardisation. This code focuses on the process in general, while other axial codes focus on specific standards.

Standardisation is often viewed as a promising means to harmonise the V2G system, but it is also recognised as a slow process. Additionally, the adoption of specific standards may impact the business models of various stakeholders. For instance, ISO 15118-2 is noted to diminish the role of the e-Mobility Service Provider (eMSP), as charge cards become obsolete, according to CPO1.

The latter three axial codes were identified in the final stages of the analysis. Initially, the focus was directed towards axial codes that encompass open codes associated with specific technical challenges. The identification of the first five codes led to two overarching categories of technical challenges: technical requirements deficiency and technical requirements disparities. Most open codes within the axial codes related to the charging standard, DSO integration, and network codes pertained to one or both of these categories, capturing the nature of the predominant issues. Additionally, the theme of standardisation prominently surfaced in the top two open codes derived from the data, showing its significance. In this manner, the development of the eight axial codes provides a comprehensive overview of the phenomena observed in the dataset.

5.3.2 Groundedness

Table 16 illustrates the groundedness of the axial codes. The contribution of each participant is showcased, revealing the number of open codes linked to a particular axial code emerging in the empirical data. This table aids in identifying predominant themes in the interviews and estimating the respective significance of each interview to the axial code. For instance, CPOs exhibit a relatively greater concern about requirements deficiency compared to requirements disparities. Furthermore, standardisation emerges as a prominent theme in the interviews with R1, R2, and DSO2, distinguishing them from the other interviews. The axial code related to the control authority for V2G sessions is mostly emerging in the interviews with the EV manufacturers and CPOs. The integration of the DSO into the EV charging ecosystem has a relatively low occurrence in the interviews with the EV manufacturers since they are less dependent on these developments. The axial codes related to the charging standard, network codes, and pilot environment are emerging relatively equally in most interviews.

Table 16: *Axial Codes Groundedness.*

Axial Code	Size	R1	R2	EVSE1	EVSE2	CPO1	CPO2	EV1	EV2	DSO1	DSO2
charging standard ambiguity	7	1	1	5	5	4	4	4	4	6	2
control authority V2G sessions	8	3	1	2	5	4	3	6	6	1	2
DSO integration	3	3	1	3	3	2	2	1	1	3	1
pilot conditions	9	6	1	2	6	6	3	6	6	4	3
network codes	11	3	3	5	2	5	6	3	4	4	1
technical requirements deficiency	17	2	1	5	8	10	9	6	5	5	7
technical requirements disparities	7	4	3	4	4	0	4	3	3	3	3
standardisation	8	8	3	2	5	3	1	3	3	3	7

Note. This table indicates the groundedness of the axial codes, i.e., the number of open codes related to a particular axial code emerging in the specific interview.

5.4 Selective Coding

In the process of selective coding, a central theme emerges to guide the development of an overarching theory of the phenomena observed. The primary objective of selective coding is to identify a central concept that synthesises and organises the relationships among the axial codes. Figure 13 visualises the connections between the axial codes and the core category, referred to as the selective code. The identified core category is denoted as *stakeholder coordination*, signifying coordination attempts by or a need for improved coordination among stakeholders within the V2G ecosystem.

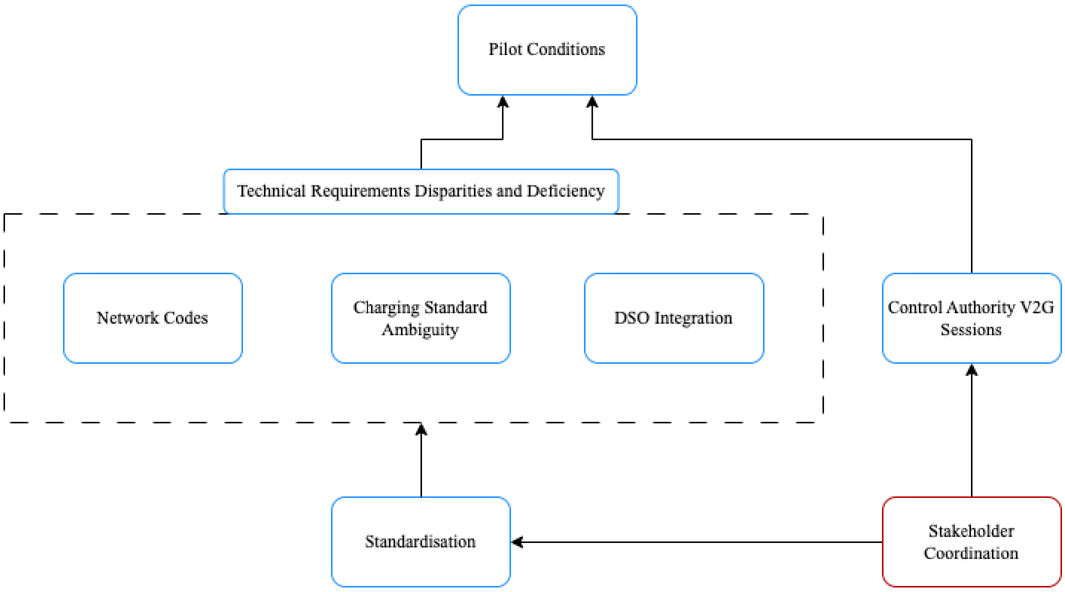

Figure 13: *Axial Codes and Selective Code with Interconnections.*
Note. Axial codes are in blue, selective code in red. The directed arrows indicate relationships between codes.

5.4.1 Connecting the Codes

Three axial codes uncover issues related to technical requirements disparities and deficiency. Both overarching themes are present with either axial code. As demonstrated earlier, variations in network codes, DSO integration, and the charging standard across different countries underscore requirements disparities. Concurrently, within each of these three categories, a lack of clear guidelines and uncertainty on how OEMs and CPOs can become "V2G-ready" exemplify technical requirements deficiency. Figure 13 visualises the connection between the three axial codes related to the technical issues and the two related to the technical requirements of the V2G system.

Standardisation is a frequently recurring theme within three axial codes: network codes, charging standard ambiguity, and DSO integration. For each of these technical challenges, standardisation is often seen as the required solution. The OEMs (i.e., EV1, EV2, EVSE1, and EVSE2) demand a European-wide decision on the charging standard and network codes to be able to offer a single product for the European market since diverging requirements would affect the design of the hardware of their products. This way, market fragmentation would be prevented, as stated by these participants. Simultaneously, DSO1, CPO1, CPO2, and EVSE1 demand a uniform solution for communication between CPOs and DSOs to enable V2G. Standards such as OpenADR and OCPP are mentioned by the participants and are expected to play a role here. Therefore, standardisation and the three technical challenges discussed can be linked, as visualised in Figure 13.

The discussion surrounding the control authority of V2G sessions is a relatively distinctive subject. The participants do not highlight standardisation as a means to enhance clarity. However, according to EV2, a cohesive decision is imperative to prevent market segmentation. Participants underscored that market entities are currently initiating one-to-one solutions due to the absence of a unified perspective on V2G session management. Consequently, EV manufacturers are initiating exclusive collaborations with other market players, such as EVSE manufacturers, CPOs, and energy utilities, to facilitate V2G integration with their products. The determination of the control authority is presented separately from the previously discussed technical requirements, as it aligns primarily with business considerations. As articulated by R1, the government is urged to endorse an open market accommodating diverse business models, thus maintaining a neutral position. Therefore, the market is largely entrusted to navigate on its own.

The axial code that captures the conditions for pilot projects is linked to disparities and deficiencies in technical requirements, along with the control authority of V2G sessions. These three challenges are identified as primary obstacles for market entities aiming to initiate pilot initiatives and explore V2G functionalities. As CPO1 emphasised, pilot projects must take place in a realistic environment with realistic requirements, so that they are easier to scale. Both CPO1 and CPO2 express their anticipation for EV manufacturers to provide V2G-enabled hardware. In contrast, EV2 and R1 highlight the lack of V2G infrastructure as a limiting factor. However, as stated by EV1, experimenting with outdated standards yields limited insights for manufacturers. The organisations expected to offer clarity on technical requirements often fall short, advocating a 'just do something and test it' approach. However, manufacturers cannot justify such experimentation to their international headquarters, as explained by EV1. Consequently, EV1, alongside EV2, EVSE1, and EVSE2, demand European-wide standards to facilitate V2G. Therefore, the lack of clear, unified guidelines results in these manufacturers being reluctant to bring V2G-enabled products to market and showcase limited conditions for pilot projects.

5.4.2 Stakeholder Coordination: The Core of V2G Implementation

The interplay between actors awaiting each other for V2G hardware provision and those seeking clarity on which standards to apply underscores classic chicken-and-egg dilemmas. As emerging from the interviews, it becomes evident that the various stakeholders are mutually dependent to collectively develop a functional V2G system. Consequently, the core category that emerges through the selective coding approach is *stakeholder coordination*. This coordination, including, collaboration, becomes imperative when formulating standards for technical aspects such as network codes, charging standards, and DSO integration. The divergence of network codes across Europe necessitates alignment among European system operators to harmonise requirements, as highlighted by DSO1, R2, and EVSE1. Achieving this alignment also calls for coordination with manufacturers, given that network codes influence product requirements, as emphasised by CPO1, CPO2, EVSE1, EV1, and EV2. Simultaneously, the charging standard impacts hardware requirements for both EVSE and EVs, necessitating coordination between OEMs and contracting authorities. However, the integration of DSOs predominantly affects infrastructures among CPOs, EVSE manufacturers, and DSO, as observed in the insights from CPO1, CPO2, DSO1, EVSE1, and EVSE2. Once again, this integration calls for coordination among the various actors to design and optimise the system, including aligning communication protocols. Therefore, stakeholder coordination can be linked to the technical requirements disparities and deficiencies, where standardisation could play a key role in defining the requirements. In contrast, considerations regarding control authority demand a different form of coordination. As previously demonstrated, regulators maintain a neutral position, allowing the market to determine who is in control. While CPO1, CPO2, and EV1 express their perspectives on their preferred roles in the system, EV2 underscores the necessity for a uniform decision to manage conflicting demands. Coordination, therefore, becomes paramount in addressing the multifaceted challenges associated with V2G development and establishing a harmonised system. The next chapter consults the integrated framework presented in Chapter 4 to interpret the empirical findings. This helps understanding the effect of the barriers identified on the adoption of V2G and the affiliated socio-technical transition.

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6 Discussion

This chapter presents a comprehensive discussion about the issues obstructing diffusion of vehicle-to-grid (V2G) technology presented in Chapter 5. The discussion is guided by the three research sub-questions presented in Chapter 3. It addresses key dimensions considered vital for understanding and navigating the barriers encountered in the V2G domain. Firstly, Section 6.1 delineates the primary barriers in technical requirements that have emerged from the empirical study. The barriers are organised and described by consulting the Institutional Analysis & Development (IAD) framework. Subsequently, Section 6.2 explores the root causes that underlie these issues, delving into the factors and system failures contributing to their emergence. For this purpose, the Multi-Level Perspective (MLP) is applied. The consequences observed of the barriers are then addressed in Section 6.3, highlighting the implications for various stakeholders and the overarching V2G system. Section 6.4 offers pragmatic implications drawn from the main findings, aimed at informing and guiding policymakers and stakeholders. Finally, a theoretical evaluation in Section 6.5 examines the research approach, presents inherent limitations, and proposes avenues for future research, thereby contributing to the academic field and further advancement of V2G literature.

6.1 The Main Barriers

This section recalls the first research sub-question:

SQ1: *What are the main barriers in the technical implementation of vehicle-to-grid technology obstructing its adoption?*

As shown in Chapter 5, this study has identified four key barriers related to technical requirements. These are stated as follows:

1. DSO Integration: the lack of communication infrastructure between Distribution System Operator (DSO) and Charge Point Operator (CPO), and the affiliated communication standard ambiguity.
2. Network Codes: non-harmonised and undefined network codes in addition to lacking communication protocols resulting in implementation uncertainties.
3. Charging Standard Ambiguity: lack of unified vision on charging standard resulting in uncertainties and financial risks to Original Equipment Manufacturer (OEM) and CPO.
4. Control Authority V2G Sessions: conflicting stakeholder views due to business model risks slow coherent vision on V2G session control.

The IAD framework is consulted to explicate the barriers based on the interactions perceived between rules (e.g., requirements, specifications, etc.) and actors. Figure 14 shows the part of the IAD framework presenting the scope of this analysis. It helps understand how barriers arising from technical requirements affect the actors, or how actor interactions affect the constitution of these requirements. As explained in Section 4.1.3, technical requirements (e.g., product standards, protocols, etc.) form the core of this study, since these are the types of rules applicable to the policy issue (i.e., the rules-in-use) related to V2G.

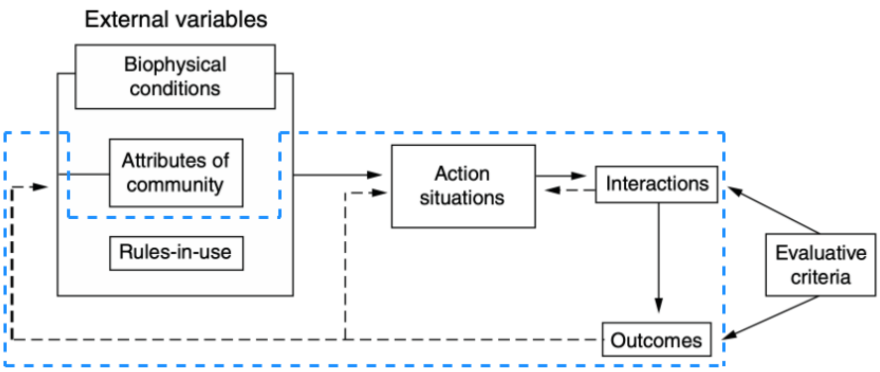

Figure 14: *Scope of the Analysis, Visualised within the IAD Framework (adapted from (Ostrom, 2010)).*
Note. The elements within the blue borders are considered part of the scope.

Analysing the interactions between actors and rules, either formal or informal, contributes to understanding the dynamics observed. As shown in Section 5.4, the first three technical barriers are affiliated with either requirements disparities or requirements deficiency, or both. Sections 6.1.1 until 6.1.3 present the institutional analysis related to these barriers. In contrast to the first three barriers, the fourth barrier, as shown in Table E2, is only little affiliated with technical requirements. However, other associated types of rules and institutional arrangements can be identified from the analysis. Section 6.1.4 elaborates on this.

6.1.1 Integration of DSOs

The first barrier is about the integration of DSOs into the electric vehicle (EV) charging infrastructure. At the moment, DSOs do not have an active role, meaning they do not actively affect charging schedules. For smart charging purposes, and V2G in particular, the DSO becomes an active player. V2G is expected to help balance the electricity grid, meaning discharging sessions should consider real-time grid loads. This requires information from DSOs. Currently, CPOs are responsible for facilitating charging sessions. Therefore, as mentioned in six interviews (see Table E3), V2G requires new communication infrastructures between CPOs and DSOs. This emphasises the changing *position rules* of the institutional context, defining the roles each actor holds. The DSO, therefore, is assigned to a new position in the action arena, meaning it will be able to influence the outcomes of V2G sessions and interacts more actively with other actors. This way, charging profiles can be adapted to the applicable grid conditions. DSO1 emphasises the importance of V2G activities to operate safely and following the applicable rules, but does not demand an active role necessarily. Moreover, re-designing or extending the communication systems of DSOs is a time-consuming process, as mentioned by DSO1. This might slow the process of integrating DSOs. Simultaneously, there is no consensus on the definitive communication protocol yet. This protocol defines data entries and standardises communication between DSOs and other actors. OpenADR is mentioned as a potential protocol, but no nationwide nor European-wide decision has been made. While a European standard is preferred by EVSE2 and DSO1, a European standard is especially effective when OEMs need to offer different hardware architectures otherwise. This would prevent market fragmentation and accelerate adoption by OEMs. CPOs are often operational nationally only, as CPO1 and CPO2, so they would not need a European standard necessarily.

