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Institutional barriers to vehicle-to-grid implementation in Europe

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Executive Summary

Vehicle-to-grid (V2G) could help balance and regulate the electricity grid. While research papers have focused primarily on the technological potential of V2G services and consumer adaptation, the institutional barriers obstructing the industry from implementing V2G are hardly researched. This study, therefore, explored these institutional barriers using grounded theory and stakeholder interviews. The results showed an array of barriers related to communication standard ambiguity, non-harmonised and undefined network codes, charging standard ambiguity resulting in uncertainties and financial risks, and conflicting stakeholder needs about who should control V2G operations. We conclude that large-scale adoption of V2G in Europe is hindered because it is unclear to the actors involved how to become "V2G-ready". This lack of clarity results in an innovation that is in a wait-and-see phase. We give practical recommendations to potentially become V2G-ready and for further research.

Keywords: V2G, institutions, socio-technical change, innovation theory, grounded theory.

1 Introduction

Smart charging of electric vehicles (EVs) is seen as a breakthrough technology in the e-mobility industry [2]. Smart charging offers the possibility to adjust charging speeds and power supply to the grid conditions. This can limit 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 [9, 57]. With the help of this technology, EVs connected to a charging station can discharge their batteries and deliver electricity back to the grid [32]. These vehicles can be either battery-electric vehicles or plug-in hybrids. For simplicity, this paper refers to these concepts by using the general term 'electric vehicles' or 'EVs'. Fuel-cell vehicles are left out of scope, since these apply V2G by producing electricity directly inside the car instead of discharging the battery [36].

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 [23, 30, 32, 49]. Depending on the business model, V2G could also ensure cost savings for fleet owners, EV drivers, and other actors [50].

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 [22]. This requires additional technical measures 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 [53]. Therefore, market players, such as EV supply equipment (EVSE) and EV manufacturers, are demanding clear guidelines for their products enabling bidirectional power flows [33, 39]. However, technical requirements for systems and products enabling V2G have not been specified yet for various elements [24]. Moreover, non-harmonised requirements pose a significant burden for internationally oriented original equipment manufacturers (OEMs) in Europe. Non-harmonised requirements constrain the industry to develop and implement V2G technology. Research papers have focused primarily on the technological potential of V2G services and barriers in consumer adaptation. For example, in 2017, Sovacool et al. [51] showed that a majority of 197 articles reviewed focused on technical aspects and modeling of V2G. Moreover, studies have shown smart and bidirectional charging strategies could reduce charging cost by more than 32% [46] and European energy supply system costs by up to 12.6% [35]. Also, one study reviewed noted that introducing V2G could increase renewable energy development by 30% on a system level [40]. Only a minority of the articles reviewed focused on socio-technical aspects. However, social aspects such as public perceptions are considered key barriers to adoption of EVs and V2G technology [34]. Therefore, these barriers have been studied by others later with focus on consumer adaptability and social acceptance [27, 7]. However, a gap in literature regarding the institutional barriers obstructing the industry to implement V2G technically remains. Therefore, following an empirical approach, this study presents key barriers obstructing the adoption of V2G technology by niche actors and its technical implementation. The study focuses on barriers of institutional nature, i.e., social rules and procedures such as policy, regulations, technical standards, social interactions, and requirements [28]. Our contribution is twofold. First, we bring new scientific knowledge on institutional issues related to V2G because, in line with innovation theories (see our discussion in Section 5), adoption of technical innovations is not only dependent on technical readiness but also on policies, cooperation among key stakeholders, and standardisation. Second, our contribution is also practical. By mapping the V2G institutional issues, we aim to inspire policymakers and industry to address them so that the technology might be adopted.

This paper is structured as follows. Section 2 introduces the grounded theory approach and elaborates on the research methods applied. Next, we present the interview design and recruitment criteria, which are based on an initial stakeholder analysis. Furthermore, this section presents the coding phases following the grounded theory approach. Section 3 presents the empirical results, maintaining an open-minded approach by preventing theoretical insights from affecting the analysis. In Section 4, we consult literature and previous research to discuss the results and present implications for the academic field and practitioners. Section 5 provides conclusions and recommendations. Additionally, this section outlines potential avenues for future research to contribute to knowledge development, to accelerate the advancement of V2G technology.

2 Grounded theory

This study explores institutional barriers obstructing the adoption of V2G. We have chosen a grounded theory approach as it is useful and suitable for such an exploratory study as we do where a priori little was known about the barriers [8, 31]. In this approach, the emerging theory providing insight into a specific phenomenon under study is 'grounded' in the data [10]. So, we did not start with a hypothesis. The empirical data from interviews (see below) were our starting point and guided the research activities. A theory (or hypothesis) is developed in this paper rather than tested [54], see discussion (Section 4) below. We employed 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 [54]. Grounded theory has proven before to be a valuable approach in the EV and EV charging domains to explore perspectives and identify barriers to technology diffusion [37, 44, 58].

In a grounded theory study, data analysis and sampling happen simultaneously, facilitating theoretical sampling [8]. 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 [54]. However, this study did not exert iterative sampling, because data saturation was already achieved with the limited number of participants. Interviews were employed with a predetermined number of participants. Nonetheless, the topic guide was refined continuously based on the interviews performed and analysed so far and data saturation was tracked.

The empirical data were analysed through qualitative coding, in which recurring concepts and overarching categories are constructed. For this purpose, this study employed ATLAS.ti and its data analysis tools [14]. The coding process, visualised in Figure 1, consisted of three phases: open coding, axial coding, and selective coding [31]. Open coding refers to identifying recurring concepts. The empirical data were 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 [8, 31]. Constant comparative analysis supports coding and category development by stimulating continuous comparison of codes, identifying structural differences and similarities between codes [10]. This process enables a consistent, iterative approach to coding, ensuring that the analysis remains driven by the data rather than personal biases or preconceptions. For instance, during axial coding, when an open code does not fit existing axial codes, it prompts the researcher to revise or create a new code, ensuring responsiveness to the data. Memoing further supports data analysis by allowing the researcher to document emerging concepts, categories, and insights [6]. Memoing works in tandem with constant comparison by providing written reflections that guide our comparisons and ensure consistency between codes, categories, and the evolving theory. Multiple reviews of coding, concepts, and memos also helped maintain objectivity. Additionally, quantitative methods were employed to analyse the groundedness of codes, representing the degree to which codes reoccur in the data. The iterative comparison process, in combination with quantitative analysis, ensures that categories and codes evolve directly from the data, reducing the influence of personal biases and fostering a more objective, data-driven analysis.

