38th International Electric Vehicle Symposium and Exhibition (EVS38) Göteborg, Sweden, June 15-18, 2025

V2G Service Blueprint co-design: Case study from Sweden

Elena Malakhatka[1], Johansson, Mia[2], Wallin, Emanuella[2], Albert Petersson[3], David Steen[1]

[1]*Chalmers University of Technology, elenamal@chalmers.se, david.steen@chalmers.se*

[2]*Polestar, mia.johansson@polestar.com, emanuella.wallin@polestar.com*

[3]*Vattenfall, albert1.petersson@vattenfall.com*

Executive Summary

This study explores the development of a Vehicle-to-Grid (V2G) Service Blueprint, with a focus on a collaborative case study from Sweden. The project employed an iterative, co-design approach involving stakeholder workshops to map and refine the V2G service process. The result is a detailed blueprint that captures the full-service journey, spanning phases from user awareness and adoption to engagement and retention. The blueprint highlights crucial touchpoints for users and service providers, such as customer support, technical troubleshooting, and educational resources, which are essential to building trust and facilitating user adoption in a field that demands a significant learning curve. Additionally, the blueprint addresses vital technological components, including bidirectional charging infrastructure, real-time data management, and communication protocols necessary for dynamic pricing and demand response. Key issues include adapting grid access policies and ensuring fair compensation for EV owners. This study underscores the importance of a structured, multi-stakeholder approach to effectively deploy V2G services and provides a replicable framework that other regions can adapt to support global sustainable energy goals.

Keywords: V2G, Service Blueprint, Co-Design

1 Introduction

The Vehicle-to-Grid (V2G) concept, which allows electric vehicles (EVs) to interact with the power grid, has gained considerable attention for its potential to support grid stability, enhance energy flexibility, and accelerate the transition to renewable energy systems [1-3]. V2G services enable bidirectional energy flows, allowing EVs to supply stored electricity back to the grid during peak demand or when renewable generation is low, and recharge when surplus electricity is available. This functionality not only positions EVs as mobile energy storage units but also transforms them into active participants in the energy system, contributing to both load balancing and renewable integration [4,5]. Realizing V2G requires seamless coordination and interaction among a diverse array of stakeholders, including EV owners, vehicle manufacturers, charging infrastructure providers, energy suppliers, aggregators, distribution system operators (DSOs), and transmission system operators (TSOs). Effectively managing these interactions, aligning technological components, navigating evolving regulatory landscapes, and ensuring a positive user experience present substantial hurdles. The sociotechnical nature of V2G integration, involving user behaviour, technology acceptance, and supportive policy frameworks, adds further layers of complexity. Key challenges often highlighted include establishing viable business models, ensuring interoperability between different technologies, addressing grid impacts, managing battery degradation concerns, and overcoming regulatory barriers.

The V2G system interaction is shown in Figure 1, where an EV owner can use their car's battery to interact with the power grid. The system relies on a bidirectional charger - Electrical Vehicle Supply

Equipment (EVSE) and optionally works alongside home solar panels (Solar PV) and a smart meter. A key player is the Aggregator, which acts as a middleman, managing the EV's charging and discharging to participate in energy markets (like Nord Pool in Scandinavian context [6]) and offer services to grid operators. Specifically, the Aggregator enables the EV to provide crucial grid-balancing services, such as Frequency Containment Reserves (FCR) and Frequency Restoration Reserves (aFRR/mFRR), to the Swedish TSO. This usually requires the Aggregator to function as, or partner with, a Balancing Service Provider (BSP). Additionally, the Aggregator can offer the EV's flexibility to the local DSO to help manage grid congestion, participating in local flexibility markets. In essence, this system uses the EV's battery, coordinated by an Aggregator, to support the stability of both the national TSO and local DSO power grids while potentially earning revenue for the EV owner through market participation. Potential value flows (indicated by dark blue arrows) include the supply of electricity to the user, the provision of the EV's flexibility resource to the Aggregator, and the offering of balancing capabilities to grid operators. Corresponding potential revenue streams (indicated by green arrows) flow in return, such as payments from the energy supplier for consumed electricity (to the supplier), payments from the Aggregator or market/grid operators to the EV owner (via the Aggregator) for providing grid services like FCR and aFRR/mFRR to TSO, and for offering flexibility to the local DSO. Thus, the system leverages the EV battery to create value for the grid (stability, congestion management) while generating potential revenue for the participant through market mechanisms.