In general, the discussions related to the integration of DSOs showcase the lack of *information rules* specifying communication and data exchange among actors. These are considered a requisite for the effective operation of V2G and the necessary extension of the EV charging infrastructure.

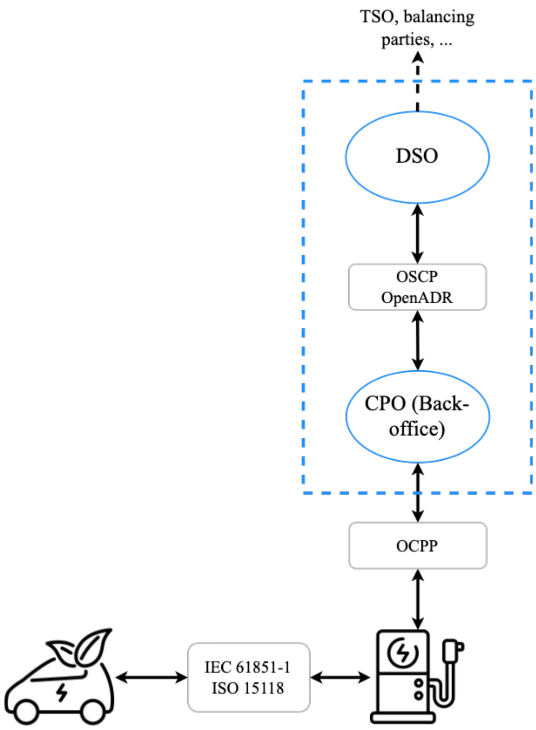

Figure 15: *Simplified Schematic of Communication Infrastructure involving CPO and DSO.*

6.1.2 Non-Harmonised Network Codes

Network codes are a prevalent theme in the interviews. They are considered undefined for V2G purposes and OEMs are afraid of divergent requirements within the EU. At the moment, grid codes are not specifically defined for V2G systems, resulting in uncertainties for V2G actors (see CPO1, CPO2, DSO1, EV1, EV2, EVSE1, and R2). As stated by R2 and observed at the second event shown in Table F1, there are developments regarding the harmonisation of network codes specific to V2G. For the alternating current (AC) situation, where the charging session is AC-powered, EVs are expected to comply with the applicable network codes. For the direct current (DC) situation, this is the responsibility of the EV supply equipment (EVSE), following the network codes for stationary storage systems. This way, *position rules* defining who is responsible for network code compliance are introduced.

Network codes specific to the AC situation will be harmonised, as demanded by market players, but local variations will still be possible (see R2). Divergent network codes within the European Union (EU) showcase the lacking *boundary rules* defining who can take part in V2G in the specific area. It means one can only participate when the applicable network code is supported and compliance can be shown. Moreover, it is still unknown whether harmonised network codes will prevent divergent hardware requirements, but R2 expects hardware is not affected by the allowable variations in network codes. Nonetheless, there are still uncertainties concerning the implementation of network codes (see CPO2, EV2, and EVSE1). For example, a European-wide network code could specify a maximum reduction of power output when the frequency is dropped, but the EVSE and EV still need to determine how to act upon this. This raises the question: who determines this? This showcases the lack of *choice rules* specifying which actors are allowed to control the implementation of the network code. It also raises the question of how to communicate the network codes to the EV in the AC situation. While EVSE1 claims this is already possible with ISO 15118-20, CPO1, DSO1, EV1, EV2, and EVSE2 state this is not true. Notably, as verified through personal communications with a co-author of the ISO 15118 protocol (January 23, 2024), an amendment to ISO 15118-20 is needed for network code communication to EVs and thereby to ensure compliance. An amendment is expected to be published in the second quarter of 2024. Nonetheless, it is expected network codes can be communicated to CPOs via OpenADR 3.0 or future versions of OCPP (OpenADR Alliance, n.d.). The uncertainties related to the communication protocols to be used for network code communication showcase the need for new or adjusted *information rules*.

6.1.3 AC or DC?

The third barrier concerns the ambiguity surrounding the charging standard. Seven interviewees question: will it be AC or DC? As mentioned earlier, public charging infrastructure in the Netherlands mainly consists of AC charging stations, but DC has its advantages for V2G purposes. The primary issue with this ambiguity is the potential effects on CPOs and EVSE manufacturers. AC chargers currently operational in the public domain do not support V2G, meaning they will have to be replaced or adjusted (see DSO1, CPO1, EVSE1, and EVSE2). This reflects a significant financial uncertainty for CPOs and EVSE manufacturers. This especially holds if EVSE manufacturers claim their products support V2G but future requirements or protocols demand unexpected hardware changes. If EVSE manufacturers have agreed on upgrading charging stations for V2G capabilities within the contract term, they are financially responsible. Otherwise, CPOs are financially at risk when V2G support requires an upgrade. This might result in the CPO to switch to different EVSE suppliers after the contract term, however. Simultaneously, while some contracting authorities are already demanding "V2G-ready" charging stations, OEMs and CPOs do not know what this entails (see CPO1, CPO2, EV1, EV2, and EVSE2). Several requirements related to V2G are not defined yet, such as network code compliance and the support of certain communication protocols. Therefore, five participants are doubtful about V2G-related claims by some OEMs.

A unified vision within the EU is preferred, especially for EV manufacturers. If AC becomes the prevailing standard, they need to ensure their cars can comply with network codes and need an onboard power inverter. On the contrary, if DC becomes the standard, this is not needed. EVSE1 and DSO1 expect EV manufacturers prefer this due to cost savings, giving them a large influence on the charging standard consideration. On the other hand, CPO1 and CPO2 expect DSOs to have a large influence on the matter. There is a possibility, however, that both standards will be employed in practice since European regulators are reluctant to prescribe technological solutions. If markets are fragmented due to diverging requirements related to the charging standard, EV manufacturers would need to offer multiple versions of their cars or only offer cars enabling AC V2G encompassing higher cost prices. Concurrently, EVSE manufacturers and CPOs would need to adapt too and offer products based on the market standard. The charging standard consideration will determine who must pay the price: the CPOs and EVSE manufacturers, or EV manufacturers? Any formal *payoff rules*, specifying how costs are distributed to the actors, are not ideal, since this would negatively affect competitive market dynamics (see R1). Therefore, a European vision is considered most effective for OEMs. This might be unlikely, but the EU has shown before to be able to step in and prescribe technological solutions (e.g., USB-C as charging standard for consumer electronics) (Sajn, 2023).

6.1.4 Who is in Control?

The fourth barrier concerns the control of V2G sessions, showcasing uncertainty concerning the applicable *choice rules*. The actors question who should be 'in the driving seat', i.e., who has the authority to initiate and manage a discharging session. Due to the changing roles of DSOs and the opportunity for EV manufacturers to enter a new market as an 'energy supplier', several *position rules* are changing. DSOs might want to optimise discharging schedules based on what the grid demands, while EV manufacturers, such as EV1, want to control discharging to optimise revenues on flexibility markets to compensate for research and development (R&D) investments and increased warranty claims. As mentioned by EV1, EV manufacturers know what is best for the battery and want to prevent warranty claims caused by potential battery degradation. In addition, they believe they should receive compensation in return for the costs made to develop V2G technology, which is now seen as a significant investment (see EV2). Therefore, according to EV1, EV manufacturers might not open up their systems, while this is required for other parties to manage discharging sessions.

Nonetheless, the charging station and the car must not conflict with the charging profile they want to apply. A charging station must therefore be able to view more information from the car, or the car must have more control over the charging station. This showcases the need for adjusted *information rules* specifying which information must be shared to enable V2G. However, CPOs are financially at risk with the charging sessions since the charging load should match the energy procured (see CPO1 and CPO2). Therefore, they must predict charging demand accurately, which is at risk when control is lost. This could result in fines for the CPOs. Again, this showcases a need for clear *payoff rules*, but governments generally do not take a position in this discussion to maintain a competitive market (see R1).

6.1.5 Additional Remarks

The rules discussed so far define the lacking conditions for V2G pilots. The rules are either incomplete, undefined, or divergent, obstructing V2G actors to experiment with V2G technology and equipment. As can be seen in Section 5.2, the CPOs and EV manufacturers are linked to a relatively large number of open codes. This emphasises the pressure on these actors resulting from the lagging adoption of V2G technology. As shown in Table 16, CPO1 and CPO2 are mainly concerned about technical requirements deficiency. Generally, they are not concerned with international disparities due to their national geographical focus. Nonetheless, they are struggling with the demands of contracting authorities to offer "V2G-ready" EVSE, while the CPOs believe the requirements are too incomplete or undefined to claim V2G-readiness reliably. Network codes specific to V2G are not defined yet, creating uncertainty for future requirements. Communication protocols required for V2G operations are not definitive, again creating uncertainties. On the other hand, EV manufacturers have an international geographical focus, meaning they are merely concerned about potential market fragmentation or segmentation.

6.2 Regime System Failures

The previous section elaborated on the main barriers in technical requirements emerging from the empirical data. This section elaborates on the potential causes of these barriers by recalling the second research sub-question:

SQ2: *What underlying factors contribute to the emergence of the barriers identified?*

For this analysis, the MLP and the transformational system failures introduced by Weber and Rohracher (2012) are consulted to identify dynamics within the socio-technical regime potentially causing the barriers identified earlier. The MLP recognises the role of the regime in shaping the conditions for the acceptance and integration of innovative technologies such as V2G (Geels, 2002). However, within the regime, selection pressures are observed, i.e., factors that highly influence the success and adoption of innovations within a particular environment (Smith & Raven, 2012). Section 4.2.1 presented six dimensions of the regime. The barriers presented in the previous section can be organised based on the regime dimensions, while selection pressures can be identified as underlying causes of the barriers. These selection pressures could be explained by system failures conceptualised by Weber and Rohracher (2012).

The first three barriers, as explained earlier, are mainly part of the technologies and infrastructures dimension of the socio-technical regime. This dimension entails technical standards and infrastructural requirements and interacts with the policy dimension (Smith & Raven, 2012). As shown in the previous section, the prevailing standards and requirements disadvantage V2G. This requires different or adjusted standards and infrastructures. The absence or shortcomings of requirements specific to V2G showcase *institutional failure*, either demanding formal or informal institutions (e.g., standards, regulations, etc.) to provide clarity to the actors. The charging standard ambiguity demands a consolidated direction of change, indicating *directionality failure* caused by a lack of shared vision and insufficient guiding regulations and standards. This discussion also affects network code compliance, determining who should comply with the applicable rules. With AC as the prevailing standard, EVs should comply with the network code. With DC, the EVSE is responsible for compliance. Moreover, the undefined network codes specific to V2G showcase multi-level *policy coordination failure*. Non-harmonised network codes are troubling for OEMs due to divergent requirements, therefore demanding unison between Member States of the EU. For all three barriers, a lack of coherence between contracting authorities, regulators, and market players emphasises *policy coordination failure* affecting the establishment of clear guidelines for V2G products. Grid congestion demands quick implementation of V2G, but the complicated technologies and processes required for V2G and the international focus of OEMs should not be forgotten.

The discussion surrounding the control authority of V2G sessions can be classified as pressure within the industry structure dimension of the regime. This dimension entails business models and organisational networks between actors (Smith & Raven, 2012). Discussions about the control authority involve considerations of market power. Currently, EV manufacturers have a dominant position in the industry. Therefore, they seek to influence or control V2G sessions to maximise their profits. Within the established regime, however, CPOs have control of EV charging in the public domain, showcasing selection pressure for EV manufacturers trying to enter the V2G market. V2G creates opportunities for new business models within EV charging, putting pressure on the regime. However, this results in extensive discussions obstructing the implementation of V2G and possibly leading to market segmentation, where only one-to-one solutions can be provided. This showcases *directionality failure* as lacking collective coordination between V2G actors on who should take control. The government does not take a position here to maintain a competitive market, so the market should self-organise. However, market players are unsure how this will develop and whether market segmentation can be prevented. For the other three barriers mentioned earlier, however, standardisation and governmental intervention are seen as viable solutions to solve key issues and harmonise the EV charging system to implement V2G effectively.

6.3 Lacking Pilot Conditions Obstructing Niche-Innovations

The four technical barriers cause difficulties for actors to implement V2G technology. This section recalls the third research sub-question:

SQ3: *How do the barriers identified affect the key stakeholders in the vehicle-to-grid ecosystem?*

First, this section presents the perceived effects of the barriers on the key stakeholders. While the impact on each stakeholder differs, all barriers show a significant effect on the general pilot conditions for V2G experimentation. Subsequently, this section presents an analysis of the effect of these lacking pilot conditions on the diffusion of niche innovations and socio-technical transitions based on the MLP and related literature.

6.3.1 Perceived Effects

Each of the four barriers identified earlier obstructs the V2G niche actors differently. First of all, the charging standard ambiguity mainly affects OEMs and CPOs. As elaborated on in Section 6.1.3, the charging standard affects who should pay the price. Particularly, if DC-powered V2G becomes the standard, CPOs will need to invest greatly in the more expensive DC charging stations, possibly resulting in higher charge fees. If DC becomes the charging standard, this limits the market potential for EVSE manufacturers focusing primarily on AC chargers, since the DC market for EVSE is currently limited compared to AC. On the contrary, EV manufacturers will have the opportunity to reduce costs, since the EV requires fewer hardware such as an inverter. If AC becomes the primary standard, however, EV manufacturers will need to provide inverters in their cars and need to ensure the EV can comply with network codes. This results in a higher cost price. Subsequently, CPOs do not have to invest in expensive DC-powered charging infrastructure.

Secondly, integrating the DSO primarily affects DSOs, CPOs, and possibly EVSE manufacturers. DSOs will need to design their systems to enable proactive management of charging infrastructure, requiring significant investments. This also holds for CPOs who need to ensure, together with the DSO, communication infrastructure between the back-office of the EVSE and the DSOs. Simultaneously, EVSE manufacturers need to ensure their products are compatible with the definitive communication standard, but the specific requirements are unknown yet.

Third, the non-harmonised network codes and their incompleteness for V2G purposes affect various actors. However, this depends on the charging standard too. While DSOs could propose regional requirements, OEMs are demanding unified requirements. If AC becomes the charging standard, the non-stationary nature of EVs becomes problematic for network code compliance. In this situation, the EV needs to ensure compliance. Therefore, if the network codes specific to V2G differ for each region, the EV needs to adapt if crossing borders. This becomes very problematic if the network codes diverge significantly and require different hardware. In addition, both EV and EVSE need to provide compatibility with the proposed amendment of ISO 15118-20 to ensure network code communications. For the DC situation, the EVSE manufacturers and CPOs need to ensure network code compliance in the specific region. Nonetheless, international regulators are indicating an amendment to the EU network codes is in development, ensuring harmonised requirements and guidelines. However, the extent to which variations in implementation are still possible is unclear.

Fourth, the control authority discussion mainly affects the business models of market players. Currently, CPOs are primarily responsible for EVSE management and operation in the public domain. However, as explained earlier, EV manufacturers are exerting influence to gain control of V2G sessions to increase their profits. Governmental organisations and regulators do not take a position in the discussion, creating uncertainty for the future ecosystem of V2G. Therefore, CPOs are hesitant to invest in the development of V2G applications because their future role and revenue streams are uncertain. In addition, the uncertainties have resulted already in some V2G niche actors initiating one-to-one solutions. EV manufacturers might decide to only open up their systems with specific organisations instead of all CPOs, possibly resulting in a segmented market (see EV1 and EV2). For the vehicle-to-home (V2H) domain, this has resulted in various one-to-one solutions already, where EV manufacturers are founding separate business units for related energy services (Randall, 2023; Schonebeek, 2023). These initiatives involve a specific set of stakeholders to enable bidirectional charging with only particular products and applications.