We employed individual in-depth interviews to collect data for this study, allowing a deep understanding of stakeholder perspectives. We conducted semi-structured interviews organised around a coherent set of predetermined open questions and maintaining room for emerging follow-up questions [11]. Both face-to-face and digital interviews were 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 [13]. How-

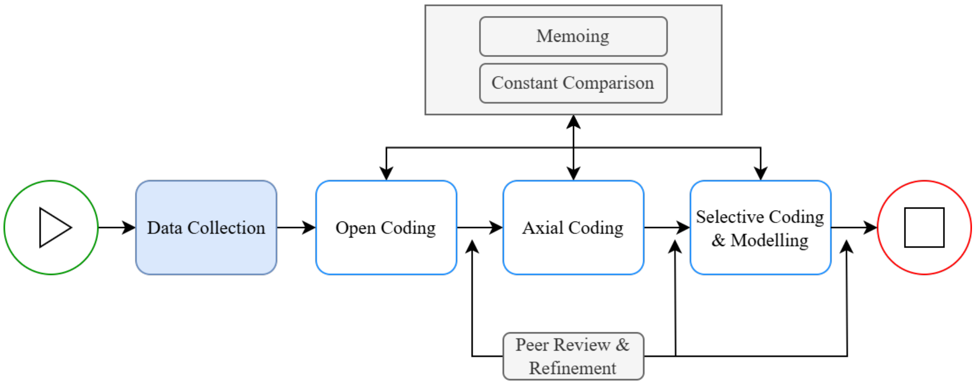

Figure 1: Process flow of the coding process, including the constant comparison method, memoing, and peer reviewing.

ever, the interviewer should not steer the interview based on published literature and theories or their views on the matter. This was achieved by preventing suggesting solutions, using open questions only, and maintaining a neutral position in discussions [31, 38]. The topic guide included predetermined, open-ended questions leaving room to be discussed in flexible order [19]. Interviews were automatically transcribed using Microsoft Teams. Summaries were constructed based on the interview transcripts and approved by the participants within two weeks after receiving the summary digitally. Figure 2 visualises the interview approach.

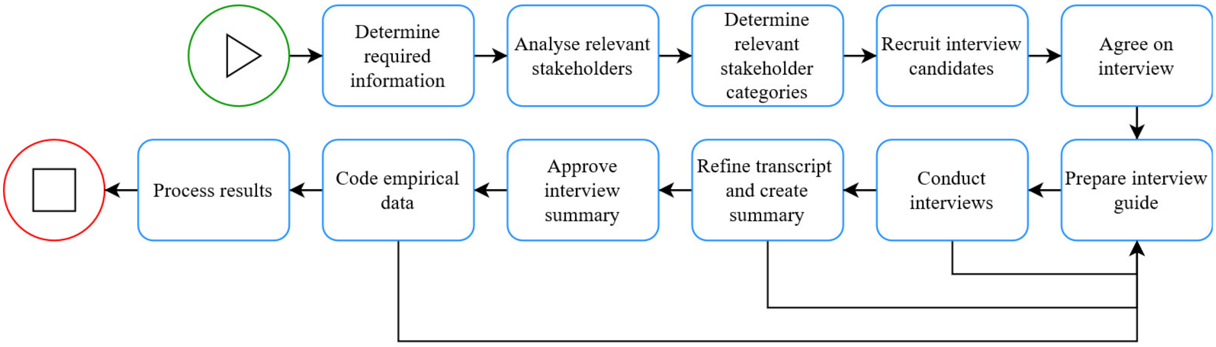

Figure 2: Process flow of the interview approach, including iterative steps for refinement of research methods.

Participants were sampled through a purposeful selection of people from organisations relevant to the phenomenon under study [8]. Five key stakeholder categories were identified, namely the regulator, EVSE manufacturer, Charge Point Operator (CPO), EV manufacturer, and Distribution System Operator (DSO). These stakeholder groups were 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 or implementation of the requirements, or both. Other actors, such as the e-Mobility Service Provider (eMSP), Smart Charging Service Provider (SCSP), and energy supplier, were 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 were 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 was considered redundant.

Table 1 presents the participants of this study, grouped in the five stakeholder categories identified earlier. A total of 12 participants was representing 10 organisations. Ideally, as explained earlier, data saturation is achieved. Data saturation was monitored continuously.

The selection of research participants 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 (mostly within Europe) to capture related challenges. CPOs and DSOs are commonly only operational within a single 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. They were required to sign an

Table 1: Profiles of the research participants at the time of the interview.

Profession	Organisation	Reference	Professional Experience (Years)		Geographical Focus
			EV Charging	V2G	
Policy Officer Electromobility & EU	Regulator 1	R1	11	5	National
Team Leader	Regulator 2	R2	4	1	International
Product Manager Public Charging	EVSE Manufacturer 1	EVSE1	1	1	International
Head of Strategic Enablement	EVSE Manufacturer 2	EVSE2	6	1	International
Product Manager Smart Charging	EVSE Manufacturer 2	EVSE2	3	1	International
Product Manager E-Mobility	Charge Point Operator 1	CPO1	6	3	National
Product Owner Smart Charging	Charge Point Operator 1	CPO1	3	2	National
Energy Development Manager	Charge Point Operator 2	CPO2	13	6	National
Manager New Business & Mobility	EV Manufacturer 1	EV1	5	2	International
Business Development Manager	EV Manufacturer 2	EV2	6	4	International
Innovation Manager Electric Mobility	Distribution System Operator 1	DSO1	15	5	National
Senior Advisor Electric Mobility	Distribution System Operator 2	DSO2	15	12	National

informed consent form to ensure autonomy and data privacy, but participation remained voluntary [18]. In addition, mandatory approval from the Delft University of Technology ethics committee was obtained.

3 Results

This section covers the insights derived from the coding process. In the open coding phase, the empirical data retrieved from the interviews were broken down into discrete components to uncover emergent governance themes. Subsequently, our axial coding interconnects the open codes, revealing recurring patterns and relationships that underlie the complexities of V2G. Finally, 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.