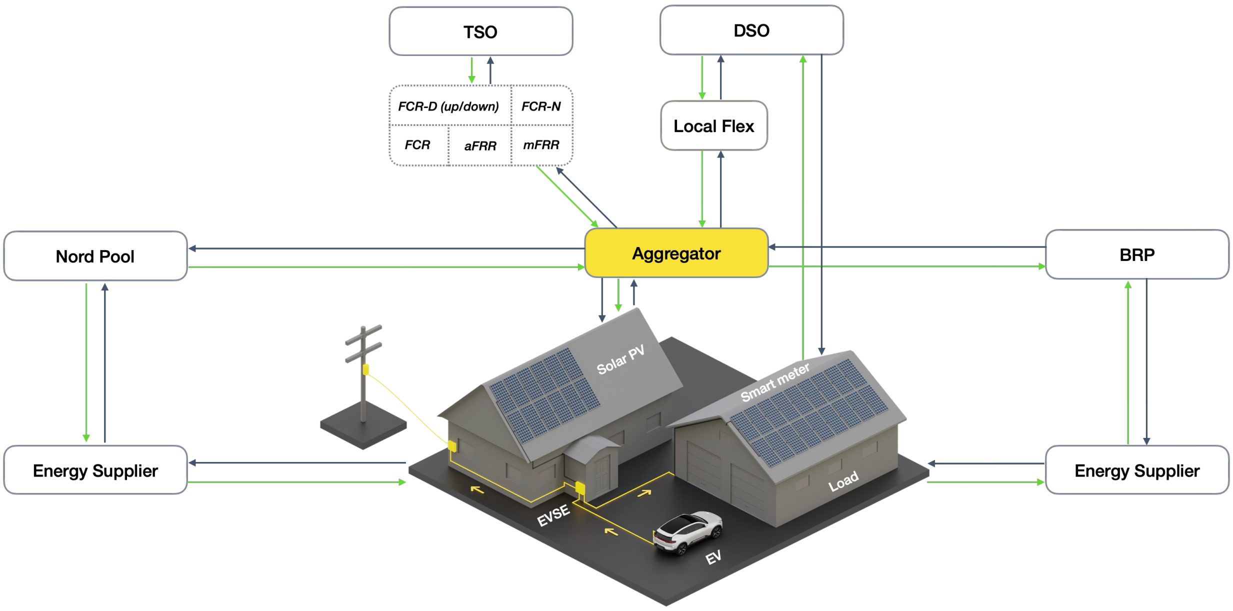

Figure 1. V2G Conceptual representation

Given the intricate web of technical components, diverse stakeholders, and complex value and revenue flows illustrated in the V2G system (Figure 1), successful implementation hinges on more than just technological feasibility. To fully grasp the service being designed, it's helpful to view it through the lens of a Service Concept framework (Figure 2), which mediates between the Strategic Intent of providers and the Customer needs, while defining *What* the service offers and *How* it is delivered [7, 8]. For V2G, the Strategic Intent involves enhancing grid stability, integrating renewables, and creating new value streams for energy and automotive stakeholders. Customer Needs encompass potential financial benefits, contributing to sustainability, ensuring vehicle availability, requiring a seamless user experience, and building trust. What the service offers is the opportunity for EV owners to provide grid flexibility (e.g., ancillary services) via their vehicle's battery in return for compensation. How this is delivered involves bidirectional chargers, aggregation platforms managing energy flow based on grid signals and user preferences and supporting processes like installation and customer service. Effectively aligning these dimensions is the core challenge the V2G service concept addresses. Methodologies from service design, such as Service Blueprinting [9, 10], are crucial for mapping out these complex ecosystems, identifying critical touchpoints, and aligning stakeholder activities [11]. This study specifically utilizes V2G Service Blueprinting, a technique proven useful for service innovation [12], to systematically visualize, analyze, and structure the V2G service delivery process, building on the recognized need for user-centric approaches to provide a clear roadmap for deployment and enhance the overall V2G service experience.