6.3.2 Pilot Projects and Socio-Technical Change

While the deficiency and disparities in technical requirements, and the control authority discussion result in the effects explained in the previous section, all barriers affect the conditions for experimentation with V2G technology. Various stakeholders are reluctant to initiate pilot projects. These actors are demanding realistic pilot conditions, such as definitive technical standards and specified network codes (see CPO1, CPO2, and EV1). Besides, EV manufacturers demand V2G-compatible EVSE to experiment (see EV2, R1), while EVSE manufacturers and CPOs await EVs to support V2G (see CPO1, CPO2, DSO1, EVSE2, and R1). This presents a classic chicken-and-egg dilemma in which actors are awaiting each other to continue their R&D activities. Another chicken-and-egg dilemma can be observed related to actors awaiting definitive technical standards and specifications. As mentioned by EV1, experimenting with 'old' standards yields limited insights. Therefore, OEMs await new standards and guidelines to understand what these mean for their products. However, if R&D can only continue when these guidelines are officially published, the diffusion of V2G is prolonged inevitably. Concurrently, standardisation organisations are commonly reliant on input from the industry, as mentioned by R2, meaning experimentation is required to provide relevant insights contributing to the development of technical standards. So, the deficiency and disparities in technical requirements lead to undesired conditions for pilot projects, obstructing V2G niche actors to experiment with V2G technology. This seems to obstruct the diffusion of niche innovation.

Realistic pilot conditions make it easier to scale V2G activities, as stated by CPO1. Pilot projects are defined as "highly-novel socio-technical configuration[s] likely to lead to substantial (environmental) sustainability gains" (Berkhout et al., 2014, p. 3). Most participants are indicating the lacking pilot conditions are obstructing the implementation of V2G. Pilot projects play an important role in exploring the possibilities of V2G technology. They form an essential starting point for developing definitive configurations and designs before large-scale diffusion can be realised. Literature introduces various transition pathways to describe the emergence of new socio-technical configurations and new regimes (Berkhout et al., 2014). However, which pathway V2G will follow remains unpredictable. While V2G offers a highly demanded flexibility service, which is unique in the power system regime, V2G is only one of multiple potential technologies to offer this. Stationary battery storage and hydrogen storage are some alternatives. However, one could state the current power system is transitioning towards a more decentralised system, in which EVs offering bidirectional charging can play a significant role. V2G, therefore, shows resemblance with the reconfiguration pathway introduced by Geels and Schot (2007). Following the reconfiguration pathway, V2G is a mere add-on to the current regime, much like stationary storage, resulting in the reconfiguration of the basic architecture of the regime. The cumulative adoption of various types of storage technologies substantially changes the regime from a relatively centralised system to a decentralised system. Nonetheless, various other pathways have been introduced so far which could characterise the pathway V2G might follow (Geels, 2019).

Currently, V2G positions in the end of the conceptual experimentation phase of socio-technical transitions (see Figure 16). It awaits necessary developments within the socio-technical regime, such as technical standard development, network code amendments, and stakeholder alignment. This way, a stabilised set of technical requirements for V2G products can be established, providing sufficient clarity for V2G actors. The first phase of socio-technical transitions is characterised by R&D, including real-world experiments and pilot projects (Geels, 2019). This stimulates learning about technical performance, social acceptance, user needs, and feasibility. Niche innovations, however, are prone to fragmentation of initiatives, market segmentation, and a tendency to remain isolated, reducing their potential for wide-ranging change (Turnheim et al., 2018). This was also acknowledged by six research participants as a significant risk to current V2G developments (see CPO2, DSO1, EV1, EV2, EVSE1, and EVSE2). They mentioned the lack of clear, unified guidelines leads to niche actors initiating one-to-one solutions, resulting in market segmentation. The landscape is putting pressure on the regime by demanding uptakes in renewable energy use, while the socio-technical regime is struggling to cope with the resulting intermittency and fluctuations in supply. Therefore, flexibility services and storage capabilities are demanded, creating 'windows of opportunity' for niche innovations such as V2G (Geels, 2002). Nonetheless, due to various system failures and lacking alignment between key stakeholders, V2G is obstructed to diffuse and stabilise into a dominant design. A circulation of experiences and learning processes resulting from pilot projects is demanded to transition to Phase 2, but current conditions are complicating such initiatives.

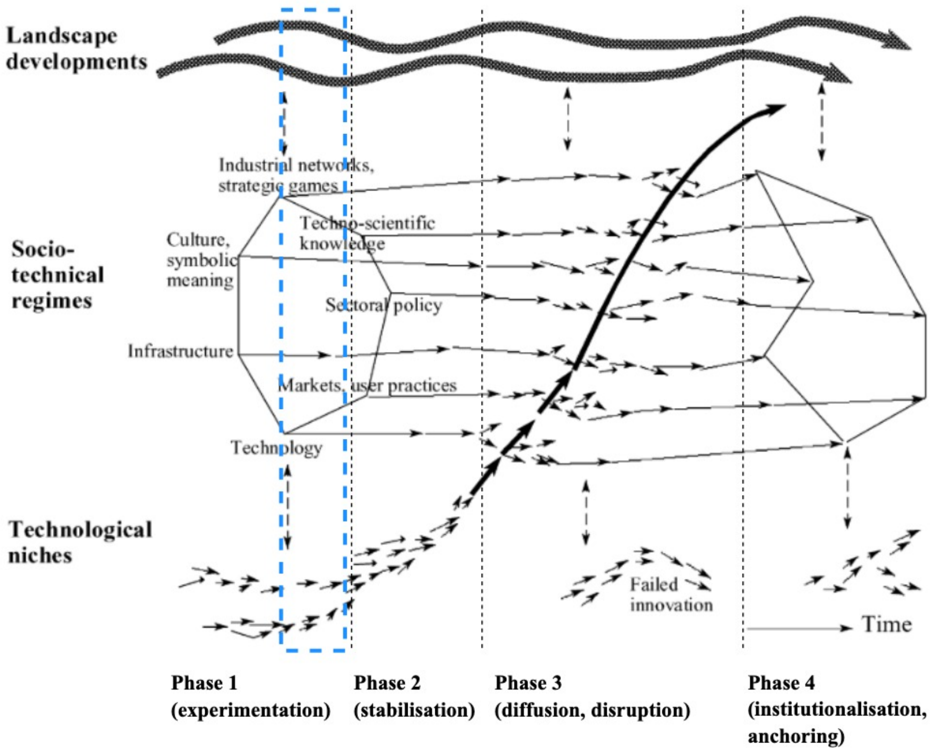

Figure 16: *Current Stage of V2G Visualised in the MLP (adapted from Geels (2002)).*

Smith and Raven (2012) presented three functional properties of protection of niche innovations in so-called protective spaces. Within these spaces, the innovation is *shielded* against selection pressures within the regime and *nurtured* by niche actors to become more robust through processes that support its development. A third property is defined as *empowerment* of the niche. As niche innovations are nurtured into forms that become competitive within the established regime, the protective shields become redundant and can be removed. This empowerment of the niche innovation, driven by its growing competitiveness, paves the way for widespread diffusion. Smith and Raven (2012) identify two forms of empowerment: fit and conform empowerment and stretch and transform empowerment. The first represents niche innovations becoming competitive within unchanged selection environments, while the latter presents the restructuring of regime selection environments in ways favourable to the niche innovation. Currently, V2G demands institutional reforms encompassing of harmonisation of requirements and standardisation, as shown earlier. Therefore, empowering to stretch and transform is demanded to enable large-scale diffusion of V2G technology. However, for this to be realised, one must acknowledge the agency of certain actors and underlying politics (Smith & Raven, 2012). As shown in Chapter 5, the research participants showed various conflicting demands (e.g., charging standard ambiguity) and observed inequitable power distribution among actors (e.g., EV manufacturers exerting influence on requirement-setting). In addition, as mentioned by R1 and DSO2, the automotive industry in Europe is reluctant to embrace OCPP, but does not offer alternatives. All in all, these dynamics require a coordinated approach to empower and stabilise the development of V2G technology and enable widespread diffusion.

6.4 Practical Implications for V2G Actors

Previous sections have identified the key issues obstructing the adoption of V2G technology by niche actors. But how to tackle these issues? This section elaborates on the practical implications of the key findings of this study and proposes avenues to V2G actors for actions to take to accelerate the implementation of V2G technology. Table 17 summarises the actions proposed to niche actors.

First of all, grid operators, contracting authorities, and regulators fail to provide clear guidelines on what is meant by "V2G-ready". In the Netherlands, several initiatives are assembling relevant stakeholders to define strategies related to charging infrastructure. However, as stated by some of the research participants, the main focus of these gatherings is smart charging in general. One must not ignore the complexity of V2G and the importance of aligning stakeholders to realise a desired scale of implementation. While "V2G-ready" cannot be specified yet due to lacking standards, contracting authorities and CPOs should recognise the risks associated with changing requirements specific to V2G. This requires clear agreements on who bears the costs if chargers must be upgraded or replaced. This was also demanded by CPO1 and CPO2. For contracting authorities and regulators, it is evident a unified vision regarding the charging standard is preferred. The definitive decision could affect OEMs and CPOs significantly, meaning they need time to adjust. EV charging infrastructure in the Netherlands mainly relies on public AC chargers. Therefore, one could assume AC remains the prevailing standard in a V2G-enabling system. Otherwise, public chargers need to be replaced or the more expensive DC charging stations will need to be installed from now on, resulting in extremely high investments. This raises the question of whether installing only V2G-compatible charging stations in the future will achieve a sufficient scale for effective operation.

The AC situation would imply EVs are expected to comply with the applicable network codes (see R2), meaning DSOs and EV manufacturers need to align. While DSOs are expected to take a more active role in the charging ecosystem, current infrastructures and information systems need to adapt. To determine whether a European standard for communication between CPOs and DSOs is needed, regulators and DSOs must align with OEMs to prevent market fragmentation within Europe. Currently, EVSE manufacturers already experience extreme workloads to adapt to national regulations, so harmonisation of requirements is desirable. As stated by R2, network codes are expected to be harmonised by the responsible European entity by an amendment specific to V2G, but the extent to which Member States retain freedom in implementation and their impact on OEMs regarding hardware requirements remains unclear.

Another prevalent discussion is related to the control authority of V2G sessions. This issue is likely not to be solved by the introduction of standards or regulations. Governments need to maintain a competitive market, so self-organisation by market players is expected. This requires extensive stakeholder coordination. However, the DSO could take a key role as a neutral party. Policies are likely to be tailored to implementing V2G for grid balancing purposes, meaning CPOs and EV manufacturers have limited room to initiate discharging sessions aimed at maximising revenues. Therefore, CPOs and EV manufacturers are expecting compensation for offering flexibility services, but it is unclear how this should be organised. DSO1 states the DSO does not demand an active role in determining charging schedules, as long as safety is ensured and discharging contributes to balancing loads. While EV manufacturers exert power to gain control, this is likely to lead to market segmentation including one-to-one solutions, thereby negatively affecting the competitive market. Therefore, a balance must be found between compensating EV manufacturers by offering compensation and retrieving required data and control from EVs to enable V2G controlled by third parties. Therefore, DSOs, CPOs, and EV manufacturers should align and potentially develop trilateral agreements specifying cost and benefit distribution.

A third theme discussed earlier relates to the chicken-and-egg dilemmas mentioned earlier. Actors await each other to offer V2G products. Concurrently, OEMs and CPOs await technical standards to initiate pilot projects, while standardisation organisations are relying on lessons learned from such experiments. The limited number of initiatives complicates the possibility for market players to differentiate themselves in terms of V2G. However, OEMs and CPOs should show more active involvement with standard-setting activities. This way, they develop a better understanding of the direction of certain standards and policies and can provide input. This might also enable these actors to experiment with draft versions of certain protocols and standards, yielding relevant insights for V2G architectures. This way, they can act quickly when definitive standards and requirements are set. An EVSE manufacturer or CPO cannot wait for EVs to support V2G capabilities, because then they are considered too late to enter the market. The niche actors need to be at the front of the developments, meaning active involvement with standardisation and requirement-setting. Besides, such active involvement offers great learning opportunities and stimulates collaborations between niche actors. Market fragmentation and segmentation are detrimental to both V2G actors and the overall system, so efforts should be made to prevent these to the greatest extent possible.

Table 17: *Practical Implications for V2G Actors Summarised.*

General	Actions	Actors
Specify "V2G-ready"	Actively involve industry. Define V2G strategy next to smart charging strategy, align with European strategies. While standards and requirements are lacking, recognise implications for industry. Make clear agreements with CPOs and OEMs in response to potential hardware adjustments due to future requirements.	DSO, Regulator, Contracting Authority
Define charging standard	Define national charging standard if no European decision is to be made. Could also stimulate the use of both standards, as long as this is clear to the industry so they could adjust accordingly.	Contracting Authority, Regulator
Adopt EU network code	Adopt the amendment of the network codes specific to V2G quickly, and prevent significant variations of implementing the requirements. Align with neighbouring DSOs. Also align with EV manufacturers to ensure compliance.	DSO, EV Manufacturer
Implement DSO-CPO communication standard	Implement a DSO-CPO communication standard. Assess whether European standard is preferred and its potential effect on EVSE requirements. Prevent market fragmentation for EVSE manufacturers.	DSO, CPO, Contracting Authority, EVSE Manufacturer
Select control authority	Investigate how to determine the designated control authority. Assess whether CPOs should maintain their position and how EV manufacturers and CPOs can be compensated for their services and products.	DSO, CPO, EV Manufacturer
Actively contribute to standard-setting	Experiment with latest/proposed specifications V2G and share lessons learned. Contribute actively to standardisation and requirement-setting.	CPO, EV Manufacturer, EVSE Manufacturer
Adopt amendment ISO 15118-20	Adopt the amendment of ISO 15118-20 once published.	EV Manufacturer, EVSE Manufacturer

6.5 Theoretical Evaluation

This section elaborates on the theoretical implications of the research findings and emphasises the contribution of this study to existing literature in the academic field. Next, this section addresses the research approach and presents inherent limitations. Finally, the section proposes avenues for future research, thereby contributing to the academic literature on V2G.

6.5.1 Theoretical Implications

While the IAD framework emphasises micro-level interactions between actors and rules, it lacks consideration for broader societal influences and long-term implications of institutional barriers. On the other hand, the MLP may overlook the complexity of micro-level interactions and institutional arrangements. Combining both frameworks, therefore, provided a more comprehensive understanding of the socio-technical system and the diffusion of the niche innovation of V2G technology. The integrated approach bridged micro-level interactions (IAD) and macro-level contextual influences (MLP). This offered novel insights into how institutional arrangements within the socio-technical regime impact niche actors and the adoption of V2G. This integrated approach is therefore considered useful for analysing niche innovations dealing with a complex institutional context, such as the EV charging industry. However, niche innovations with little reliance on institutional arrangements are less suitable for this approach. Particularly, systems with a relatively great reliance on formal institutions instead of informal arrangements are considered less applicable. Informal arrangements between niche actors, such as small-scale standardisation or pilot projects, are key in niche innovation development. Niche actors often have little influence on formal rule-making, so the implications generated from the integrated analysis might have limited effect on policy and decision-makers. The EV charging ecosystem, however, is reliant on many open standards involving various stakeholders, therefore an institutional analysis of the impact of existing and potential future standards is vital. Furthermore, identifying system failures within the regime helps in understanding the dynamics between rules and actor interactions. Moreover, a focus on transformational system failures and their impact on multi-level dynamics complements the analysis of socio-technical transitions.

The MLP recognises the potential dynamics between the dimensions of the socio-technical regime. However, it does not provide the tools to analyse such dynamics. For example, this study has identified a relationship between destabilised policies and the destabilisation of technologies and infrastructures. While the landscape puts pressure on the regime due to the need for renewable energy and flexibility services, regulatory frameworks (e.g., network codes) are destabilised, in turn creating disruptions in the other dimensions, such as prevailing technical standards (e.g., ISO 15118). Therefore, complementing the MLP with the IAD framework provided insights into how destabilised dimensions interact with other dimensions, influencing the overall dynamics of the regime and socio-technical transitions.