First, Section 3.1 addresses data saturation. The succeeding sections present the themes emerging from the data.

3.1 Data saturation

Figure 3 shows the number of insights gained throughout the data collection phase. The number of insights represents the number of open codes emerging in the data and were tracked after the interviews were done. After conducting 10 interviews, a total of 44 insights were gathered. As shown in Figure 3, few new insights were observed after the sixth interview. This implies data saturation was 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” [26, p. 2]. Figure 3 shows that interviews R1, 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.

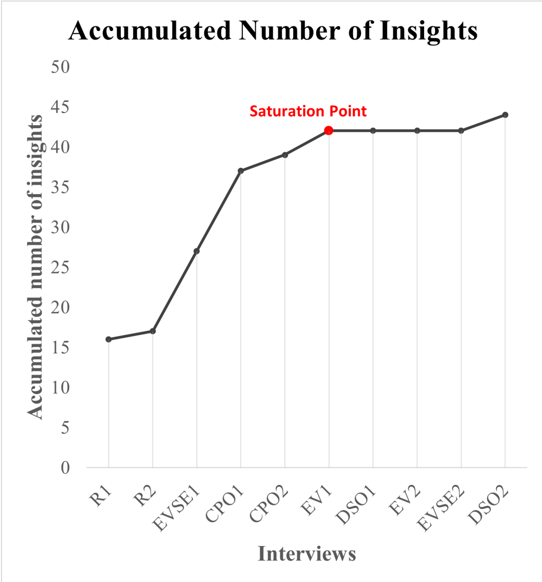

Figure 3: Accumulation of insights (i.e., open codes presenting barriers to V2G implementation and related causes and effects) over time in sequential interviews, indicating data saturation.

3.2 Emergent patterns

In total, 44 open codes were identified among the 10 interviews. Table 2 presents the open codes emerging the most. 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 3 presents the axial codes.

We identified the latter three axial codes of Table 3 in the final stages of the analysis. Initially, we focused on 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 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.

The participants often view standardisation as a promising means to harmonise the V2G system, but it is also recognised as a slow process. Additionally, participants pointed out that 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.

3.3 Selective coding

In 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 4 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. Below, in Sections 3.3.1 and 3.3.2, we explain this finding more elaborately.

3.3.1 Connecting the codes

Three axial codes uncovered issues related to technical requirements disparities and deficiency (Table 3). Variations in network codes, the integration of DSOs into the ecosystem, 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 4 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

Table 2: Open codes emerging more than five times in the interview data, ordered by groundedness (i.e., the total number of times the code emerges in the dataset).

Open Code	**Groundedness**	**Mentioned by**
Call for standardisation in general	9 / 10	CPO1, CPO2, DSO1, DSO2, EV1, EV2, EVSE1, EVSE2, R1.
Need for common standard across Europe	8 / 10	DSO1, DSO2, EV1, EV2, EVSE1, EVSE2, R1, R2.
Charging standard ambiguity (AC or DC)	7 / 10	CPO1, CPO2, DSO1, EV1, EV2, EVSE1, EVSE2
Network codes requirements ambiguity	7 / 10	CPO1, CPO2, DSO1, EV1, EV2, EVSE1, R2.
Ambiguity in future protocol requirements	6 / 10	CPO1, CPO2, DSO2, EV1, EVSE1, EVSE2.
DSO-CPO communication standard ambiguity	6 / 10	CPO1, CPO2, DSO1, EVSE1, EVSE2, R1.
Hardware requirements specific to V2G are unknown	6 / 10	CPO1, CPO2, DSO1, EV1, EV2, EVSE2.
Lack of DSO-CPO communication infrastructure	6 / 10	CPO1, CPO2, DSO1, EVSE1, EVSE2, R1.
Lack of V2G EVs as limiting factor	6 / 10	CPO1, CPO2, DSO1, EV2, EVSE2, R1.
Process of standardisation is slow	6 / 10	DSO1, DSO2, EV2, EVSE2, R1, R2.
Risk of market fragmentation Europe	6 / 10	CPO2, DSO1, EV1, EV2, EVSE1, EVSE2.
Who should be in control V2G session	6 / 10	CPO1, CPO2, DSO2, EV1, EV2, R1.

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 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 on the bottom left in Figure 4.

The discussion surrounding the control authority of V2G operations is a largely distinctive subject. The participants do not highlight clear technical requirements as the only source to enhance clarity in this market. Therefore, in Figure 4, determination of the control authority is presented separately from these previously discussed technical requirements. According to EV2, a cohesive decision on who should be in control 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 who should be in control of the discharging activities. Consequently, EV manufacturers are initiating exclusive collaborations with other market players, such as EVSE manufacturers, CPOs, and energy utilities, to facilitate exclusive V2G integration with their products. CPO1 and CPO2 are afraid to lose control with EVSE management since they want to gain control of discharging sessions to ensure profitability. EV manufacturers also see opportunities for new revenue streams. Additionally, the EV manufacturers (EV1 and EV2) want to prevent warranty claims by their users because of battery degradation due to misuse of the battery, so they would like to gain control of these discharging sessions because of this. 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 entrusted to navigate on its own. However, a connection between the control authority discussion and the technical requirements disparities and deficiency is created to represent their relation. The absence of a clear market role distribution creates uncertainty, delaying consensus on a communication standard. Conversely, without an agreed-upon standard, it becomes difficult to define responsibilities and implement a coordinated V2G system.

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 operations. 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 expressed their anticipation for EV manufacturers to provide V2G-enabled hardware. In contrast, EV2 and R1 highlighted 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

Table 3: Axial codes in alphabetical order, with the fourth column showing the size of each category, i.e. the number of open codes.

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 of 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

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 highlight limited conditions for pilot projects.

3.3.2 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. It becomes evident from the interviews 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, in particular the network code Requirements for Generators (RfG), 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 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.