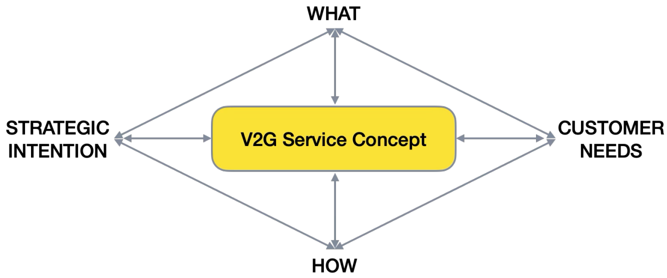

Figure 2. A model of the basic structure of the service (Adapted from [14])

The co-design process involved iterative workshops and data triangulation feedback sessions where stakeholders engaged in discussions to clarify their roles, identify critical service processes, and pinpoint the necessary technological and policy requirements for effective V2G service delivery [13,14]. This paper addresses the need for a structured, collaborative approach by presenting a case study from Sweden focused on the co-design of a V2G Service Blueprint for privatly owned EV with V2G function. Through active engagement with key stakeholders within the Swedish V2G ecosystem, this research aimed to develop a comprehensive blueprint that maps the necessary interactions, processes, and touchpoints for effective V2G service delivery. The primary objective is to detail this co-design process and the resulting blueprint, highlighting its components and the insights gained. This Swedish case study serves as a model for developing V2G Service Blueprints in other regions and V2G applications, emphasizing the importance of a collaborative approach in addressing the operational and strategic complexities of V2G. By actively involving diverse stakeholders in the design process, this study not only facilitated the exchange of domain-specific knowledge but also fostered a shared understanding of the V2G ecosystem's challenges and opportunities.

2 Methodology

To frame the methodological approach, we first position this research within new service development theory, as it relates to the purpose of co-creating service concepts. Johnson et al. define new service development (NSD) as the overall process of developing new service offerings, covering all steps from idea generation to market introduction [15]. Service design (SD), in contrast, aims for a service concept and overlaps only partly with NSD, primarily contributing to areas such as user orientation, contextualization, and strategic design [8]. The initial stage of the service design process often involves service concept development. Edvardsson et al. define the service concept as a detailed description of customer needs, how they are to be satisfied, what is to be done for the customer, and how this is achieved [15]. The service concept plays a key role not only as a core design element but also as an important initial stage for bridging involved actors and defining their needs and expectations, mediating between customer needs and the organization's strategic intent. This theoretical grounding in NSD and SD informs the specific methodology chosen for this study. To translate the abstract service concept into a tangible, operational plan, particularly for complex, multi-actor services like V2G, specific tools are required. The Service Blueprint, introduced by Shostack [9] and recognized as a practical technique for service innovation and design [10], provides such a tool. It allows for the detailed visualization of the service process, mapping customer actions, frontstage and backstage interactions involving different stakeholders, and the underlying support systems. Therefore, adopting the Service Blueprint methodology enables this research to systematically structure and analyze the co-created V2G service concept, clarifying roles, processes, and touchpoints essential for its successful implementation. The service blueprinting technique utilizes a structured diagrammatic format, typically organized into parallel lanes, each representing a distinct category of service activity or component. While variations exist, the bluepring in this study includes the following core elements:

Customer Actions: This topmost lane chronologically maps the steps, choices, activities, and interactions that the EV owner performs as they experience the service.

Frontstage Actions: These represent the actions of service contact employees, systems, or physical elements that are directly visible to the customer during the interaction.

Backstage Actions: This lane captures the essential activities performed by service employees or systems that are invisible to the customer but are crucial for supporting the frontstage actions and overall service delivery.

Support Processes: These are the underlying internal steps, systems, or activities that support the service providers (both frontstage and backstage) in delivering the service.