Section 2.3 presented two knowledge gaps that can be identified in existing literature. The first knowledge gap encompasses the lack of knowledge on the extent to which harmonisation in the V2G system is needed and how this is achieved. By consulting the IAD framework and MLP, this study has identified avenues for harmonisation and standardisation. The barriers identified are considered vital obstacles to the diffusion of V2G technology. The study also addresses the significance of technical standards in EV charging infrastructures and the dependency of V2G developments on such standards. This signifies the importance of harmonisation and standardisation efforts. Concurrently, this study has identified various effects of institutional failures in technical requirements on business models and market positions of V2G actors. Therefore, it contributes to the second knowledge gap identified in Section 2.3 by providing an understanding of how harmonisation and standardisation of certain aspects of the charging ecosystem might affect business models.

6.5.2 Research Limitations

This section addresses the limitations of the research approach and methods applied. Firstly, it is evident a relatively small sample size has been used. even though data saturation was achieved, one must be careful in translating the findings into comprehensive conclusions for specific stakeholder categories. While data saturation across all participants suggests that further interviews may not yield substantially new information, the ability to generalise findings to specific stakeholder groups might be constrained by the small sample size within each group. For example, DSO1 stated it is not seeking an active role in discharging sessions, but one cannot conclude this applies to all DSOs. Nonetheless, this study has shown the possibility of DSOs not willing to take full control of EVSE discharging, indicating potential implications for V2G architectures and institutional arrangements. Moreover, the regulators have played a limited role in this study. Since regulators are often very specialised, their input was limited to a specific aspect of the V2G ecosystem. For example, in the Netherlands, network codes are likely to be part of the scope of the Ministry of Economic Affairs and Climate Policy, while EV charging fits within the domain of the Ministry of Infrastructure and Water Management. This may have provided limited insights from the perspective of the regulator in the V2G system. Concurrently, while most participants claimed to have a significant responsibility related to V2G strategies within their organisations, some showed limited knowledge of certain aspects of V2G technology due to its novelty. This might have resulted in incompleteness or inaccuracies of some statements by participants. For example, participants showed diverging knowledge related to the capabilities of the ISO 15118-20 protocol (see Table D12). The EV charging ecosystem is complex due to the many applicable standards and involved stakeholders. For this study, therefore, extensive domain knowledge by the researcher was vital in interpreting the research findings effectively, especially concerning the time constraints. However, grounded theory research entails maintaining an open mind, so the domain knowledge of the researcher could have created bias with interpretation. Therefore, professional experts were consulted to both help validate the research findings and limit interpretation biases.

Secondly, frameworks such as the IAD framework and MLP possess inherent limitations, as addressed in Sections 4.1.5 and 4.2.2. The integrated approach ensures the two frameworks complement each other effectively to analyse perceived barriers to V2G implementation. However, it demands consulting of additional theories from innovation or transition studies to explain observations, generalise results, and help predict the future transition pathway of V2G technology. Interpretation of the results is prone to the domain knowledge and interpretive creativity of the analyst. Therefore, policymakers must take caution when translating the analyses into legislative decisions or rule-making.

6.5.3 Future Research Avenues

This section presents avenues for future research. First of all, as explained earlier, more research participants should be involved when aiming to understand the implications of the barriers identified for specific stakeholder groups. This way, data saturation for each type of stakeholder should be monitored. Additionally, more diverse recruitment could be employed to enhance the breadth and depth of participant insights to deal with the limited knowledge of participants resulting from the novelty of V2G. Moreover, other stakeholder groups could be involved, such as the Transmission System Operator (TSO) and energy supplier. However, it is expected this will not yield different insights since the stakeholder groups involved are considered to be the most affiliated with and affected by technical implementation of V2G (see Section 3.3.1). Nonetheless, involving more types of stakeholders could help identify how these actors are related to the barriers and implications identified in this study.

Secondly, with grounded research, a theory is developed rather than tested (Turner & Astin, 2021). This means the barriers and implications presented in this chapter could be tested in practice using validation techniques, such as focus groups or in-depth case studies. For example, these focus groups and case studies could be tailored to specific stakeholder groups to identify whether the implementation of specific standards will stimulate them to adopt V2G technology. Moreover, pilot projects that have taken place already could be analysed. Delving into these projects can uncover insights into how initiators navigated the barriers identified in this study. For example, do they agree with the implications presented earlier? How would they propose to accelerate the adoption of V2G? However, the number of pilot projects in the Netherlands is very limited, so an attempt could be made to reach out to initiators of other pilot projects across Europe. This might also yield different views on the role of regulatory frameworks and policies on the adoption of V2G.

EVSE is usually built to last around ten years, yet dynamic shifts within the industry continually force OEMs to conform to new standards and regulations. This ongoing adaptation places a substantial strain on OEMs, diverting valuable resources away from R&D activities. The need for harmonisation and standardisation becomes apparent. Nonetheless, the uptake of specific technical standards appears to progress at a low pace. Take for example ISO 15118-20, which, despite its official publication, is only supported by a limited number of products. Concurrently, an ongoing amendment seeks to enable network code communication. This observation raises questions about the potential effects of standardisation on innovation. Therefore, future researchers could delve into the reasons behind the hesitancy among industry actors to adopt newly published standards and the impact of this on the broader adoption of V2G technology. In addition, future researchers could extend their focus to explore the extent to which standardisation and harmonisation may impose limitations on innovation within the EV charging industry. This contributes to finding a balance between standardisation and fostering innovation. Furthermore, researchers might delve into evaluating whether national policymakers and regulators should wait for European standards or opt for the standard preferred within their country. For instance, CPOs and DSOs are advocating for a communication infrastructure facilitating data exchange between these entities. While several protocols exist, a unified consensus at the European level has not been achieved yet. Should stakeholders within a particular Member State anticipate a European decision, or should they proceed with implementing their favoured protocol, especially considering the growing barriers posed by grid congestion? If the latter is chosen, what potential implications may arise if another protocol is adopted later as the European standard?

Furthermore, the charging standard ambiguity has raised the question of whether a single standard must be chosen to achieve the desired outcomes. While AC V2G requires additional hardware to be integrated into EVs and most operational EVSE, DC V2G requires a significantly more expensive charging station. Future studies could focus on whether operating two standards simultaneously would be beneficial. Researchers could aim to identify what is the optimal strategy to transition to a V2G system based on investment costs, stakeholder demands, and time constraints. In addition, future studies could aim to find the number of V2G chargers required to ensure sufficient flexibility to the power grid.

The institutional barrier surrounding the control authority of discharging sessions within the context of V2G services presents a complicated barrier. A promising avenue for future research lies in delving into the role of self-organisation within socio-technical transitions. As previously highlighted, policymakers and regulators are likely to remain neutral in the discussion, necessitating market players to organise and determine the entity responsible for overseeing and managing V2G services. To contribute to this discussion, prospective researchers could concentrate on elucidating how self-organisation could unfold within the EV charging industry by investigating historical experiences within the industry. Furthermore, the research could focus on whether the process of self-organisation is anticipated to yield desired outcomes. By exploring these dimensions, future researchers can shed light on the feasibility, efficacy, and implications of self-organisation as a mechanism for addressing the barriers associated with control authority in V2G services. Moreover, the control authority discussion raised questions related to the future role of CPOs. If EV manufacturers are indeed gaining influence in the public charging infrastructure, CPOs and their main activities are likely to be affected. Therefore, future studies could focus on this prospective scenario. In addition, the control authority discussion could become more complicated when grid operators issue collective contracts with grid users (Netbeheer Nederland, 2023). This raises the question who should be in control then, and who should benefit from V2G activities. For example, if two organisations have a collective agreement with the grid operator, should the one organisation facilitating V2G share the benefits with the other organisation? And who determines the discharging schedules, if either organisation could have control as CPO? Future studies, therefore, could focus on the affect of these collective contracts on V2G operations and consider the control authority discussion.

7 Conclusions

This study aimed to explore the primary barriers obstructing the widespread adoption of vehicle-to-grid (V2G) technology. The study was guided by the following main research question:

How do institutional barriers in the technical implementation of vehicle-to-grid technology influence its adoption?

Interviews with ten industry experts revealed four main barriers obstructing V2G implementation. The participants represented five key stakeholder groups within the electric vehicle (EV) charging industry. The semi-structured interviews were conducted and analysed following the grounded theory approach, ensuring an open-minded approach to uncovering the various perspectives of the stakeholders. The views of the participants shaped emerging insights on the influence of institutional barriers in the technical operation of V2G. This study argued that three main barriers arise from requirements disparities and deficiency. In particular, the ambiguity surrounding the alternating current (AC) and direct current (DC) charging standards raises uncertainty for EV manufacturers seeking to offer a universal product for the European market. Charging stations operating on AC are the prevailing standard in many countries, but V2G is likely to require additional hardware in both EV supply equipment (EVSE) and EVs. On the contrary, V2G could also be enabled using the more expensive DC-powered charging stations, increasing investments by Charge Point Operators (CPO)s but reducing costs for EV manufacturers. Concurrently, the charging standard determines which entity must comply with the applicable network codes to ensure safe connection to the power grid; the charging station or the vehicle. While the requirements specific to V2G are undefined yet, the non-stationary nature of EVs demands harmonised network codes across Europe. Next to safe connection to the grid, V2G requires new infrastructures and protocols. For example, data exchange between CPOs and Distribution System Operators (DSOs) needs to be facilitated. For these barriers arising from disparities and deficiency in technical requirements, it becomes apparent that European standardisation and harmonisation are preferred. However, a balance must be found to both maximise innovation efforts and prevent market fragmentation and segmentation. Besides technical standards and regulations, other institutional arrangements affect the adoption of V2G technology. DSOs are likely to take a more active role in managing discharging sessions to balance the power grid and prevent congestion. However, CPOs and EV manufacturers are exerting influence to gain control over these sessions to maximise their profits. These conflicting demands delay a unified vision of the control authority of the discharging sessions, while governmental organisations and regulators are reluctant to take a position in the discussion to maintain a competitive market.

This study has shown it is unclear to niche actors how to become "V2G-ready" due to a lack of clear guidelines. Requirements deficiency and disparities and the control authority discussion show constraining effects on the conditions for pilot projects. Realistic pilot conditions are shown to be essential for scaling V2G activities, and pilot projects are considered vital for exploring the possibilities of V2G technology. However, lacking conditions obstruct the development of definitive V2G configurations and designs necessary for large-scale diffusion. This study has shown two chicken-and-egg dilemmas play a significant role in the slow adoption of V2G. Niche actors are awaiting each other to continue their research and development activities. EV manufacturers demand V2G-compatible EVSE to experiment with V2G technology, while EVSE manufacturers and CPOs await V2G-compatible EVs. Moreover, niche actors await definitive technical standards, while standardisation organisations and regulators are reliant on insights retrieved from practical experimentation to develop effective standards and regulations. These dynamics require a coordinated approach to empower and stabilise the development of V2G technology and enable widespread diffusion. Niche actors should be at the front of the developments, so active involvement with standardisation and requirement-setting is advised. Besides, collaborations between niche actors across Europe should be stimulated to prevent market fragmentation and segmentation, since these effects are detrimental to all V2G actors and the system in general. Therefore, the barriers identified pose a significant influence on pilot conditions, constraining experimentation, implementation, and the overall development of V2G technology.

The grounded theory research methods have proven to establish an emerging narrative on the socio-technical transition of the V2G niche innovation. The process of data collection reached a point of saturation, indicating that additional data gathering would not yield new or substantially different insights. The subsequent empirical results emphasised the significance of technical standards in the EV charging ecosystem and identified various institutional and transformational system failures. The comprehensive approach of integrating the analytical tools of the Institutional Analysis & Development (IAD) framework and Multi-Level Perspective (MLP) has shown how micro-level interactions and macro-level contextual influences interact. Lacking institutional arrangements within the socio-technical regime impact niche actors and thereby hinder the adoption of V2G. This integrated approach is deemed valuable for analysing niche innovations within complex institutional contexts, such as the EV charging ecosystem. Besides, complementing the MLP with the IAD framework helps analyse interactions between destabilised dimensions and other dimensions within the socio-technical regime, which in turn impact the overall dynamics of socio-technical transitions.

This study presents various avenues for complementary research. In particular, future studies could explore the role of self-organisation in socio-technical transitions, specifically within the EV charging industry. This contributes to the control authority discussion obstructing V2G implementation. Regulators and policymakers are expected to remain neutral in this discussion, leaving market players to self-organise. The control authority discussion also revealed the need of EV manufacturers to gain control. Therefore, future research could also aim to explore the potential effects on the role of the CPO in such a scenario. Furthermore, researchers could examine potential limitations of (European) standardisation and harmonisation of technical requirements in the EV charging industry. The reliance on technical standards may hinder innovation, particularly if standards are established prematurely. This also holds for the charging standard ambiguity. Therefore, future studies could focus on identifying what the most optimal roll-out strategy would be based on stakeholder needs, investment costs, and time constraints. These studies could aim to identify how sufficient flexibility in the power grid can be ensured.

Moreover, it is essential to note that grounded theory research focuses on theory development rather than hypothesis testing. This study has proposed hypotheses on the influence of institutional barriers on V2G adoption. Therefore, complementary studies could test these hypotheses by analysing existing pilot projects, employing focus groups, or conducting case studies. Moreover, expanding the sample sizes of the stakeholder groups could provide more nuanced insights and implications for these specific groups rather than the overall system. Nonetheless, this study has unveiled pathways for achieving harmonisation and standardisation to effectively tackle critical barriers within the current system. This dimension was not adequately addressed in the existing literature. The results have highlighted the significance of technical standards and uniform requirements for the progression of V2G developments. Additionally, the study has demonstrated the influence of the technical architecture of the V2G ecosystem on the business models of specific actors. This was exemplified by the implications arising from the charging standard ambiguity and control authority discussions. All in all, effective stakeholder coordination and collaboration were identified as viable pathways to accelerate the transition towards a flexible energy system driven by bidirectional charging of EVs.

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A Research Flow Diagram

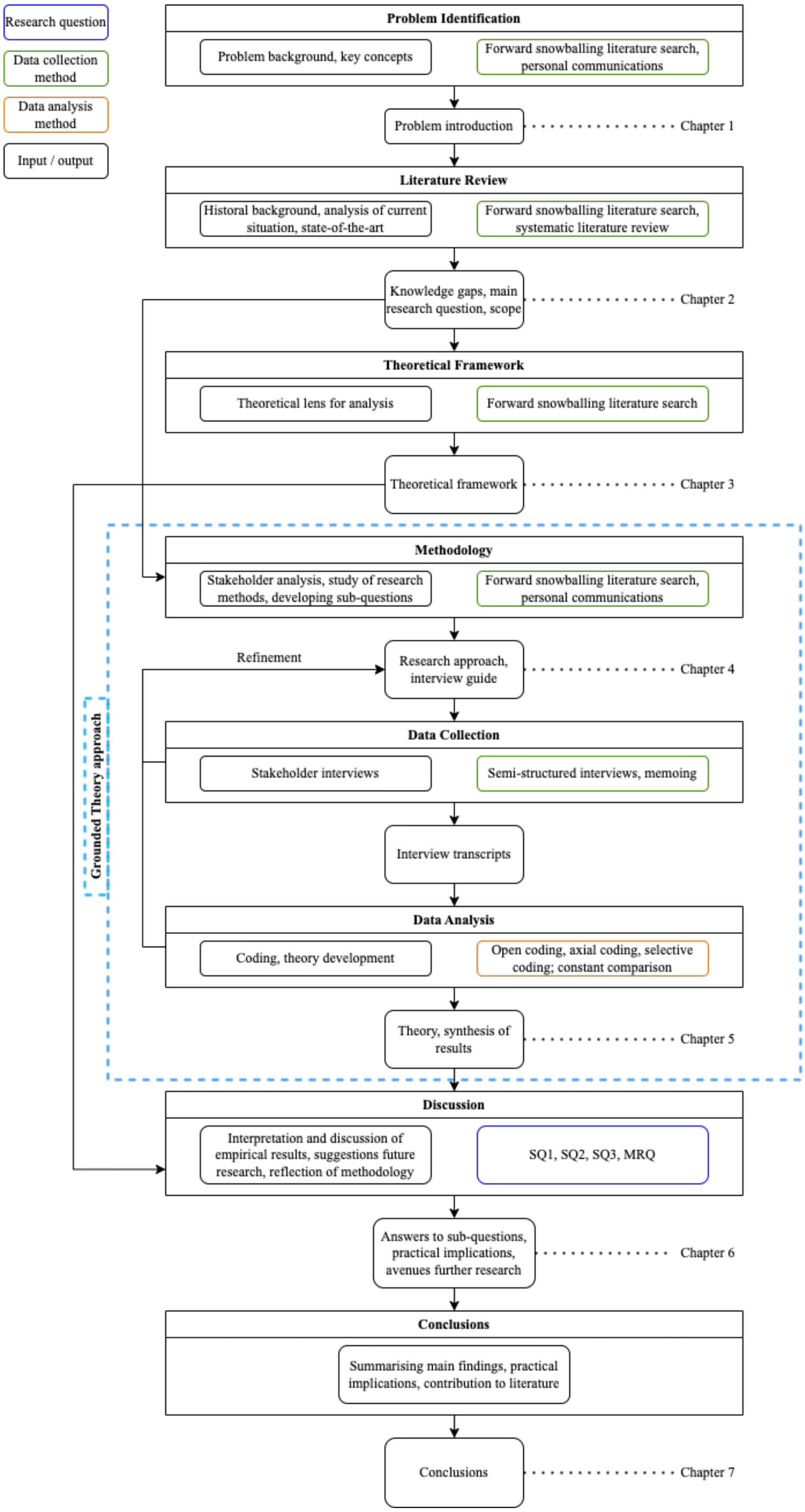

Figure A1: *Research Flow Diagram.*

B Interview Topic Guide

This guide presents the main topics to be discussed during the interviews. The questions listed serve as a guideline, but can be altered if desired.