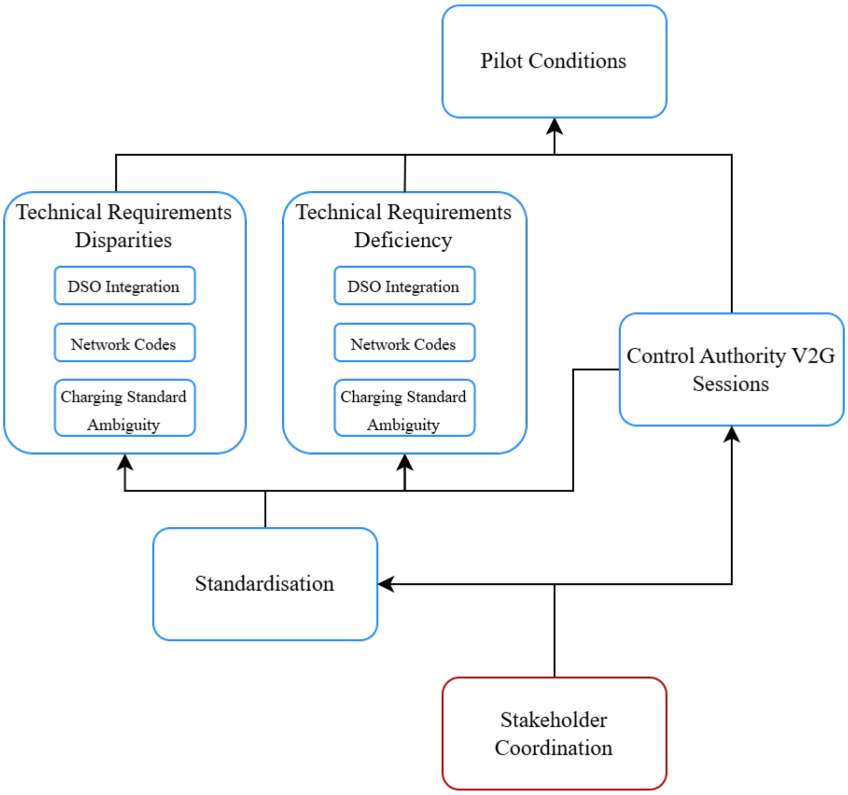

Figure 4: Axial codes (in blue) and selective code (in red). The arrows indicate emergent, latent relationships between codes.

4 Discussion

This section presents a comprehensive discussion about the issues obstructing diffusion of V2G technology. The discussion addresses key dimensions considered vital for understanding and navigating the barriers presented in Section 3. Firstly, Section 4.1 delineates the primary barriers in technical requirements that have emerged from the empirical study. Subsequently, Section 4.2 suggests relationships between the barriers and experimentation (in the form of pilot projects). Section 4.3 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) and socio-technical change theory are employed. Section 4.4 offers pragmatic implications and solutions drawn from the main findings, aimed at informing and guiding policymakers and stakeholders to accelerate the development of V2G.

4.1 Key barriers and which actors they affect

This study has identified four key institutional barriers related to the implementation of V2G. These are stated as follows:

1. DSO Integration: the lack of communication infrastructure between DSO and 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 OEM and CPO.

4. Control Authority V2G Operations: conflicting stakeholder needs due to business model risks create uncertainty who should control V2G operations.

Each of the four barriers obstructs the V2G actors differently. First, the charging standard ambiguity affects OEMs and CPOs. The charging standard affects who should pay the price. In 2025, DC charging stations are expected to be more than two times more expensive than AC charging stations [35]. If DC-powered V2G becomes the standard, CPOs will need to invest in the more expensive DC charging stations, likely 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. In the EU, at the end of 2023, out of more than 630,000 charging stations, around 87% was AC (22 kW or less) [1]. On the contrary, with DC, EV manufacturers will have the opportunity to reduce costs, since the EV requires fewer hardware such as an onboard inverter for AC/DC conversion. If AC becomes the primary standard, however, EV manufacturers will need to provide advanced inverters in their cars and need to ensure the EV can comply with local network codes. This generally results in a higher cost price. Subsequently, CPOs do not have to invest in expensive DC-powered charging infrastructure. This charging standard ambiguity shows the potential impact of choosing either AC or DC as the sole standard for V2G, but also creates a diversified ecosystem. It creates uncertainty for several actors, slowing technological development and investment. Without a clear direction, manufacturers and CPOs hesitate to commit resources to either AC or DC, fearing that future regulations or market shifts could render their technology obsolete. This leads to fragmented R&D efforts, where companies either delay innovation or develop incompatible solutions, hindering interoperability. Grid operators also struggle to plan for V2G integration, as different technical requirements for AC and DC impact grid stability and capacity. Nevertheless, policymakers are hesitant to steer policy towards a single standard as this could create an unfair market, reduce competition, and limit technological innovation. A dual-standard approach would encourage broader innovation and market fairness, allowing both AC- and DC-based solutions to evolve based on technological advancements and regional needs.

Secondly, integrating the DSO primarily affects DSOs, CPOs, and EVSE manufacturers. DSOs will need to design their systems to enable monitoring or 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 communication standard, but the specific requirements are unknown yet. Without standard communication protocols, manufacturers and CPOs develop proprietary, incompatible systems instead of interoperable V2G solutions. This fragmentation leads to higher development costs and limited scalability, discouraging further innovation in V2G technologies. At the same time, due to these uncertainties, DSOs are hesitant to upgrade their digital infrastructures, further delaying potential incentives for V2G services.

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 DC becomes the charging standard, the EVSE manufacturers and CPOs need to ensure network code compliance in the specific region. 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 when crossing borders. This becomes very problematic if the network codes diverge significantly and require different hardware specifications. Ongoing discussions about the uncertainties and technical challenges caused by non-harmonised network codes have led to several institutional developments. In particular, international regulators are indicating an amendment to the EU RfG network code is in development, ensuring harmonised requirements and guidelines. The industry, of which EV and EVSE manufacturers, are consulted regularly in the form of stakeholder committees and public consultation rounds. However, the extent to which variations in national implementation of the network codes remain possible is unclear. In addition, the uncertainties related to AC V2G led to the development of an amendment to communication standard ISO 15118-20, since both EV and EVSE need to ensure compatibility to incorporate local network code communications. The current version of this communication protocol was lacking this feature.

Since the current proposal of the network code amendment suggests that the requirements will come into effect three years after the entry into force, it will take several years before a harmonised system is fully realised. This extended timeline for harmonisation not only delays the widespread adoption of V2G but also postpones the realisation of the expected €9.7 billion per year in energy system cost reductions [35]. As the harmonisation process progresses more slowly, these anticipated savings will be deferred, further extending the timeline for energy system optimisation and the associated economic benefits.