The V2G ecosystem inherently brings together stakeholders from traditionally disparate fields, including automotive manufacturing, energy utilities, information technology, software development, regulatory bodies, and installation services. Each group possesses its own technical language, operational paradigms, and strategic priorities. In such a multi-disciplinary environment, establishing a shared understanding of the end-to-end service process is paramount yet challenging. Service blueprinting addresses this by providing a common visual language. The blueprint diagram acts as a shared artifact that transcends domain-specific terminology, allowing engineers, marketers, grid operators, policymakers, installers, and customer service representatives to collectively visualize the service flow, understand their respective roles within it, identify critical interdependencies, and engage in constructive dialogue about design, potential issues, and improvement opportunities. This facilitation of cross-disciplinary communication and alignment is particularly valuable in the rapidly evolving V2G field, where roles, responsibilities, business models, and technical standards are often still under development or subject to change. The blueprint serves as a stable reference point for navigating this dynamic landscape. Applying this methodology to V2G involves mapping the entire service lifecycle, starting from customer awareness and acquisition, moving through enrollment, hardware installation, system configuration, ongoing V2G participation (charging, discharging, responding to grid events), performance monitoring, billing, and customer support. The resulting blueprint visually articulates how the diverse actors within the V2G ecosystem – Customer, Wallbox Installer, EVSE, Aggregator, DSO, TSO, Energy Supplier, BSPs and Insurance provider– contribute actions and interact at different stages. It provides a holistic view that clarifies the distinction between the relatively simple customer-facing interactions and the highly complex, multi-party coordination happening behind the scenes to enable grid services.

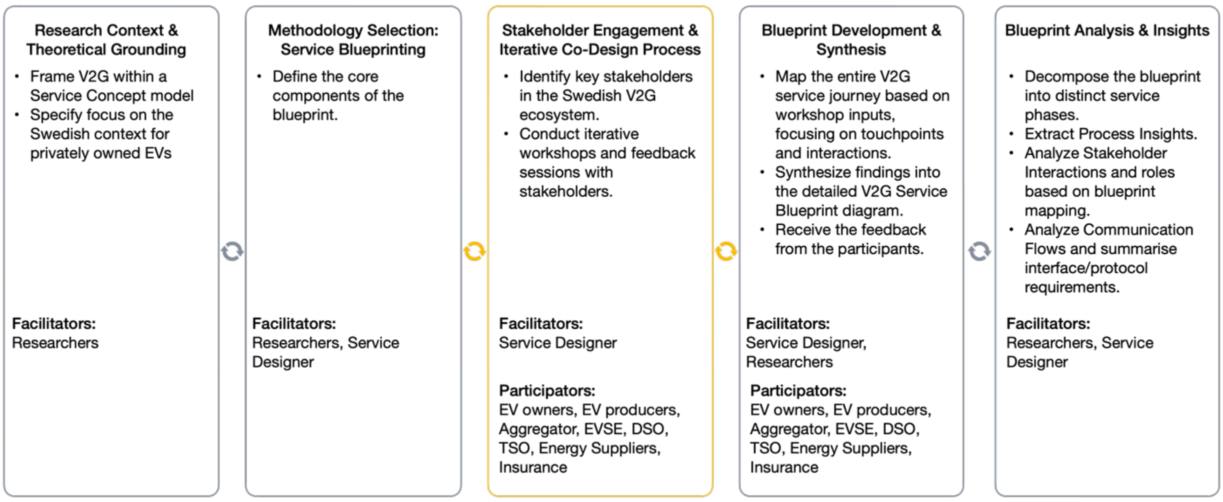

Figure 3. Overview of the study methodology

The methodological core of this study involved an iterative co-design process, guided by facilitators from the research team and service design experts, as conceptually illustrated in Figure 3. This collaborative approach was crucial for navigating the complexities of the V2G ecosystem and brought together a purposefully selected group of 18 participants. These participants represented the critical nodes of the Swedish V2G value chain, including end-users (EV owners), technology providers (EV producers, EVSE manufacturers), service operators (Aggregators, energy suppliers), infrastructure managers (DSO and TSO representatives), and enabling functions (insurance providers). Over a series of structured workshops and feedback loops, these stakeholders actively engaged in co-creation activities. Facilitators guided discussions aimed at clarifying stakeholder roles and responsibilities, mapping the end-to-end service processes from multiple perspectives, identifying crucial technical and policy requirements, and uncovering potential operational challenges.