Introduction to Interview Protocol [5 min.]

- Repeat purpose of thesis and goal of the interview. Emphasise European focus.
- Discuss interview protocol, informed consent, data management plan.
- Sign informed consent.

Start recording.

Introduction of Interviewee [10 min.]

- How would you classify your organisation?
- What is your current position at your organisation, and what does it entail?
- How much experience do you have...
  - ...in the general field of your organisation?
  - ...in the field of EV charging?
  - ...in the field of V2G?

V2G Objectives

- How would you describe the current stage of V2G in general?
  - How would you describe the current stage of V2G at your organisation?
  - What is currently the role of your organisation in the implementation of V2G?
    - Nationally?
    - Internationally?
- What are the main objectives of your organisation w.r.t. V2G?
  - What would be the main responsibilities of your organisation in the future V2G ecosystem?
  - Why does your organisation have these objectives?
  - What is your personal role w.r.t. these objectives?
  - In which countries does your organisation want to enable V2G?

V2G Implementation

- What is the role of your organisation and/or products in the technical implementation of V2G? (e.g., how to implement the technical guidelines, or how to regulate the market and support industry needs?)
- Does your organisation experience or observe any obstacles w.r.t. grid integration and technical implementation of V2G?
  If yes:
  - What are for your organisation the biggest challenges? And why?
  - Do you observe a need for harmonisation to tackle these obstacles?
    If yes:
    - Why? And to what extent?
    - How would you like to see this be realised? What would be the role of your organisation, in relation to the other stakeholders?

    If no:

    * Why not?
    * What is the position of your organisation w.r.t. harmonisation in Europe?
  - What does your organisation do to express its needs w.r.t. the obstacles mentioned (e.g., in the development of network codes or technical standards)?
    * How do you experience this? Why? *If negative:* What can or should be improved? Why?
- Did your organisation experience or observe any (similar) obstacles w.r.t. V2G in the past? If so, how did you deal with these obstacles? What went well? What did not?

Closing Remarks [5 min]

- Do you have any questions for me?
- Do you think the interview covered all relevant aspects? If not, what should we discuss as well?
- What stakeholders do you think would be very relevant for this research too? Why?

End recording.

C Interview Summaries

C.1 Regulator 1

V2G in general is seen as a promising technology, but there is still much to be done. There is mainly a lot to be done in the field of standardisation.

Government's role is being the driving factor. Pilots were supported already.

Biggest problem now: grid congestion. The grid operator was unable to solve it, causing problems in the roll-out of charging infrastructure, so the government had to intervene.

National charging infrastructure agenda (NAL) plays an important role in facilitating discussions between industry, government, and grid operators.

It is now becoming increasingly common that even slow charging cannot be rolled out due to grid congestion. Even bigger problems for fast chargers, although in principle they can be installed at a faster pace.

Industry sees a role for government in drawing up and coordinating the Smart Charging For Everyone approach. Governance is expected. Set similar objectives and create action plans. If certain issues cannot be solved jointly, legislation and regulations will come into play to enforce things. But this is a slower process.

Societal interest comes first.

The Netherlands is generally more ambitious than Europe regarding electric driving.

European regulations, such as AFIR, make it easier for Dutch EV drivers to drive through Europe, thus strengthening the European market. Can also ensure lower prices in the Netherlands.

Standardisation is the way to make big steps. But these are not established in the Netherlands, that is determined via the EU or UN. The Netherlands is one of the leaders in terms of charging infrastructure, so we have a lot to contribute. But when it comes to voting, we only have a single vote like the other Member States.

You want a competitive market, so that also includes competing protocols.

In the Netherlands, the Dutch protocols OCPP and OCPI are the de facto standard. They do have international moderating organisations. There are still competing protocols. The development team is in the Netherlands, so we have some influence on that.

With new innovations you want to grow and try things out. But as soon as it becomes bigger and you want to make an impact, stricter rules are needed. We have reached that moment for electric driving and there are good protocols that are already widely accepted in the market. But the government does want standards that are transparent and without the need for a license. Societal interest must be safeguarded.

In Europe there are Member States, and perhaps the European Commission, that show resistance to OCPP and OCPI. It is still unclear what exactly that resistance is. But there are concerns about whether the responsible organisations of those protocols are the right ones, and whether they have good representation. The Netherlands is generally in favor of standardisation. OCPP, OCPI, and ISO 15118 are especially important. The Netherlands does not want protocols to be proprietary and wants them to be free of licenses. But if you want to make OCPP and OCPI an IEC or ISO standard, you will lose influence as a country, which will also affect the protocol and the speed of implementation. Standardisation organisations do not excel in speed.

The main goal is CO2 reduction. So, how will a standard contribute to CO2 reduction? In the short term, it is more important that V2G contributes to solving grid congestion. Other government departments have different main goals. Take Chinese electric cars for example. China has been accused of over-subsidising the EV market, causing cheap cars to appear on the European market. This is good for CO2 reduction, but less good for the European car market.

No clear picture of whether market parties in the Netherlands support ISO 15118.

Research for the government showed that the Dutch network code is not an obstacle to the implementation of V2G.

There is an obstacle for the German government because they have many different grid codes, which makes large-scale implementation difficult.

Biggest challenges V2G:

1. Volume is needed, so charging infrastructure that support V2G, cars that support V2G, and people who want to perform V2G.
2. Systems must be able to talk to each other (i.e., clear communication protocols).
3. Double energy tax.
4. No business model for the users determined yet.

Regarding V2G, there is a big debate about who will be 'in the driving seat'. EV manufacturer, EVSE manufacturer, or CPO/eMSP? EV manufacturer has the information about the battery and has first contact with the driver. EVSE manufacturer is the best able to adjust power and charge direction of energy flows. CPO/eMSP monitors financial transactions with driver. The government does not take a position here. Government must advocate an open market with different business models. Action is being taken in a situation comparable to Tesla, which was eventually obliged in Europe to also use Type 2 and CCS plugs. For Tesla it was a way to retain customers, but on a societal level this was not optimal.

Market players may consider ISO 15118 to be a threat because it affects business models. Threat that EV manufacturers will gain too much influence.

Smart charging will be faster to implement and will help tackle grid congestion. V2G offers extra added value.

C.2 Regulator 2

Looked at how to involve electric vehicles in the design of the electric power system.

Huge uptake of EVs will have impact on the electric power system behaviour. Looking at how to bridge the hurdles of electric mobility.

Main pillars: seamless cross-border movement and secondary market of EVs in the EU.

Goal: fully integrated electricity market.

European EV manufacturer indicated to produce only V2G-compatible EVs in five years time.

Some manufacturers indicated to be thinking of pulling their EV fleets into aggregated capacities to provide certain (ancillary) services. Additional Demand Response Network Code in development for market access for this service.

Grid connection is ensuring that the system design is done the right way so that all devices that connect to the system and have a significant impact on system behaviour are taken care of in the grid connection network codes. For system users providing ancillary services, there are complementary, non-discriminating requirements. The grid connection codes provide for system users capabilities that form the first line of defence, including autonomous reaction from different system users when the system would see detrimental behaviour. With grid connection, we are focusing on the first few moments after the large event occurs.

The European Commission will be looking into the proposals and will discuss it with the Member States, publicly consult it on a platform, and see if there is a need for additional changes, and they will adopt is as a delegated act.

Observed diverging, non-harmonised grid connection requirements in the Member States and identified that as a hurdle for electric mobility. Discussed with NRAs that there was a need for harmonised requirements for charging infrastructure. NRAs were aware of the national policies. Also, there was some communication with national ministries. Positive feedback about harmonisation.

Data exchange is separate chapter, part of system operation codes (type B, C and D generation units). Encompasses communication between system operators and significant system users. Grid connection requirements are the conditions for the connection and does not prescribe which data protocols or standards be used for data exchange.

Advice by European Commission: do not refer to any specific European standard; keep the requirements of the network codes at the high level. Based on the existing practice, this is believed to be a more efficient way of implementing the EU requirements, because standardisation takes time as they are adding technical details. The network codes define the required performance; how that performance is achieved can be done via standards but is out of scope of the network code. Standards can be referred to in implementation guidance documents, brought forward by system operators (ENTSO-E, possibly DSO Entity in the future). Organisation of interviewee prescribes capabilities, but not how these capabilities should be delivered at the Member State's level.

Non-exhaustive requirements offer room for Member States to implement national requirements efficiently. In doing so, they can refer in their national legal framework to specific standards, but these are voluntarily applied. Experience leaves confidence that after grid codes revision, Member States and industry can decide on the development and implementation of standards.

Currently, the organisation of the interviewee is invited to technical committee meetings as observers for standards development. This way, they are involved early. Now, they are already developing certain technical standards for anticipating the adoption of the to be revised network codes, meaning standards can be provided in due time after adoption of the new network code. The organisation of the interviewee also provides non-binding views on the standards in development.

Objectives V2G implementation:

- System resilience: consider the impact of the uptake of the e-mobility and treat new actors (such as V2G actors) equitably.
- Mandating harmonised requirements in EU to:
  - Enhance undisturbed cross-border mobility.
  - Efficiencies gained through economies of scale.
  - No requirements for e-mobility before, so easier to harmonise than for other power generating modules.
    * Negative feedback from some DSO, because they wanted to make national choices, but this would hamper e-mobility. Because then, onboard converters/inverters on EVs and EVSE would have different requirements in different Member States.
    * Identified non-exhaustive requirements and eliminated all of them.
    * Benefits of proposal will be reflected via economies of scale.
    * Cannot harmonise all requirements for generators since there are site specific situations, but for EVs more possible because starting from scratch and need to allow for cross-border mobility.
    * Single certificate on the V2G EV to be valid across entire EU.

Some debates about specific aspects of new network codes. For example, from system perspective, it is important that the EV connecting to the network can quickly identify whether the system frequency is at normal operation, such that the EV is not connected when the frequency is deteriorated. But this requirement could be complicated for manufacturers and requires adaptation.

Reasoning and justifying of making compromises are key to the Commission.

In the past, stakeholders were complaining about the lack of standards, so a standardisation organisation joined the network codes implementation and development processes.

Timing wise, preference for European standards instead of intercontinental.

Electricity storage was excluded from RfG, but now to be included. Also, EV manufacturers and EVSE organisations were not included in the beginning of the development of RfG 1.0. Today, European stakeholders are increasingly engaged and active.

Not prescribing solutions, because too technology prescriptive. Would not allow for other solutions to be implemented. Not inefficient but is not something network code could do. It is too specific and is sensitive to biases.

C.3 EVSE Manufacturer 1

V2G, following the Gartner hype cycle, is past the first major peak and trough. The biggest hype is over, the problems have been addressed, now it is time for the solution.

The manufacturer has a good idea of how it could all work, and an initial inventory has been made for the necessary hardware, but the software is not ready yet. There is also not enough demand from the market.

The aim is to have a uniform charging station for all of Europe. But matters such as complying with the grid codes and communicating about this type of data must be regulated more uniformly.

The manufacturer focuses a lot on using energy smartly, and V2G can play a role in this. Especially in reducing grid congestion.

Public charging station has sufficient hardware to make V2G possible. The expected role for public charging stations in V2G is to be 'the police officer'. Measuring and passing on from the network to the car. Also check what the car returns and whether everything matches the grid code. Kind of a hatch.

Unequal grid codes are an obstacle, as is a clear communication system. A car is not bound by a border. Software-wise, it is technically possible to deal with differences per country. But it is also mainly about communication about the dynamic part of the grid code, which must be communicated from a central system by a grid operator.

Want to prevent the charging stations in the field from having to be visited in an X number of years for new hardware due to new grid codes. Communication details can be updated. According to their own specialists, no new hardware appears to be needed. Generally, research is being conducted into the future requirements, but these are not yet conclusive.

The advantage of AC charging is that it takes longer and therefore creates more room for smart charging and V2G. Public stations are often connected all night long. With a low-power DC charger you would still spend less time charging, leaving less room for V2G. The advantage of DC charging is that the inverter is located in the charger, which reduces the technical challenges caused by the mobile EVs. DC chargers, on the other hand, are much more expensive, often more than five times as expensive, due to additional hardware. Do not expect this to be reduced anytime soon. Perhaps if EV manufacturers decide not to use on-board chargers as a cost saving measure. This gives these manufacturers a lot of influence on the market. Similar to omitting chargers from new phones.

Uncertainty surrounding the required certification for V2G. Indication that now each combination of car and charging station requires a separate certificate; are seen together as a single energy supplier. But there is a need for unilateral certification, so that every car can work with any charging station. That certification must show that it is safe and that it can adhere to the grid code. According to the law, car and charging station are now a single object. But V2G will never take off this way. Aware of an EV manufacturer that wants to launch its own charging station as a result of this current system. Then you get a situation where, for example, you can only charge with a Volvo at a Volvo charging station, which had to be prevented with standard 'Mode 3' for charging profiles.

Network codes are not uniform in Europe, and they can change over time. Communication regarding network codes must be in the car with AC V2G. There is still a lack of communication between charging station and grid operator. There are developments within OCPP. Alternative standard will result in extra work and costs, which is not desirable. It is expected that the only feasible solution will be through OCPP. This manufacturer does not care where the back-office at the CPO gets the information from (i.e. the communication line between the back-office and the grid). New versions of OCPP and addition of other communication lines may require new hardware. ISO 15118 already has sufficient data fields to communicate about grid codes.

Wants to be involved in standardisation. Already involved in standards committees, lobbyists and industry representatives.

The type of standard does not matter much, it is mainly about the way of communicating. A given situation should always lead to a certain action, not to a possible action.

Certification in the Netherlands via energieleveren.nl. Based on NC RfG. Conformity is possible based on EN 50549 and 50549-2.

C.4 EVSE Manufacturer 2

V2G as the holy grail of the charging industry. Still waiting for the successful implementation of important protocols and standards.

Mainly looking at V2H, V2G is still a step too far. There are still many obstacles. Try to make this possible with the right regulations and standardisation, preferably at European level. But not actively developing V2G internally.

Not a matter of technology, obstacles are mainly in the area of legislation and regulations.