Fourth, the control authority discussion affects the business models of several market players. Currently, CPOs are primarily responsible for EVSE management and operation. However, as explained earlier, EV manufacturers are exerting influence to gain control of V2G operations to increase their profits and limit warranty claims. The lacking digital infrastructure between CPOs, EVSE, and DSOs prevents DSOs from having real-time insight into V2G operations, also contributing to the uncertainty in defining clear market roles for V2G. This further delays compensation models for grid services. Due to the lack of direct communication with V2G assets as well as the limited practical experience, DSOs are unsure whether they should directly manage V2G energy flows (as they do with grid assets like transformers), delegate control to aggregators or CPOs, or rely on price signals from wholesale markets to influence V2G behavior indirectly. Governmental organisations and regulators do not take a position in the discussion, creating uncertainty for the future ecosystem of V2G. This uncertainty, in turn, slows down investment in V2G by CPOs and manufacturers as business models and financial incentives remain unclear. However, as more pilot projects prove the value of V2G, regulators and DSOs are being pressured to adopt standardised communication frameworks, driving institutional change, as we explain in Section 4.2. In one study, for larger semi-public EVSE networks, incremental profitability was found to range between 15% and 30% higher for V2G-enable aFRR (automated frequency restoration reserve) services compared to regular charging operations [20]. Exact revenues, however, also depend on other variables, such as electricity pricing and market conditions. A different study showed that offering FCR (frequency containment reserve) services with V2G-enabled DC EVSE can generate additional revenue streams ranging from €0.03 to €0.15 per kWh of discharged energy, with EBIT (earnings before interest and taxes) potentially increasing by 20% to 30% under favorable market conditions [21]. The latter study also acknowledged that the profitability could increase when these services are enabled by less expensive AC charging stations. These studies emphasise that V2G services offer great profitability potential and show why several actors are adapting business models to these services.

The business model uncertainties have resulted already in some V2G niche actors initiating one-to-one solutions. EV manufacturers might decide to only open their systems with specific organisations instead of all CPOs, potentially resulting in a segmented market (see EV1 and EV2). For the residential V2G domain, this has resulted in various one-to-one solutions already, where EV manufacturers are founding separate business units for related energy services [42, 45]. These initiatives involve a specific set of stakeholders to enable bidirectional charging with only particular products and applications. These often also include the implementation of non-standardised, proprietary solutions. The diverging needs on V2G control, therefore, also affect the adoption and development of the ISO 15118-20 standard. This technical standard for both EVSE and EV is expected to be essential to enable harmonised V2G services in the public domain [39]. However, EV manufacturers are reluctant to implement the standard due to the risk of battery degradation, affecting the development of the technical design of the standard. Nonetheless, EVSE manufacturers will need to comply with ISO 15118-20 from Janaury 1, 2027, since the standard is expected to be included in the new Alternative Fuels Infrastructure Regulation (AFIR) [12]. This creates a great incentive for EV manufacturers to follow and a less fragmented market in Europe.

4.2 Pilot projects

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 actors from experimenting with V2G technology. This obstructs the diffusion of this 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" [4, p. 3]. Most participants indicated the lack of pilot conditions which is obstructing the implementation of V2G. Pilot projects play a key 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 [4]. 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.

4.3 Socio-technical change theory

Our grounded approach resulted in insights that do not point to the need for the development of a new or improved innovation theory because our insights fit well into two already existing mainstream innovation theories. First, the results fit in the socio-technical change theory. V2G resembles the reconfiguration pathway introduced by Geels and Schot [17]. This pathway characterises incremental integration of innovations into existing regimes. V2G can be seen as 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 diverse types of storage technologies changes the regime from a centralised system to a decentralised system. Therefore, V2G can co-exist with other flexibility services and storage facilities.

Currently, V2G could be positioned at the end of phase 1 in this pathway, the conceptual experimentation phase of socio-technical transitions [16]. Our results show that the technology 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. According to this socio-technical change theory, the first phase of socio-technical transitions is characterised by R&D, including real-world experiments and pilot projects [16]. This stimulates learning about technical performance, social acceptance, user needs, and feasibility. Innovations in the niche phase, however, are prone to fragmentation of initiatives, market segmentation, and a tendency to remain isolated, reducing their potential for wide-ranging change [55]. 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 which 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 [15]. In response, several initiatives in Europe are driving the development of local flexibility markets, providing financial incentives for grid services and demand-response technologies such as V2G [47]. Simultaneously, as mentioned in Section 4.1, European regulators initiate regulatory harmonisation efforts for EV charging infrastructures by mandating ISO 15118-20 compliance and revising European network codes to enable V2G services and stimulate interoperability. Additionally, smart charging business models are gaining traction, fueled by the wider adoption of dynamic electricity pricing and grid digitalisation. These developments make V2G a more viable and attractive solution for grid services. However, despite these developments, structural barriers remain. A lack of stakeholder alignment and persistent technical and regulatory uncertainties hinder V2G from scaling into a dominant design (Phase 2). The transition to large-scale deployment requires extensive pilot projects, but fragmented market conditions and regulatory inconsistencies complicate their success. Addressing these challenges through continued learning processes, cross-sectoral collaboration, and policy refinement is essential for unlocking the full potential of V2G.

A second innovation theory, which fits well with our findings, is the Technology Innovation System (TIS) theory. According to this theory, innovation takes place in systems or socio-technical systems, that is, a ”group of components (devices, objects and agents) serving a common purpose. The components of an innovation system are the actors, networks and institutions contributing to the overall function of developing, diffusing and utilizing new products (goods and services) and processes” [3, p. 408]. V2G is typically a new product or service that involves many actors and institutions, as we have shown. According to this theory, a so-called system functions analysis is needed to understand if an innovation system works as intended [25]. These systems functions can be interpreted as actions or activities that actors undertake to successfully implement the innovation, such as entrepreneurial activities, setting clear policy goals, knowledge development, et cetera. According to Suurs and Hekkert, innovation system functions may reinforce each other over time resulting in a ‘motor of innovation’ or may also reinforce each other ‘downwards’, resulting in a vicious cycle: ‘a motor of decline’ [52]. Our four key barriers obstructing V2G implementation do not point at a positive V2G innovation motor and not per se at a motor of decline but more at an ‘idling motor of innovation’: V2G development seems to be in a standstill and wait-and-see phase.