3 Results: The V2G Service Blueprint

3.1 V2G Service Blueprint insights

The collaborative co-design process was synthesized into a detailed V2G Service Blueprint, presented in Figure 4. This blueprint serves as the primary outcome of the study, mapping the intricate V2G service ecosystem for privately owned EVs in the Swedish context. It visualizes the customer journey alongside the orchestrated frontstage and backstage actions of the multi-stakeholder network, revealing the operational complexities and interdependencies required for service delivery. The blueprint systematically decomposes the V2G service into distinct phases:

1. *Awareness & Interest:* This initial phase involves the customer (EV owner) becoming aware of V2G services, often through marketing efforts by Aggregators, Wallbox Installers, or Energy Suppliers. Key touchpoints include websites and informational materials. Backstage, stakeholders refine marketing strategies and define value propositions.
1. *Selection & Inquiry:* The customer actively seeks information, comparing offers from different V2G Aggregators. Touchpoints involve V2G info portals, pre-qualification checks (involving DSOs backstage for grid capacity assessment), and direct inquiries. Stakeholders like Aggregators provide detailed service information and eligibility criteria.
2. *Contracting & Acquisition:* The customer selects a provider and enters into a service agreement with the Aggregator. This phase involves critical frontstage interactions like signing contracts and agreeing to terms with an Energy Supplier. Backstage, Aggregators, and partner BSPs, finalize contractual details and initiate onboarding processes.
3. *Preparation & Installation:* This phase focuses on the physical setup. The Wallbox Installer performs a site inspection (frontstage) and coordinates with the customer. Backstage activities involve the Aggregator, Installer, and possibly the DSO ensuring technical requirements are met and scheduling the installation.
4. *Installation & Configuration:* The certified Wallbox Installer installs and configures the bidirectional EVSE (frontstage touchpoint). Backstage, the Installer confirms successful installation, and the Aggregator integrates the new asset into their platform, involving communication checks with the DSO and TSO systems.
5. *V2G Pre-qualification:* Before active participation, the Aggregator performs tests to ensure the EV and EVSE meet technical requirements for grid services (e.g., FCR, aFRR/mFRR). This is primarily a backstage process involving the Aggregator, BSP, and coordination with the TSO to ensure compliance with grid codes. The customer may be informed upon successful qualification (touchpoint).
6. *Usage:* This is the operational phase where the customer uses the V2G service via an app or portal (touchpoint) to manage charging preferences and view earnings. Frontstage, the customer experiences automated charging/discharging based on grid needs and their settings. Backstage, the Aggregator's platform dynamically manages the EV's energy flow, interacting with energy markets and grid operators to provide flexibility and ancillary services. This involves complex data management and communication protocols. Billing and payments (touchpoint) are handled, often involving the Energy Supplier and Aggregator.
7. *Engagement:* Ongoing interaction occurs through customer support channels for troubleshooting or inquiries, managed primarily by the Aggregator. Backstage, stakeholders monitor system performance, provide maintenance, and offer service upgrades or educational resources to retain the customer.
8. *Termination:* If the customer chooses to end the service, this phase involves final billing settlements (touchpoint) and deactivation procedures. Backstage, the Aggregator, Energy Supplier, and grid operators update their systems to reflect the termination.