Grid operators mainly have short-term plans, while the electrification of the various sectors requires a long-term vision and approach. But the way in which these companies are now organised makes an investment agenda difficult. This translates into uncertainty for the industry. A European vision for grid management is also not emerging in Europe. As a result, no clear vision about V2X. There are no good business cases yet.

In the Netherlands, it mainly focuses on grid-aware charging in public spaces. A vision is still needed for operating charging infrastructure for V2G. It will take a long time before there is a joint approach to this at European level, but it is necessary.

Cars currently on the road use a 'not-so-smart' protocol IEC 61851, which means that little information can be exchanged between charging station and car. This certainly means you cannot charge bidirectionally. The car manufacturer therefore also has the responsibility to make more progress in this regard. The charging infrastructure lies between the car manufacturer and the communication to the CPO, so it depends on both developments. There is now more movement among car manufacturers. At first the battery degradation was seen as the major obstacle, but now the technology and batteries seem capable of doing V2G. Car manufacturers are now even applying for licenses to become energy suppliers (through V2G).

EV is not the problem regarding grid congestion, but part of the solution. V2G offers a great system that can help to further stabilise the grid to prevent or postpone major investments by grid operators. The current electricity grid still requires further digitisation.

The role of eMSP is diminishing. The focus was mainly on expanding the network, but little focus on improving the service aimed at the user. At first there were mainly business EV drivers, but private drivers have more incentives for smart charging.

Car manufacturers would like ISO 15118-2, because then they determine which eMSP is programmed in the vehicle. Not convenient for the consumer, because they want to have a choice. That is what ISO 15118-20 is for. ISO 15118-2 does mean that eMSPs must be more creative in their relationship with the user. CPOs are not interested in being told which eMSP should be compatible with their charging stations. Most of the industry is not like Tesla who build their own infrastructure. The great thing about European legislation is that abuse of power and restrictions on competition are tackled harshly.

ISO 15118-20 can allow bidirectional charging, but mainly V2H because grid codes are not included in the standard. Standardisation is also needed in communication between CPO and grid operator, because that is still lacking.

There are too many different rules within Europe, which makes charging stations expensive. Every country has different requirements, which translates into different hardware. There is no European type approval, as is the case with cars. The EVSE manufacturer often spends more than 50% of their time adapting existing products to the various rules and requirements. So it is not yet worthwhile to be very active in V2G. They are afraid that this will also apply to V2G. But there is no clear picture yet of what V2G would mean for hardware requirements because there are no standards yet. So at the moment they are waiting. Focus on V2H first, with V2G as the last step. There is more to be achieved at V2H at the moment. V2G is a lot more complex because of the many actors involved. Consumers also want V2H. CPOs want distributed energy resources, which they can use to serve their business model and then invest more in the charging infrastructure. Unique situation in the Netherlands, because there is a large urban area, which means a lot of public charging (AC). To make V2G possible there, incentives are needed.

Own chargers not tested and validated for V2G. AC chargers will probably require additional hardware outside the charger. Likely within the charger in the future.

Grid operators must provide clarity about the requirements for public AC stations, but the requirements are also increasingly changing. It is important to take into account the many AC chargers that have already been installed, and what is needed to make these V2G-ready.

Public market for chargers is becoming less interesting due to over-dimensional requirements, high costs, long lead times, difficult application processes, and small series. This makes a difficult business case.

Mainly see potential for V2G in charging plazas, also with stationary batteries and solar panels. V2G is difficult to realise, because a market must be created, preferably throughout Europe.

Also signals that slow DC chargers are coming to the market, also for the home market.

Regulatory framework needed at European level. Time for pioneering is finished, now a healthy economic business model is needed on a European scale.

The slow phasing out of the 'salderingsregeling' in the Netherlands is slowing down innovation for V2G, because it is not yet worthwhile to store solar energy instead of supplying it to the grid.

Various governmental organisations do not seem to communicate well. For example, the charging infrastructure sector requires that different disciplines such as transport, energy and digitisation talk to each other. Otherwise nothing happens.

Member of a European organisation to provide policy advice and stimulate European legislation for charging infrastructure. There must be awareness that charging infrastructure is a new sector and needs more supervision. So they also argue for more power for the European legislators. Must be a level playing field.

Also help develop standards such as OCPP.

Becoming more difficult to distinguish yourself in hardware. There is price competition going on, but the distinction is mainly based on software.

Attention should also be paid to the use of V2G for the TSO (balancing market) and the consequences for local grid loads. Low voltage part of the grid is also not yet digitised much, so more digital measurements are needed. If incentives are given that cause an imbalance, it must be assumed that the CPO will take action to address this.

C.5 CPO 1

Their aim is that everyone can charge without any worries. That is also what the municipalities expect from them. It is about high availability and security.

No relevant practical experience with V2G. Recently, they have been delving deeply into the technology and the possibilities. Pilots have been done in the past with ChaDeMo for V2G, but this is not the European standard so the experience is not relevant. The aim now is to develop the use cases in the short term.

V2G still in its infancy. There is no car on the market that actually supports it. Regulation regarding grid codes and other requirements have also not yet been defined.

It is said in their professional environment that some car manufacturers seem to have more experience than the system operators, which must provide clarity to the industry regarding technical requirements.

Requirements for tenders for charging stations are very strict, such as that the stations must be V2G ready. As a result, many charging stations that have not been in place for long are being replaced because they do not have the necessary hardware for V2G. But it is not yet certain whether the charging station that will replace it is really V2G-ready, because the regulations have not yet been defined. This may therefore have consequences for the future, if it turns out that additional hardware is needed.

Want to set up projects to test and research V2G, and then come up with use cases for a business model. These projects must take place in a realistic environment with realistic requirements, so that they are also easier to scale. For example, with ChaDeMo chargers you will not be any wiser. But they also don't know where exactly to start, so they look for industry partners to work with, such as charging station manufacturers and car manufacturers.

Not a general purpose for V2G, because it is a sword that cuts both ways. They mainly want to keep up with the market for commercial reasons, and at the same time be at the forefront. The CPO feels responsible for bringing manufacturers together to take the first step. Other parties are needed to set it up, so cooperation is necessary. For example, the grid operator must be involved, because they will play a more active role in managing bidirectional charging. Lots of potential in arbitration and imbalance enforcement, FCR. FCR requires a low response time. But making V2G possible mainly lies with the manufacturers and suppliers. The CPO can then choose exactly how they want to deploy it.

The CPO wants to remain in control. They do not want another party to do smart charging, such as the eMSP. The eMSP seems to lose its right to exist due to ISO 15118-2 Plug & Charge, so they are looking for new business models. The CPO wants to remain in control because they purchase the energy, and that must match the energy sold. They must therefore be able to accurately predict at what time how much energy is consumed. If an eMSP controls and influences the charging process, the predictions will deviate more from reality, and the CPO will run financial risk (including fines).

Consultants are involved in drawing up tenders for the municipalities. They hear about standards such as ISO 15118 and other technical requirements and then include them in the tender. But they do not actually know what this means and what this means for the manufacturers. The CPO got the feeling that there is a lot of lobbying for certain standards that were created by commercial parties.

In tenders, the program of requirements often states that you must comply with certain protocols, but also with future versions of that protocol. But it is not yet known what the consequences of future versions will be for the hardware. Additional hardware could be required in the future.

It is still unclear who must comply with the network code. The car or the charging station? The system operator does not provide clarity. The focus is mainly on AC V2G, so it is expected that the car must comply with the grid code. If this is not the case, many street charging stations will need to be replaced or require additional hardware. This is also a major financial risk for the CPO.

Voices in the sector about the use of OpenADR for communication between DSO and CPO back-office. But this protocol appears to be outdated.

At this time, a network code is not yet communicated via the current communication infrastructure. The system operators must play a major role in providing clarity about who is responsible for compliance with the grid codes, and how this should be communicated.

Many people they speak to are not yet deeply involved in V2G.

CPO also plays a role in advising municipalities on the use of certain protocols and standards.

Not very actively involved in the development of OCPP, network codes, and other standards. They often run financial risk, so they should take a more active role in this. Involved in the national charging infrastructure agenda (NAL), but it is mainly about Smart Charging, and not V2G. Notice that the Netherlands wants a pioneering role.

OCPP is now no longer a choice, but very often a requirement from the tenders. Requirements also often to comply with future versions.

The CPO is in favor of standardisation, but often finds it a problem if there is a demand to comply with future versions because this can lead to hardware adjustments. That is why good agreements must be made about this.

Would like to know what V2G-ready actually means. Some charging station manufacturers already claim to have V2G ready products, while the rules have not yet been defined.

C.6 CPO 2

The CPO does not directly have customers, but rather users of their network. The customers are the government agencies (the contract authorities) that organise the tenders. The CPO is responsible for purchasing, installing and maintaining the charging stations. Also responsible for purchasing and selling energy, and charging station services such as smart charging.

The CPO wants to offer more innovative charging services, taking sustainable energy, grid load and grid congestion into account, and adapting services accordingly. The CPO wants and must keep up with developments and considers itself a pioneer in smart charging because they have been conducting tests for years. The interviewee believes that charging infrastructure can make an impact in the energy transition and combat grid congestion. Personally, the interviewee believes that the charging station and car are being placed in the centre of attention in combating grid congestion, and believes that there is sometimes too much pressure from the grid operators. Yes, there is flexibility in charging electric cars, but that is mainly due to created use cases, for which the CPO expects a reward.

Expects that V2G has been researched for 80-95% on paper, and 5-20% has been researched in practice. With smart charging, the transition to practice has now started and is slowly becoming an obligation. There is a dependency between V2G and smart charging; smaller step from smart charging to V2G than from conventional charging to smart charging.

They once did a V2B trial with an EV manufacturer that had provided shared cars. So they didn't really have to deal with network codes, because it was a behind-the-meter solution. Thought about use case and partially implementation thereof. ISO 15118 was used. The project was temporary, but it is unknown how the EV manufacturer will continue with it. Apparently it has R&D in this area. The CPO now also has projects underway with V2G charging plazas, but mainly research on paper about reducing impact on the grid. Also wants to coordinate discharging based on CO2 emissions in the energy mix of the Netherlands. But there is little practical experience yet because there are no cars supporting V2G available yet.

The Dutch market is increasingly demanding bidirectional solutions.

V2G service depends on what the driver wants. Do they want to charge as cheaply as possible? Then V2G can play a role. Especially potential in V2G for truly clean electric driving. The vast majority of kWh are charged at times when the most CO2 is emitted in the energy mix, and that is a shame. With V2G on top of smart charging, more impact can be made.

The CPO wants to be as independent as possible from suppliers and therefore mainly benefits from suppliers meeting the requirements and standards. That is why the CPO is looking for standardisation of technology and protocols. But the requirements in the Netherlands for public charging are very strict (such as the built-in smart meter), which reduces the number of alternative suppliers. This is probably because the Netherlands is unique in the large scale of public charging, and therefore the network operators have a lot of influence on the charging infrastructure and the associated requirements.

The risk surrounding the different requirements within Europe lies mainly with the charging station suppliers, which means that the CPO cannot easily choose international suppliers. Car manufacturers also see a risk that they will not be able to offer the same V2G EV model on the Dutch market and on the German market for V2G simultaneously. The CPO had actually expected that this problem surrounding the varying network codes could be solved using software. The interviewee notices that there are actually few people who know exactly how this works.

It is difficult for the CPO to see how the charging station manufacturers distinguish themselves in V2G technology. Unclear how the grid codes should be implemented and who is responsible for compliance; the car or the charging station? And will this work with all cars or just some? There is now a risk that you buy a charging station that claims to be V2G-ready, but actually is not before the technical requirements become more formalised. This creates a financial risk for the CPO. The charging stations are designed to be operational for a long time, but if they all require hardware changes to facilitate V2G, it will be an expensive situation. The requirements surrounding V2G are currently very unclear. It does not go beyond complying with the latest and future OCPP and ISO 15118-20, making the explicit current and future hardware requirements unclear. The contracting authorities of the tenders often do not know the answer to this question. There was even a situation in which the requirement (about switching off the charging station during a power outage; island mode) was removed from the program of requirements after a CPO indicated that current developments in technology cannot yet meet the specific requirement they drew up. This implies that even the contracting authorities often do not know what they are talking about and what exactly they are demanding. The CPO experiences this as an almost daily reality. The difficulty is that some economic operators (EVSE manufacturers, CPOs) claim that they can meet that requirement, while this cannot be said with certainty at all. As a result, other parties sometimes win tenders, but then run the risk that their claim is incorrect when definitive technical requirements and standards become available. That is why the CPO wants to make good agreements with the contracting authority and be honest about the current limitations. It is not yet possible to make any estimates about the future costs that may be involved in adapting to new rules and requirements. You offer your products based on the current state of technology. Contracting authorities often demand conformity with the latest protocols, without really clearly stating why, while this does have a major impact on the hardware requirements. Example: OCPP 1.6 and 2.0.1. The CPO believes that some organisations exert too much influence on the requirements set by the contracting authorities. Also afraid that the same situation will continue with V2G, but because it is a significantly new service, the interviewee can understand that additional hardware is needed.

There is still uncertainty about how the grid operator will communicate about local grid congestion, and how this will affect the V2G activities at the charging stations. This has not yet been determined in the Netherlands, and the grid operator has not yet commented on this. There are developments within OCPP.

The CPO can be sufficiently involved in the development of standards and protocols, but also sees that most of the consequences are for the manufacturers.

The CPO is not afraid of additional competition from, for example, eMSPs as a result of the V2G developments.

The consideration of AC and DC V2G mainly lies in the costs. The CPO wants to prevent charging stations for V2G from becoming twice as expensive, so consideration must be given to whether this is worth it.

According to the interviewee, standardisation is well organised in the Netherlands. Still curious whether the problems that occur with smart charging will also be observed with V2G, such as some cars not starting the charging session for no apparent reason. A lot of time is spent developing protocols, which are actually very simple, but deviations in the implementation of the protocol can cause problems. With V2G, the risk of problems may be even greater due to the complicated technology.

Harmonisation is particularly desirable in terms of technical support and interoperability between car and charging station. The interviewee is less concerned about supporting OCPP and therefore the control of the charging station.

You notice in the working groups in NAL, for example, that the Netherlands has no automotive industry, which means that technology is only discussed to a limited extent, including V2G.

There is also a difference between charging station manufacturers and controller manufacturers. Some manufacturers make their own controllers, which may make them more flexible to changing requirements.

Manufacturers could distinguish themselves by demonstrating that they actively carry out testing with V2G and that they actively monitor, or perhaps even influence, developments surrounding standards, regulations and technical requirements. But once V2G requirements are clear, suppliers will be less able to distinguish themselves.

There is a lot of uncertainty about how you can show that you are V2G-ready.

C.7 EV Manufacturer 1

The most extensive research into V2G for this EV manufacturer takes place in the Netherlands. Ultimate goal to bring V2X to all users. The majority of customers are private individuals and not business. A different business case is needed. First they will focus on V2H. They expect the most demand for this in the Netherlands, and see that this implementation is the most straightforward. In the public space, for V2G, there are many more actors involved, which makes it very complex. Technically there is little difference between V2G and V2H, but there is an issue about who controls the session.

If the netting arrangement ('salderingsregeling') disappears, V2H offers a great opportunity to store energy from solar panels. For V2H there is no additional actor between the EV manufacturer and the charging session.

This EV manufacturer also sees potential in V2G applications for shared cars. At peak times when energy demand is high (late afternoon, early evening), the demand for shared cars is also relatively lower, making it possible for V2G applications. Pilots are being initiated for this. V2G can then support the energy demand in a neighborhood and prevent overload. They also see its potential in greater use of green energy, i.e. charging, storing and using green energy when little green energy can be extracted from the grid.

They mainly want to learn from the pilots how their technology performs in V2G. So how is the battery health, especially in the long term. But pilots have only just started and have not yet provided useful information.

They also believe in other forms of mobility and therefore want to become a mobility provider, instead of the conventional car manufacturer.