4.4 Practical solutions

What could be solutions for the various system failures and lacking alignment between key stakeholders? Smith and Raven have presented three functional properties of protection of niche innovations in so-called protective spaces [48]. 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 identify two forms of empowerment: fit and conform empowerment and stretch and transform empowerment [48]. 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 niche innovation. Currently, V2G demands institutional reforms encompassing of harmonisation of requirements and standardisation, as shown earlier in this paper. Therefore, we think that 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 [48]. As shown in Section 4, 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. Besides, EVSE and EV manufacturers must align to facilitate transparent data transfer to enable harmonised discharging services. To prevent market segmentation, EV manufacturers should ensure sufficient data can be accessed openly by EVSE, such as state of charge information. However, manufacturers should find a balance between open data exchange, remaining competitive, and ensuring data security and privacy. This process should be guided by institutional organisations with a European focus to ensure a harmonised and fair approach.

Overall, these dynamics require a coordinated approach to strengthen and stabilise the development of V2G technology and enable widespread diffusion in Europe. International OEMs should align on technical standards facilitating V2G to prevent market fragmentation and segmentation. As acknowledged by Blind et al., in highly uncertain markets such as the EV and EV charging markets, formal standards have a positive effect on firms’ innovation efficiency [5]. In particular, large-scale adoption of the amendment of the ISO 15118-20 standard will contribute to this. A few OEMs, such as Renault and Polestar, have announced V2G-capable EVs and related services [43, 41]. However, fully interoperable solutions are still lacking. DSOs and CPOs should create digital infrastructures enabling data exchange required to ensure safe, effective, and transparent operation of V2G. Widespread implementation of a communication protocol like OpenADR will contribute to a harmonised system [29]. This is, however, more challenging than the adoption of ISO 15118-20 by manufacturers, since alignment between DSOs and CPOs requires more complex stakeholder coordination with conflicting needs. Additionally, even though DSOs are already investing in digitalisation, V2G requires more complicated infrastructures demanding greater investments. DSOs should adopt the proposed amendment to the RfG network code and work collaboratively to minimise implementation deviations with neighboring regions, ensuring consistency and fostering harmonisation across the grid. This can be achieved through active engagement with organisations such as the DSO Entity and ENTSO-E, which provide platforms for coordination, knowledge sharing, and the development of aligned implementation strategies. However, this remains challenging due to old grid infrastructures and a diversity of European DSOs with varying and regional needs. Additionally, fragmented national regulations complicate uniform implementation across Europe, potentially leading to delays in adopting V2G technology. European policymakers should align on the objectives of V2G, such as tackling grid congestion, removing regulatory barriers for V2G actors, and enabling grid operators to facilitate the demanded resources. By doing so, the V2G motor of innovation could be running. However, one must acknowledge the complex challenge of international and cross-industry alignment due to stakeholder diversity, competing interests, and long negotiation timelines. This emphasises the importance of cross-border pilot projects and V2G task forces to demonstrate the feasibility and benefits of a harmonised system and facilitate consensus-building.

5 Conclusions and recommendations

We conclude that large-scale adoption of V2G in Europe is hindered because it is unclear to the actors involved how to become ”V2G-ready”. The requirements deficiency and disparities found in the interviews and the control authority discussion show constraining effects on the conditions for pilot projects. At the same time, 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. Our data reveals two chicken-and-egg dilemmas which play a major 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.

We argue that these ‘negative’ 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.

The grounded theory research methods have proven to establish an emerging narrative on the socio-technical transition of the V2G niche innovation, which could be linked to two existing innovation theories. The process of data collection reached a point of saturation, indicating that additional data gathering would not yield new or 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. Lacking institutional arrangements within the socio-technical regime impacts niche actors and thereby hinders the adoption of V2G. Given the exploratory nature of the study and the complexity of the subject, the qualitative approach enabled a detailed analysis that uncovered the various barriers obstructing V2G implementation. Using the 44 identified insights, we developed a structured framework following a grounded theory coding approach, allowing for a systematic explanation of these barriers. This framework provides a comprehensive understanding of the key factors limiting progress and serves as a foundation for addressing these obstacles, guiding future research, policy development, and practical strategies to accelerate V2G adoption.

This study presents various avenues for complementary research. Future studies could explore the role of self-organisation in socio-technical transitions, specifically within the European 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 for 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 the 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 European power grid can be ensured. Furthermore, future research could focus on the impact of emerging technologies, such as artificial intelligence, advanced battery technologies and other flexible energy resources, on the market adoption and scalability of V2G. Studies could investigate how these innovations influence the economic viability, technical potential, and infrastructure demands of V2G technology.

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. Overall, 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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Presenter Biography

After his master's engineering degree in Complex Systems Engineering & Management at the Delft University of Technology, Mark van Eijk (26) started his professional career at system integrator Alfen in the Netherlands in the beginning of 2024. Before his master's, he was part of student team Solar Team Twente, designing and building a solar racing car from scratch for a 2500-kilometre endurance race. Currently, he is progressing his interest in sustainable energy and technology at Alfen as a Systems Engineer for the charging equipment business line, focusing on public charging.

References

[1] ACEA, 2024. Charging ahead: accelerating the roll-out of EU electric vehicle charging infrastructure. Technical Report. ACEA. URL: https://www.iea.org/reports/global-ev-outlook-2023/trends-in-charging-infrastructure#.

[2] Anisie, A., Boshell, F., Sesma, J., 2019. Electric-Vehicle Smart Charging: Innovation Landscape Brief. Technical Report. URL: https://www.irena.org/publications/2019/Sep/Electric-vehicle-smart-charging.

[3] Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research Policy 37, 407–429. doi:10.1016/j.respol.2007.12.003.

[4] Berkhout, F., Verbong, G., Wieczorek, A.J., 2014. Sustainability experiments in Asia: 'green' innovations shaping alternative development pathways. Technical Report. URL: https://www.researchgate.net/publication/228433059.