	TIMELINE	1-4 WEEKS	2-8 WEEKS	1-3 WEEKS	3-6 MONTHS		1-6 MONTHS	DAILY	N/A	1-4 WEEKS
	CUSTOMER JOURNEY	**AWARENESS & INTEREST**	**SELECTION & REQUEST**	**DECISION & CONTRACTING**	**INSTALLATION PREPARATION**	**INSTALLATION & ONBOARDING**	**TEST PRE-QUALIFICATION**	**USAGE**	**ENGAGEMENT**	**TERMINATION**
FRONTSTAGE	CUSTOMER ACTION	• Learn about V2G • Research opportunities and requirements	• Request quotes for V2G charger + installation • Provide necessary details (smart meter, PV, BESS, etc.)	• Review quote • Sign contracts	• Track V2G connection queue status • Schedule installation • Prepare site	• Create account for V2G service • Sign agreement • Choose payment method • Inform insurance		• Set up charging schedule • Charge/discharge • Monitor charging cycle • Adjust settings	• Select/accept retention offer • Contact support	• Terminate V2G contract • Inform insurance actors
FRONTSTAGE	TOUCHPOINT	• Social networks • Social Media • News & media	• Websites • Apps • Online forums	• Website • App • E-mail	• Phone, Email, SMS • Grid operator's customer portal	• Aggregator's website • Wall box app • BankID		• Aggregator's app • EV app • Wall box app	• Apps • Newsletter • Customer service	• App • Website • Customer service
FRONTSTAGE	EV SUPPLIER	• V2G info	• Pre installation checklist • Prequalified EV model		• Provide support	• Activate V2G • Provide support		• Provide charge/discharge information in car & app • Provide support	• Provide support	• Update information in EV app
FRONTSTAGE	TECHNICAL AGGREGATOR	• V2G info	• Pre-installation checklist. • Information about the process and duration	• Prepare service agreement		• Agreement with customer • Manage payment methods		• Provide usage guidance • Manage charge/discharge • Handle payments	• Offer retention • Provide support	• Handle termination • Final settlement
FRONTSTAGE	WALLBOX INSTALLER	• V2G info	• Pre installation checklist • Prepare tailored quote	• Send contract • Provide support	• Schedule installation time • Inform about installation process & preparation steps	• Install V2G wall box		• Adjustments to dynamic load balancing systems		• Remove charger • Restore electrical installation
FRONTSTAGE	EVSE (CHARGER SUPPLIER)	• V2G wallbox info	• Pre installation checklist • Prequalified wallbox					• Provide support	• Handle wall box-related queries	
FRONTSTAGE	DSO	• V2G info	• Pre installation checklist • Initial feasibility indication for V2G connection		• Update queue status • Preliminary connection date	• Inspect & approve V2G wall box installation			• Handle grid-related queries	• Remove V2G site ID
FRONTSTAGE	ENERGY SUPPLIER	• V2G info	• Pre installation checklist							
FRONTSTAGE	TSO	• Ancillary service information	• Ancillary service information							
FRONTSTAGE	INSURANCE	• V2G insurance information	• Pre installation checklist			• Confirm coverage and terms • Verify installation compliance			• Handle insurance-related queries	• Confirm contract changes
BACKSTAGE	EV SUPPLIER	• V2G Marketing strategies • Aligning actor information	• Verify vehicle V2G compatibility • List certified wall boxes		• Provide B2B support	• Provide B2B support • Allow V2G function	• Collect and send telematics data to aggregator	• Provide B2B support • Collect and send telematics data to aggregator	• Provide B2B support • Monitor, collect and send telematics data to aggregator	• Deregister customer at aggregator • Stop sending data to aggregator
BACKSTAGE	TECHNICAL AGGREGATOR	• V2G Marketing strategies • Aligning actor information	• Verify vehicle V2G compatibility • List of Prequalified EV model & charger	• Prepare service agreement		• Activate V2G service	• Review technical requirements • Notify TSO • Notify BSP	• Update BSP on availability & bids • Manage charge/discharge • Handle payments	• Analyze aggregated V2G response data • Inform future auction design and grid forecasts	• Deregister unit • Notify TSO & BSP • Archive performance data
BACKSTAGE	WALLBOX INSTALLER	• V2G Marketing strategies • Aligning actor information	• Assess installation requirements • Ensure compatibility with certified vehicle brands	• Pre-notification of V2G connection to grid operator	• Check prerequisites	• Configure wall box (charging capacity & load balancing) • Enter new grid connection ID				• Remove charger • Restore electrical installation
BACKSTAGE	EVSE (CHARGER SUPPLIER)	• V2G Marketing strategies • Aligning actor information	• Product configurator, EV validation and grid compatibility		• Ship unit to installer	• Generate Box Site ID • Verify connectivity with EV, grid, and backend systems		• Monitor device health remotely • Enable real-time communication	• Collect operational data • Identify opportunities for feature upgrades	• Remote deactivation of wallbox