Current manufacturer's cars are already V2L (vehicle-to-load) capable, but still work with old ISO standards (ISO 15118-2). The chicken-and-egg story is again applicable here, because the required standards have not yet been developed. ISO 15118–20 is also not yet complete. For example, grid codes cannot yet be communicated. With AC V2G this is necessary, because the car must adhere to the applicable grid code. The manufacturer would like to know what they want to do if, for example, they want to unveil a new car with V2G next year, but they are still waiting for new standards and what this means for the design of the car. They actually learn not much from pilots with old protocols (such as 15118-2), but they are mainly concerned with the impact on the battery with V2G. 15118-2 was the only standard available at the time.

Preferably want mass integration of cars that are bidirectional. For example, another EV manufacturer has indicated that it is focusing on DC V2G, which means that the car's onboard charger does not have to be bidirectional. But this EV manufacturer has not made a decision yet.

With their cars currently on the road, V2G is technically possible, but not desirable. Hardware for optimal battery management is still missing.

V2G also influences the choice of new business models. Mainly see a role in reducing grid congestion. Saying that one must be careful that there will not be enough investments in the grid, which will mean that there will no longer be charging security.

Grid congestion mainly only occurs in the Netherlands, but this is also expected in surrounding countries. That is why they see the Netherlands as an example for the future of the rest of Europe. This makes the Netherlands a good testing ground for new technology. But the EV manufacturer does have Europe as its full scope.

California already has legislation requiring V2G. They see this as the solution to grid congestion.

Do not know what is meant by V2G-ready. Want to break the chicken-and-egg story by pushing the technology through pilots. We are now in a situation where no one provides clarity about the guidelines in Europe. The Dutch organisations that should provide clarity are also not providing it. These organisations often say: just do something and test it. But the manufacturers cannot 'sell' this to their headquarters (HQ), that is not how it works within a commercial company. That is why manufacturers now have to spend a lot of time themselves to get an idea of the expected guidelines, and they are in contact with the international HQ. In this way they hope to form a basis for the new guidelines. Technically, manufacturers are almost ready, but are still waiting for clear guidelines and legislation to take the final step, especially regarding standardisation. Because there is no grid congestion yet in other European countries, the urgency for drawing up European legislation is still low.

You can be the only car brand to start with V2H, which is a competitive advantage, but then there is a good chance that your hardware will not meet the future guidelines for V2G.

The EV manufacturer is particularly afraid of losing control with V2G, in the public domain. The EV manufacturer believes that they know what is best for the car, and can create the best charging and discharging profiles based on that. There are many concessions about V2G charging stations so that V2G is possible as soon as the cars are available, but there is a chance that the EV manufacturers will not release their system for management by a third party. The EV manufacturer must still be able to provide a warranty on the battery. There is also a revenue model, which in the public domain comes from one party, the CPO, but not from the EV manufacturer. That one party may have all the advantages, but not the disadvantages such as possible battery degradation. The car manufacturer also bears all development costs, but receives nothing in return. This discussion may therefore cause delays in the public domain. It is therefore likely that only V2H is possible for the time being. This discussion also means that EV manufacturers are considering developing their own charging station, but only for V2H. There are many charging station manufacturers who are fully committed to ISO 15118-20 implementation, but who are completely dependent on the car models that come onto the market. But the EV manufacturer does believe in economies of scale, so they expect that you can also do V2H with charging stations from other manufacturers in the future.

It is unclear what the requirements are around grid codes, and it is especially important that the correct information is communicated to the car. The grid codes programmed in the car must match the charging station and the region. Also, the car and charging station must use the same communication protocol. The idea is to have the right hardware in the car to store network codes, and the network code must be added for each region for V2G. For AC V2G required. It is expected that not every region will require new hardware due to the applicable grid codes, but developments are still required from the software and communications side.

They have not yet decided whether they will focus on DC or AC V2G. Depends mainly on the costs for the end user.
To summarise the biggest obstacles:

- What are the technical requirements?
- Who controls the V2G session?
- Will it be AC or DC V2G?

A charging station or other external platform does not have all the information from the car, which means that bidirectional charging or a delayed charging session cause the car to go into sleep mode, but still consumes power at low voltage. This can cause the car to run out of power and become unable to start up. Current vehicles are not built for smart charging. But in the public domain, the EV manufacturer manages the charging station. The result may be that the user may have to use a different app at each charging station and in each city.

Double taxation is also a barrier. Also for V2H.

C.8 EV Manufacturer 2

V2G is necessary. The car is basically ready. Still a big challenge surrounding the grid codes. Which grid code should the car apply, and how is it received? Who will take the lead in determining how the car will implement the grid code? The charging station? The car? It is about the AC V2G situation.

If you connect the right stakeholders, you can easily do DC V2G. But there are no public charging points that allow slow DC (dis)charging. There are only DC fast chargers.

At AC V2G mainly a chicken-and-egg dilemma. Charging points that support V2G are not yet available, because the charging station manufacturer does not know what the car manufacturer is doing. The car manufacturer is dependent on the charging station manufacturer. Both parties have not yet agreed on what their role in the value chain will be. There is agreement on ISO 15118, but that does not say anything about the grid code implementation. This car manufacturer has already made an assumption, but as a result they can only make V2G possible by entering into specific partnerships with charging station manufacturers. There are more charging station manufacturers, so we need to work on a universal solution.

We have to think about how the car will be registered for V2G, and how it shows the public that it can do V2G and complies with the grid code.

They are testing with V2G. But it is a big challenge to get all stakeholders on the same page. As a car manufacturer, they look at the global aspect, because the car is sold on a large scale and also crosses national borders.

V2G offers added value for consumers. It is a revenue model for them. V2G is part of smart charging. Three most important pillars for V2G: increasing the share of green energy, reducing the societal problem of grid congestion, allowing consumers to save on charging costs.

V2G is now an investment for the EV manufacturer. Not necessarily a separate business model, but should contribute to strengthening the brand. The car manufacturer goes beyond just mobility and is no longer the conventional car manufacturer. They want to relieve the consumer of worries regarding charging, and want to offer a car, with associated services, to distinguish the brand from the rest. There is a shift from car ownership to car use, i.e. more of a service such as car sharing.

Obstacle regarding V2G: who is the master, who is the slave? Must become more universal, to prevent them from becoming only one-to-one solutions, i.e., only certain cars work with certain charging stations. You already see car brands in Europe entering into partnerships with specific charging station manufacturers to set up V2G because there is no standard yet.

The current ISO 15118 and OCPP protocols do not sufficiently cover grid code implementation. That is why you now have to provide additional information outside those protocols, and you need specific collaborations for this. This concerns, for example, state-of-charge information. The charging station and the car must not conflict with the charging profile they want to apply. A charging station must therefore be able to view more information from the car, or the car must have more control over the charging point.

Thinks that many people working on the protocols do not have sufficient practical experience regarding what is needed to apply smart charging. Car manufacturers already want to go live. The CPOs and charging station manufacturers are lagging behind. If the protocols are only ready now, it will take years before the cars and charging stations are finally adapted to this. So the car manufacturer mainly hopes that only software adjustments are needed, and not hardware. Unclear now.

All car manufacturers saying their cars support V2G are implementing their own interpretation of the technical specifications that are now missing.

There is mainly a lack of clarity from legislation and regulations. Often sees that it is a political issue with many conflicting interests. Certain parties want to take on a major role in order to take control. The grid operator wants to control the car to determine when it charges or discharges, the car manufacturer does not want to release control to protect the battery due to product liability, and the energy company mainly wants to deal with the buffer capacity that cars can offer. Perhaps these discussions will lead to protocols development slowing down. Who will determine how smart charging and V2G will be applied at a public charging point?

Because there is so much uncertainty, the car manufacturer has also started looking for solutions itself to launch V2G with specific parties.

The car manufacturer has direct contact with the user and therefore sees an advantage in this.

Many parties can generate revenues with V2G and smart charging, but how does it remain interesting for the user?

According to this car manufacturer, there are many parties that claim that they are V2G-ready, but know that this is not the case. No one knows yet how the grid codes should be implemented. This will not work with the cars that are currently being launched, because the charging station manufacturer does not know how the car manufacturer deals with it (because there is no standard yet).

It is still unclear who is responsible for this standardisation, and how to ensure that all parties are on board. Also not convinced whether Dutch organisations have the capacity and reach to push interests within Europe. There is little automotive industry in the Netherlands, but you will really need them at R&D level.

For now, it is much easier to apply V2H first.

C.9 DSO 1

All enthusiastic about V2G. An important aspect is still: will it be AC or DC? Choice is mainly determined by the car manufacturers, and not top-down. For DC, additional inverter should be in the charging station. The car already has an inverter, but it will need to be adjusted. That also costs something, but less than a new inverter for the charging station. It therefore also depends on what the consumer sees as the most cost-efficient. DC charging stations are many times more expensive. With AC V2G, the car must comply with the grid code, but this is not well harmonised in Europe. There lies the challenge.

Pilot with AC V2G to see how this develops and what the technical barriers are. Also contributed to making OCPP and ISO-15118 suitable for V2G, of which new versions are ready now.

First expectation is V2G at homes and companies (V2H/V2B) to optimise own production and consumption.

With V2G, additional rules are required to ensure that there is no discharge in areas where, for example, a lot of energy is generated by solar panels, which worsens grid congestion. So they still look a lot at the impact on the grid in different use cases, such as discharging based on congestion management, imbalance, or electricity rates.

Do not expect to see a large fleet of V2G cars on the road in the short term. We should mainly focus on grid-aware charging as the main goal and see what the growth in electric cars means for the electricity grid, especially at peak times. Vision formation based on this. V2G will contribute to reducing grid congestion. But consumers also just like it.

For V2G we must have specific requirements, as is now being done in the new RfG.

As a grid operator, they are not specifically encouraging V2G, but they are encouraging smart charging to become the standard.

Some charging station suppliers claim that they can offer V2G, but this might be a little too early because the definitive requirements are not yet in place and V2G-compatible EVs are not on the roads yet.

The biggest responsibility for the grid operator at V2G is to ensure safety and manage peak loads. But there are already many normal EVs on the road that cannot do V2G, but do cause peak loads. The priority is therefore smart charging.

Grid operator has provided feedback on new RfG proposal with specific paragraph on V2G, which will distinguish between AC V2G and DC V2G. AC V2G will then have to be approved on the basis of certificates, for which the car manufacturer is responsible. The question remains how an AC charging station will check whether a car has the correct certificate, and how this will be acted upon.

Proposal from EU DSO Entity to harmonise Type A PGM for V2G from 100 kW. This has no Go, so Type A (under 1 MW) will not be harmonised at this time. DC V2G will follow requirements of electrical storage modules.

It is implied that grid operators should be given direct access to the charging infrastructure, but this was not the position from EU DSO Entity. It is still unclear how these rules are checked, because there is no definitive standard for the communication protocol. This is out of the scope of the RfG, and the de facto standards might differ in each country.

It is still a challenge for current charging stations in the field to comply with the rule that they must respond autonomously to frequency changes within a certain time. Being looked at by the EU. ElaadNL is afraid that too many adjustments are being asked of the charging station manufacturers. DSOs will also not be so quick to set up their systems to control charging stations. It is especially important for the grid operator that everything is done safely and in accordance with the applicable rules. TSOs in Europe want the ability to change certain parameters at TSO level, allowing the different TSOs in Europe to have different requirements and implementations. That is contrary to what the DSOs want. TSOs seem to have a bigger voice. For DSO, smaller installations (under the proposed 100 kW instead of 800 W) do not have to adhere to those stricter requirements to get V2G (mainly V2H) off the ground more easily.

Responding to threats of overload at local level is not part of the RfG but seems to be mainly managed at regional level.

According to this DSO, V2G-ready means that you comply with the RfG. But this has yet to be definitively determined. An approval process must also be set up to issue certificates. But you may not have to comply until 3 years from now. There are no rules yet. In the Netherlands you would have to register your charger via energieleveren.nl, just like solar panels.

For ElaadNL, OpenADR is the preferred interface between regional grid operators and CPOs at the moment. Will be further elaborated on in the coming months. OpenADR contains options for charging control from DSO to reduce capacity. It would be useful if this became a European standard, but there is no consensus on this within Europe yet.

It is expected by the interviewee that OCPP will one day become an IEC standard for communication between charging station and CPO. Between grid operator and CPO now OpenADR or IEC61850 for communicating frequency, voltage, and congestion management signals.

Supporter of harmonisation and standardisation. Would also be happy if one standard were now chosen in the Netherlands so that it could simply be applied without creating mismatches between grid operators and CPOs.

Sees a risk for manufacturers if the Dutch standard is different from the European standard adopted later. Can take a lot of software hours. But they keep a close eye on the European playing field. They hope to be able to charge dynamically grid-aware within a year.

They are now discussing with Dutch CPOs whether they can apply OpenADR.

C.10 DSO 2

V2G is shortly before the major market introductions.

They continuously try to identify new obstacles. PwC report from a few years ago presents technical obstacles that still apply. An additional obstacle has been added with regard to reducing the supply. Instead of continuing to supply 4 – 6 kW, really go to 0 kW. But previous tenders always required 4 – 6.

The European Commission must embrace OCPP. German automotive is very against OCPP, probably mainly about market power. But they themselves do not come up with an alternative.

The technology still has to prove itself in the form of use cases.

Many stakeholders are talking about how the V2G process will be managed and who is responsible for optimising it, and with which app. But that's not how it works, that's not the point. Everyone looks at themselves, how they will control the process. This grid operator mainly believes that the market will solve this itself.

Everyone also sees other benefits for EVs. In Europe we mainly see benefits for the climate, in America they see a car that accelerates quickly for an affordable price.

In the Netherlands we excel in innovation. So this is something we have to do. For CO2 reduction and better air quality. But it is especially important for the grid operator that we can keep up with the energy transition, and calculation models show that we are not going to keep up with just extra cables and transformer stations. We need buffer capacity. Stationary batteries are also a solution, but they are charged to the grid operator, which entails costs, as do extra cables.

The grid operator knows what they want with V2G readiness. 1) We need to be able to give a stop signal, 2) we want an anti-islanding device, 3) we want a cascade such that not everyone stops or starts supplying at the same time, and 4) the TSOs want to do frequency control.

This network operator proposes that the charging station manufacturers add hardware now, and later add/exchange additional hardware in the event of possible updates for new requirements, since a technician will come every so often for inspection anyways. So make the EVSE modular.

If you opt for a tender, you will have a consultation in which you can ask what exactly is meant by 'V2G-ready'. Not all requirements have to come from Europe. We cannot wait for European standards, we need the buffer capacity now. We can already achieve it with a select number of cars that support V2G, but we want to facilitate an open market.

We have been developing very hard through pilots, not necessarily to be the first, but by being there early you can set the standard and accelerate developments. We also actively enter into discussions with car manufacturers to check whether this works for them.

Some colleagues indicate a need for de jure standardisation, but this also causes a lot of hassle, and some standards such as OCPP have not yet been fully developed. The aim is to provide clarity to the industry when they have done well. DSO is convinced that they can already do this in sufficient mode.

If you set a standard too quickly, this can greatly hinder innovation. Perhaps we would never have had a touchscreen on our smartphones, for example. It does provide clarity, but is now seen too much as the holy grail. It also includes a bit of democracy and industrial politics. If a standard is imposed by a sector, you will see that it is abused. If you already pre-sort actors, it must be a government company to safeguard those public interests. But who? In the Netherlands there is a Ministry of Infrastructure and Water Management that deals with electric transport, but not with energy. It also differs in every country, and every country also has a different number of system operators. If you want to solve this problem, you have to free up the market somewhat.

The challenges for the industry sometimes go in all directions, so it is very difficult to draw up a report on that.

Everyone is working on V2G, but few are really working on it (i.e. in practice). The DSO indicates regularly that they do not always have the answers, but are working on the development and would like to hear whether it is workable for the industry. So bottom-up standardisation.

D Codebook: Open Coding

This appendix presents the codebook for the open coding phase. The first five sections present the open codes emerging from the interview data. The final section showcases open codes conflicting each other.