[5] Blind, K., Petersen, S.S., Riillo, C.A., 2017. The impact of standards and regulation on innovation in uncertain markets. Research Policy 46, 249–264. doi:10.1016/j.respol.2016.11.003.

[6] Chametzky, B., 2023. Writing Memos: A Vital Classic Grounded Theory Task. European Journal of Humanities and Social Sciences 3, 39–43. doi:10.24018/ejsocial.2023.3.1.377.

[7] Chen, C.f., Zarazua de Rubens, G., Noel, L., Kester, J., Sovacool, B.K., 2020. Assessing the socio-demographic, technical, economic and behavioral factors of Nordic electric vehicle adoption and the influence of vehicle-to-grid preferences. Renewable and Sustainable Energy Reviews 121, 109692. URL: https://www.sciencedirect.com/science/article/pii/S1364032119308974, doi:https://doi.org/10.1016/j.rser.2019.109692.

[8] Chun Tie, Y., Birks, M., Francis, K., 2019. Grounded theory research: A design framework for novice researchers. SAGE Open Medicine 7. doi:10.1177/2050312118822927.

[9] Clement-Nyns, K., Haesen, E., Driesen, J., 2011. The impact of vehicle-to-grid on the distribution grid. Electric Power Systems Research 81, 185–192. doi:10.1016/j.epsr.2010.08.007.

[10] Corbin, J., Strauss, A., 1990. Grounded Theory Research: Procedures, Canons, and Evaluative Criteria. Qualitative Sociology 13, 3–21.

[11] DiCicco-Bloom, B., Crabtree, B.F., 2006. The qualitative research interview. doi:10.1111/j.1365-2929.2006.02418.x.

[12] European Alternative Fuels Observatory, 2024. European Commission Published Delegated Acts for AFIR - Open for consultation. URL: https://alternative-fuels-observatory.ec.europa.eu/general-information/news/european-commission-publishes-delegated-acts-afir-open-consultation.

[13] Foley, G., Timonen, V., Conlon, C., O'Dare, C.E., 2021. Interviewing as a Vehicle for Theoretical Sampling in Grounded Theory. International Journal of Qualitative Methods 20. doi:10.1177/1609406920980957.

[14] Friese, S., 2016. Best Practices With ATLAS.ti. Technical Report.

[15] Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study.

[16] Geels, F.W., 2019. Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective. Current Opinion in Environmental Sustainability 39, 187–201. doi:10.1016/j.cosust.2019.06.009.

[17] Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Research Policy 36, 399–417. doi:10.1016/j.respol.2007.01.003.

[18] Gill, P., Baillie, J., 2018. Interviews and focus groups in qualitative research: An update for the digital age. British Dental Journal 225, 668–672. doi:10.1038/sj.bdj.2018.815.

[19] Gill, P., Stewart, K., Treasure, E., Chadwick, B., 2008. Methods of data collection in qualitative research: Interviews and focus groups. British Dental Journal 204, 291–295. doi:10.1038/bdj.2008.192.

[20] Goncearuc, A., Sapountzoglou, N., De Cauwer, C., Coosemans, T., Messagie, M., Crispeels, T., 2023a. Incremental profitability evaluation of V2G-enabled aFRR services for semi-public EVSE infrastructure: a case study in Belgium. Technical Report.

[21] Goncearuc, A., Sapountzoglou, N., De Cauwer, C., Coosemans, T., Messagie, M., Crispeels, T., 2023b. Profitability Evaluation of Vehicle-to-Grid-Enabled Frequency Containment Reserve Services into the Business Models of the Core Participants of Electric Vehicle Charging Business Ecosystem. World Electric Vehicle Journal 14. doi:10.3390/wevj14010018.

[22] Gonzalez Venegas, F., Petit, M., Perez, Y., 2021. Active integration of electric vehicles into distribution grids: Barriers and frameworks for flexibility services. Renewable and Sustainable Energy Reviews 145. doi:10.1016/j.rser.2021.111060.

[23] Guille, C., Gross, G., 2009. A conceptual framework for the vehicle-to-grid (V2G) implementation. Energy Policy 37, 4379–4390. doi:10.1016/j.enpol.2009.05.053.

[24] Gunkel, P.A., Bergaentzlé, C., Græsted Jensen, I., Scheller, F., 2020. From passive to active: Flexibility from electric vehicles in the context of transmission system development. Applied Energy 277. doi:10.1016/j.apenergy.2020.115526.

[25] Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M., 2007. Functions of innovation systems: A new approach for analysing technological change. Technological Forecasting and Social Change 74, 413–432. doi:10.1016/j.techfore.2006.03.002.

[26] Hennink, M., Kaiser, B.N., 2022. Sample sizes for saturation in qualitative research: A systematic review of empirical tests. Social Science and Medicine 292. doi:10.1016/j.socscimed.2021.114523.

[27] van Heuveln, K., Ghotge, R., Annema, J.A., van Bergen, E., van Wee, B., Pesch, U., 2021. Factors influencing consumer acceptance of vehicle-to-grid by electric vehicle drivers in the Netherlands. Travel Behaviour and Society 24, 34–45. doi:10.1016/j.tbs.2020.12.008.

[28] Hodgson, G.M., 2006. What are institutions? Journal of Economic Issues 40, 1–25. doi:10.1080/00213624.2006.11506879.

[29] Hoekstra, A., Bienert, R., Wargers, A., Singh, H., Voskuilen, P., . Using OpenADR with OCPP. Technical Report. URL: http://products.openadr.org/.

[30] Horlings, J., 2022. De auto als mobiele energiecentrale. URL: https://tweakers.net/reviews/10076/de-auto-als-mobiele-energiecentrale.html.

[31] Johannesson, P., Perjons, E., 2014. An Introduction To Design Science. Springer. doi:10.1007/978-3-319-10632-8.

[32] Kempton, W., Tomić, J., 2005. Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy. Journal of Power Sources 144, 280–294. doi:10.1016/j.jpowsour.2004.12.022.

[33] Kester, J., Noel, L., Zarazua de Rubens, G., Sovacool, B.K., 2018. Promoting Vehicle to Grid (V2G) in the Nordic region: Expert advice on policy mechanisms for accelerated diffusion. Energy Policy 116, 422–432. doi:10.1016/j.enpol.2018.02.024.

[34] Kester, J., Zarazua de Rubens, G., Sovacool, B.K., Noel, L., 2019. Public perceptions of electric vehicles and vehicle-to-grid (V2G): Insights from a Nordic focus group study. Transportation Research Part D: Transport and Environment 74, 277–293. URL: https://www.sciencedirect.com/science/article/pii/S1361920918306916, doi:https://doi.org/10.1016/j.trd.2019.08.006.

[35] Klobasa, M., Kühnbach, M., Stephan, A., Lux, B., Frank, F., Surmann, A., Kahler, J., Biener, W., Kamaci, Z., John, R., 2024. Potential of a full EV-power-system-integration in Europe & how to realise it. Technical Report. Fraunhofer ISE & Fraunhofer ISI.

[36] Lee, E.H., Lukszo, Z., Herder, P., 2018. Conceptualization of vehicle-to-grid contract types and their formalization in agent-based models. Complexity 2018. doi:10.1155/2018/3569129.

[37] Mohamed, M., Ferguson, M., Kanaroglou, P., 2018. What hinders adoption of the electric bus in Canadian transit? Perspectives of transit providers. Transportation Research Part D: Transport and Environment 64, 134–149. doi:10.1016/j.trd.2017.09.019.

[38] Myers, M.D., Newman, M., 2007. The qualitative interview in IS research: Examining the craft. Information and Organization 17, 2–26. doi:10.1016/j.infoandorg.2006.11.001.

[39] Neaimeh, M., Andersen, P.B., 2020. Mind the gap- open communication protocols for vehicle grid integration. Energy Informatics 3. doi:10.1186/s42162-020-0103-1.

[40] Noel, L., Brodie, J.F., Kempton, W., Archer, C.L., Budischak, C., 2017. Cost minimization of generation, storage, and new loads, comparing costs with and without externalities. Applied Energy 189, 110–121. URL: https://www.sciencedirect.com/science/article/pii/S0306261916318232, doi:https://doi.org/10.1016/j.apenergy.2016.12.060.

[41] Polestar, 2025. Polestar Energy: Meet the app that's changing the way drivers charge. URL: https://www.polestar.com/uk/news/polestar-energy-charging-app.

[42] Randall, C., 2023. Volvo Cars launches energy business. URL: https://www.electrive.com/2023/11/02/volvo-cars-launches-energy-business/#post-comments.

[43] Renault Group, 2023. Mobilize V2G: toekomstige Renault 5 wordt duurzame energiebron. URL: https://media.renault-group.nl/mobilize-v2g-toekomstige-renault-5-wordt-duurzame-energiebron/#artikel.

[44] Roemer, E., Henseler, J., 2022. The dynamics of electric vehicle acceptance in corporate fleets: Evidence from Germany. Technology in Society 68. doi:10.1016/j.techsoc.2022.101938.

[45] Schonebeek, K., 2023. Zo wordt de elektrische auto onderdeel van het stroomnet: 'De toekomst is er al'. URL: https://www.change.inc/mobiliteit/hoe-de-ev-onderdeel-van-het-stroomnet-wordt-40676.

[46] Schuller, A., Dietz, B., Flath, C.M., Weinhardt, C., 2014. Charging Strategies for Battery Electric Vehicles: Economic Benchmark and V2G Potential. IEEE Transactions on Power Systems 29, 2014–2022. doi:10.1109/TPWRS.2014.2301024.

[47] smartEn, 2022. Local Flexibility Markets. Technical Report. Smart Energy Europe. URL: https://smarten.eu/report-the-implementation-of-the-electricity-market-design-2022-smarten-

[48] Smith, A., Raven, R., 2012. What is protective space? Reconsidering niches in transitions to sustainability. Research Policy 41, 1025–1036. doi:10.1016/j.respol.2011.12.012.

[49] Sovacool, B.K., Hirsh, R.F., 2009. Beyond batteries: An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition. Energy Policy 37, 1095–1103. doi:10.1016/j.enpol.2008.10.005.

[50] Sovacool, B.K., Kester, J., Noel, L., Zarazua de Rubens, G., 2020. Actors, business models, and innovation activity systems for vehicle-to-grid (V2G) technology: A comprehensive review. Renewable and Sustainable Energy Reviews 131. doi:10.1016/j.rser.2020.109963.

[51] Sovacool, B.K., Noel, L., Axsen, J., Kempton, W., 2018. The neglected social dimensions to a vehicle-to-grid (V2G) transition: A critical and systematic review. doi:10.1088/1748-9326/aa9c6d.

[52] Suurs, R.A.A., Hekkert, M.P., 2009. Motors of Sustainable Innovation, chapter 7. URL: https://www.researchgate.net/publication/255587265.

[53] SWTCH, 2024. Open Charge Point Protocol (OCPP) Explained: What It Is, How It Works, And Why It Matters For EV Charging [Retrieved June 12, 2024]. URL: https://swtchenergy.com/open-charge-point-protocol-ocpp-explained-what-it-is-how-it-works-and-why-it-matter

[54] Turner, C., Astin, F., 2021. Grounded theory: what makes a grounded theory study? European Journal of Cardiovascular Nursing 20, 285–289. doi:10.1093/eurjcn/zvaa034.

[55] Turnheim, B., Kivimaa, P., Berkhout, F., 2018. Innovating Climate Governance: Moving Beyond Experiments doi:10.1017/9781108277679.002.

[56] Van Eijk, M.W., Annema, J.A., Van der Koogh, M., Lukszo, Z., 2025. Institutional barriers to vehicle-to-grid implementation in Europe. Renewable and Sustainable Energy Reviews 217. doi:10.1016/j.rser.2025.115653.

[57] Van de Weijer, B., 2022. De e-auto als elektriciteitscentrale voor thuis? Er moeten nog veel problemen overwonnen worden. URL: https://www.volkskrant.nl/nieuws-achtergrond/de-e-auto-als-elektriciteitscentrale-voor-thuis-er-moeten-nog-veel-problemen-overwo

[58] Wu, H.C., Chang, S.I., 2013. Exploration of a mobile service business model for electric vehicle charging stations. Journal of Industrial and Production Engineering 30, 363–372. URL: https://doi.org/10.1080/21681015.2013.849765, doi:10.1080/21681015.2013.849765.