For all tables, unless indicated differently, the following applies:

- Open codes are presented in alphabetical order.
- 'Groundedness' presents the total number of times the particular code emerges in all interview data.

Table D1: *Open Codes Emerging in the Empirical Data.*

Open Code	Groundedness
ambiguity in future protocol requirements	6
call for standardisation in general	9
charging standard ambiguity (AC or DC)	7
competing standards enhance competitive market	2
doubtful claims V2G-readiness	5
DSO-CPO communication standard ambiguity	6
EVSE adaptation is neglegible risk	1
EVSE adaptation risk	4
EVSE lack data from EV	3
financial risk of EVSE adaptation	3
financial risk of V2G operation	4
grid operator already specifies requirements	1
grid operator to specify hardware requirements	2
grid operator to specify network code	1
grid operator to specify network code communication	2
grid operator to specify who must comply with network code	1
hardware requirements specific to V2G are known	2
hardware requirements specific to V2G are unknown	6
impact on EV battery health	3
influence of actors on setting requirements	4
influence of actors on setting standards	3
lack of DSO-CPO communication infrastructure	6
lack of knowledge contracting authority	5
lack of V2G-compatible EVs as limiting factor	6
lack of V2G-compatible EVSE as limiting factor	2
limited supplier alternatives Europe due to technical requirements disparities	2
need for common standard across Europe	8
network code communication EV-EVSE is not possible	5
network code communication EV-EVSE is possible	1
network codes disparities Europe create uncertainty	5
network codes implementation ambiguity	3
network codes pose no challenges	1
network codes requirements ambiguity	7
pilots require diverse actors	3
pioneering role the Netherlands	5
process of standardisation is slow	6
resistance to OCPP within Europe	2
risk of market fragmentation Europe	6
risk of market segmentation Europe	5
smart charging priority over V2G	4
technical standard affecting business model	3
unrealistic pilot environment	3
who must comply with network code	3
who should be in control V2G session	6

Note. 'Groundedness' presents the total number of times the particular code emerges in all interview data. Open codes are in alphabetical order.

D.1 Regulator

Table D2: *Open Codes Regulator 1.*

R1	
Open Code	**Groundedness**
call for standardisation in general	9
competing standards enhance competitive market	2
DSO-CPO communication standard ambiguity	6
influence of actors on setting standards	3
lack of DSO-CPO communication infrastructure	6
lack of V2G-compatible EVs as limiting factor	6
lack of V2G-compatible EVSE as limiting factor	2
need for common standard across Europe	8
network codes disparities Europe create uncertainty	5
network codes pose no challenges	1
pioneering role the Netherlands	5
process of standardisation is slow	6
resistance to OCPP within Europe	2
smart charging priority over V2G	4
technical standard affecting business model	3
who should be in control V2G session	6

Table D3: *Open Codes Regulator 2.*

R2	
Open Code	**Groundedness**
influence of actors on setting standards	3
need for common standard across Europe	8
network codes disparities Europe create uncertainty	5
network codes requirements ambiguity	7
process of standardisation is slow	6

D.2 EVSE Manufacturer

Table D4: *Open Codes EVSE Manufacturer 1.*

EVSE1	
Open Code	**Groundedness**
ambiguity in future protocol requirements	6
call for standardisation in general	9
charging standard ambiguity (AC or DC)	7
DSO-CPO communication standard ambiguity	6
EVSE adaptation risk	4
hardware requirements specific to V2G are known	2
influence of actors on setting requirements	4
lack of DSO-CPO communication infrastructure	6
need for common standard across Europe	8
network code communication EV-EVSE is possible	1
network codes disparities Europe create uncertainty	5
network codes implementation ambiguity	3
network codes requirements ambiguity	7
risk of market fragmentation Europe	6
risk of market segmentation Europe	5
who must comply with network code	3

Table D5: *Open Codes EVSE Manufacturer 2.*

EVSE2	
Open Code	**Groundedness**
ambiguity in future protocol requirements	6
call for standardisation in general	9
charging standard ambiguity (AC or DC)	7
DSO-CPO communication standard ambiguity	6
EVSE adaptation risk	4
EVSE lack data from EV	3
financial risk of EVSE adaptation	3
grid operator to specify hardware requirements	2
hardware requirements specific to V2G are unknown	6
impact on EV battery health	3
lack of DSO-CPO communication infrastructure	6
lack of knowledge contracting authority	5
lack of V2G-compatible EVs as limiting factor	6
limited supplier alternatives Europe due to technical requirements disparities	2
need for common standard across Europe	8
network code communication EV-EVSE is not possible	5
pioneering role the Netherlands	5
process of standardisation is slow	6
risk of market fragmentation Europe	6
risk of market segmentation Europe	5
smart charging priority over V2G	4
technical standard affecting business model	3

D.3 CPO

Table D6: *Open Codes CPO 1.*

CPO1	
Open Code	**Groundedness**
ambiguity in future protocol requirements	6
call for standardisation in general	9
charging standard ambiguity (AC or DC)	7
doubtful claims V2G-readiness	5
DSO-CPO communication standard ambiguity	6
EVSE adaptation risk	4
financial risk of EVSE adaptation	3
financial risk of V2G operation	4
grid operator to specify network code communication	2
grid operator to specify who must comply with network code	1
hardware requirements specific to V2G are unknown	6
influence of actors on setting requirements	4
lack of DSO-CPO communication infrastructure	6
lack of knowledge contracting authority	5
lack of V2G-compatible EVs as limiting factor	6
network code communication EV-EVSE is not possible	5
network codes requirements ambiguity	7
pilots require diverse actors	3
pioneering role the Netherlands	5
smart charging priority over V2G	4
technical standard affecting business model	3
unrealistic pilot environment	3
who must comply with network code	3
who should be in control V2G session	6

Table D7: *Open Codes CPO 2.*

CPO2	
Open Code	**Groundedness**
ambiguity in future protocol requirements	6
call for standardisation in general	9
charging standard ambiguity (AC or DC)	7
doubtful claims V2G-readiness	5
DSO-CPO communication standard ambiguity	6
financial risk of EVSE adaptation	3
financial risk of V2G operation	4
grid operator to specify network code	1
grid operator to specify network code communication	2
hardware requirements specific to V2G are unknown	6
influence of actors on setting requirements	4
lack of DSO-CPO communication infrastructure	6
lack of knowledge contracting authority	5
lack of V2G-compatible EVs as limiting factor	6
limited supplier alternatives Europe due to technical requirements disparities	2
network codes disparities Europe create uncertainty	5
network codes implementation ambiguity	3
network codes requirements ambiguity	7
risk of market fragmentation Europe	6
risk of market segmentation Europe	5
unrealistic pilot environment	3
who must comply with network code	3
who should be in control V2G session	6

D.4 EV Manufacturer

Table D8: *Open Codes EV Manufacturer 1.*

EV1	
Open Code	**Groundedness**
ambiguity in future protocol requirements	6
call for standardisation in general	9
charging standard ambiguity (AC or DC)	7
doubtful claims V2G-readiness	5
EVSE lack data from EV	3
financial risk of V2G operation	4
grid operator to specify hardware requirements	2
hardware requirements specific to V2G are unknown	6
impact on EV battery health	3
need for common standard across Europe	8
network code communication EV-EVSE is not possible	5
network codes requirements ambiguity	7
pilots require diverse actors	3
pioneering role the Netherlands	5
risk of market fragmentation Europe	6
risk of market segmentation Europe	5
unrealistic pilot environment	3
who should be in control V2G session	6

Table D9: *Open Codes EV Manufacturer 2.*

EV2	
Open Code	**Groundedness**
call for standardisation in general	9
charging standard ambiguity (AC or DC)	7
doubtful claims V2G-readiness	5
EVSE lack data from EV	3
financial risk of V2G operation	4
hardware requirements specific to V2G are unknown	6
impact on EV battery health	3
lack of knowledge contracting authority	5
lack of V2G-compatible EVs as limiting factor	6
lack of V2G-compatible EVSE as limiting factor	2
need for common standard across Europe	8
network code communication EV-EVSE is not possible	5
network codes implementation ambiguity	3
network codes requirements ambiguity	7
pilots require diverse actors	3
process of standardisation is slow	6
risk of market fragmentation Europe	6
risk of market segmentation Europe	5
who should be in control V2G session	6

D.5 DSO

Table D10: *Open Codes DSO 1.*

DSO1	
Open Code	**Groundedness**
call for standardisation in general	9
charging standard ambiguity (AC or DC)	7
doubtful claims V2G-readiness	5
DSO-CPO communication standard ambiguity	6
EVSE adaptation risk	4
hardware requirements specific to V2G are unknown	6
influence of actors on setting requirements	4
lack of DSO-CPO communication infrastructure	6
lack of V2G-compatible EVs as limiting factor	6
need for common standard across Europe	8
network code communication EV-EVSE is not possible	5
network codes disparities Europe create uncertainty	5
network codes requirements ambiguity	7
process of standardisation is slow	6
risk of market fragmentation Europe	6
smart charging priority over V2G	4

Table D11: *Open Codes DSO 2.*

DSO2	
Open Code	**Groundedness**
ambiguity in future protocol requirements	6
call for standardisation in general	9
competing standards enhance competitive market	2
EVSE adaptation is neglegible risk	1
grid operator already specifies requirements	1
hardware requirements specific to V2G are known	2
influence of actors on setting standards	3
lack of knowledge contracting authority	5
need for common standard across Europe	8
pioneering role the Netherlands	5
process of standardisation is slow	6
resistance to OCPP within Europe	2
who should be in control V2G session	6

D.6 Conflicting Codes

Table D12: *Conflicting Codes related to Network Code Communication through the ISO 15118 Protocol.*

Conflicting Codes		
Network code communication through ISO 15118		
Open Code	**Groundedness**	**Participants**
network code communication EV-EVSE is possible	1	EVSE1
network code communication EV-EVSE is not possible	5	CPO1, DSO1, EV1, EV2, EVSE2

Table D13: *Conflicting Codes related to Network Codes as a Potential Obstacle to V2G Implementation.*

Conflicting Codes		
Network codes as a potential obstacle to V2G implementation		
Open Code	**Groundedness**	**Participants**
network codes pose no challenges	1	R1
network codes requirements uncertainty	7	CPO1, CPO2, DSO1, EV1, EV1, EVSE1, R2

Table D14: *Conflicting Codes related to Whether the Grid Operators Specify Technical Requirements for V2G Products Clearly.*

Conflicting Codes		
Whether grid operator specifies technical requirements for V2G products clearly.		
Open Code	**Groundedness**	**Participants**
grid operator already specifies requirements	1	DSO2
grid operator to specify network code	1	CPO2
grid operator to specify who must comply with network code	1	CPO1
grid operator to specify hardware requirements	2	EV1, EVSE2
grid operator to specify network code communication	2	CPO1, CPO2

Table D15: *Conflicting Codes related to Whether Hardware Requirements for V2G Products are Clear.*

Conflicting Codes		
Whether hardware requirements for V2G products are clear.		
Open Code	**Groundedness**	**Participants**
hardware requirements specific to V2G are known	2	DSO2, EVSE1
hardware requirements specific to V2G are unknown	6	CPO1, CPO2, DSO1, EV1, EV2, EVSE2

Table D16: *Conflicting Codes related to Competing Standards.*

Conflicting Codes		
Competing standards.		
Open Code	**Groundedness**	**Participants**
competing standards enhance competitive market	2	DSO2, R1
resistance to OCPP within Europe	2	DSO2, R1

Table D17: *Conflicting Codes related to the Risk of EVSE Adaptation due to Uncertainty regarding Future Requirements.*

Conflicting Codes		
Risk of EVSE adaptation due to uncertainty regarding future requirements		
Open Code	**Groundedness**	**Participants**
EVSE adaptation is neglegible risk	1	DSO2
EVSE adaptation risk	4	CPO1, DSO1, EVSE1, EVSE2
financial risk of EVSE adaptation	3	CPO1, CPO2, EVSE2

E Codebook: Axial Coding

This appendix presents the codebook for the axial coding phase. The tables present the related open codes for each axial code.

For all tables, unless indicated differently, the following notes apply:

- Open codes are presented in alphabetical order.
- 'Groundedness' presents the total number of times the particular code emerges in all interview data.

Table E1: *Axial Code 'charging standard ambiguity'.*

Axial Code: 'charging standard ambiguity'	
Open Code	**Groundedness**
charging standard ambiguity (AC or DC)	7
EVSE adaptation is neglegible risk	1
EVSE adaptation risk	4
hardware requirements specific to V2G are unknown	6
influence of actors on setting requirements	4
need for common standard across Europe	8
risk of market fragmentation Europe	6

Table E2: *Axial Code 'control authority V2G sessions'.*

Axial Code: 'control authority V2G sessions'	
Open Code	**Groundedness**
EVSE lack data from EV	3
financial risk of V2G operation	4
grid operator to specify who must comply with network code	1
impact on EV battery health	3
need for common standard across Europe	8
risk of market segmentation Europe	5
technical standard affecting business model	3
who should be in control V2G session	6

Table E3: *Axial Code 'DSO integration'.*

Axial Code: 'DSO integration'	
Open Code	**Groundedness**
DSO-CPO communication standard ambiguity	6
lack of DSO-CPO communication infrastructure	6
need for common standard across Europe	8

Table E4: *Axial Code 'pilot conditions'.*

Axial Code: 'pilot conditions'	
Open Code	**Groundedness**
call for standardisation in general	9
impact on EV battery health	3
lack of V2G-compatible EVs as limiting factor	6
lack of V2G-compatible EVSE as limiting factor	2
need for common standard across Europe	8
pilots require diverse actors	3
pioneering role the Netherlands	5
smart charging priority over V2G	4
unrealistic pilot environment	3

Table E5: *Axial Code 'network codes'.*

Axial Code: 'network codes'	
Open Code	**Groundedness**
grid operator to specify network code	1
grid operator to specify network code communication	2
grid operator to specify who must comply with network code	1
need for common standard across Europe	8
network code communication EV-EVSE is possible	1
network codes disparity Europe creates uncertainty	5
network codes implementation ambiguity	3
network codes pose no challenges	1
network codes requirements ambiguity	7
network code communication EV-EVSE is not possible	5
who must comply with network code	3

Table E6: *Axial Code 'technical requirements deficiency'.*

Axial Code: 'technical requirements deficiency'	
Open Code	**Groundedness**
ambiguity in future protocol requirements	6
call for standardisation in general	9
doubtful claims V2G-readiness	5
EVSE adaptation is neglegible risk	1
EVSE adaptation risk	4
EVSE lack data from EV	3
financial risk of EVSE adaptation	3
grid operator already specifies requirements	1
grid operator to specify network code	1
grid operator to specify network code communication	2
grid operator to specify who must comply with network code	1
grid operator to specify hardware requirements	2
hardware requirements specific to V2G are known	2
hardware requirements specific to V2G are unknown	6
influence of actors on setting requirements	4
influence of actors on setting standards	3
lack of knowledge contracting authority	5

Table E7: *Axial Code 'technical requirements disparities'.*

Axial Code: 'technical requirements disparities'	
Open Code	**Groundedness**
influence of actors on setting standards	3
limited supplier alternatives Europe due to technical requirements disparities	2
need for common standard across Europe	8
network codes disparity Europe creates uncertainty	5
resistance to OCPP within Europe	2
risk of market fragmentation Europe	6
risk of market segmentation Europe	5

Table E8: *Axial Code 'standardisation'.*

Axial Code: 'standardisation'	
Open Code	**Groundedness**
call for standardisation in general	9
competing standards enhance competitive market	2
influence of actors on setting standards	3
need for common standard across Europe	8
pioneering role the Netherlands	5
process of standardisation is slow	6
resistance to OCPP within Europe	2
technical standard affecting business model	3

F List of Events Attended

Table F1: *List of Events Attended.*

Event	Location	Date
AVERE E-Mobility Conference 2023	Utrecht, the Netherlands	26/09/2023 - 27/09/2023
CharIN Network Code Invite-Only Workshop	Online	10/11/2023