BACKSTAGE	DSO	• V2G Marketing strategies • Aligning actor information	• Provide grid connection data and evaluate local grid feasibility for V2G		• Analyse grid connection • Create grid connection ID & send to installer	• Process pre-notification • Inspect & approve V2G wall box installation		• Provide grid capacity data and operational constrains to aggregators	• Monitor local impacts • Assess reliability of V2G events • Provide data to DSOs/TSOs	
BACKSTAGE	BSP	• Monitor V2G market interest • Evaluate flexibility potential in system forecasts	• Pre-qualification criteria for V2G • Flexibility and capacity requirements				• Test the connection • Submit the protocol to the TSO • Create group for bidding	• Bid on flex/ancillary market • Notify aggregator • Pay to aggregator	• Analyse performance • Track energy balancing • Adjust forecasts	
BACKSTAGE	BRP					• Include V2G in balancing forecasts		• Perform balancing		
BACKSTAGE	ENERGY SUPPLIER	• V2G Marketing strategies • Aligning actor information	• Define V2G tariff • Validate user compatibility via CRM and billing systems					• Pricing information to aggregator • Supporting optimal economic utilisation of V2G assets		
BACKSTAGE	TSO	• Market analysis (theory) • Pilot studies (technology)	• Provide V2G asset qualification criteria and baseline measurement guidelines for BSPs				• Review BSP's tests – approve increased capacity or request more testing	• Activation of bid • Compensate & pay BSP for bids		• Remove capacity from group
BACKSTAGE	INSURANCE	• Aligning actor information	• Verify insurance coverage (EV/home) for V2G installation			• Review policy details • Check installation documentation				• Review policy details
PROCESS INSIGHTS	SYNCHRONISATION AREAS	• Customer expectations • Information on requirements, compatibility & processes.	• Pre-qualification criteria	• Technical requirements, installation prerequisites • Cost estimation • regulatory compliance	• Installer – Grid owner	• Data sharing aggregator – grid owner		• Balancing customer needs with grid stability		
PROCESS INSIGHTS	FACTS/METRICS	• Only ~40% of EV users are aware of V2G capabilities. • Quick V2G value indication required to maintain interest	• 70% of users want to understand cost savings before opting in • Some wall boxes are certified for certain EVs.	• Users prefer simple contracts – reading time ≤3 min • Trust in provider is key factor	• V2G connection permit applies only to approved EVs and the designated wall box	• Guided app tutorials boost onboarding success by 40% • First-week experience shapes long-term retention	• Bidding strategy determines: pre-qualified unit can be added or new test is required • Test duration depends on pre-qualification	• Peak V2G participation during early evenings • Energy return varies by user driving habits and grid needs	• Users engaged with feedback dashboards are 3×more likely to stay active	• Top reasons: low financial benefit, unclear value, technical issues, ~20% might return if services improve
PROCESS INSIGHTS	POTENTIAL PITFALLS	• Perceived technical complexity • Misconceptions about battery degradation • No guaranteed connection	• Fail to address key pain points, creating investment uncertainty • Confusing service offerings	• Uncertain connection date. • Complex contract language. • Long-term financial risk	• Long V2G approval lead times may be unexpected vs. standard wall box installations • Poor communication during the process	• Incorrect load balancing may trip the main fuse • Delay between installation and approval may delay service delivery	• Delay between installation and V2G approval delays • ROI for Customer	• Unexpected performance or financial return • Insufficient feedback on V2G impact • Grid-related issues	• Poor support • Retention offers fail to address user needs • Users feel disconnected from their value contribution	• Frustrating termination process • Loss of valuable data/insight • No exit feedback mechanism
PROCESS INSIGHTS	IDEAS OPPORTUNITIES	• Co-branded campaigns with EV-makers, grid & energy providers • Segment audiences and tailor V2G messaging	• In-app cost–benefit visualisations • Marketplace of compatible hardware/services • Photo-based pre-checks	• Transparent contract comparison tools • Personalised V2G financial projections	• Real-time preparation status tracker • Early information on timelines, uncertainties, and connection likelihood	• In-app tutorials, explain settings, usage goals, and possible gains		• Real-time impact dashboard (e.g., grid stability contribution, CO_2 saved) • Performance-based rewards	• Energy credits • Community engagement via sharing feedback, use cases or challenges	• Option for pause instead of cancellation • Smooth off boarding with data export and re-engagement offers
PROCESS INSIGHTS	COMMON POLICIES	• Electrical safety requirements. • V2G-compatible charger standards	• Installation terms • Pricing policies • Electrical Safety Authority policies	• Contract law • Consumer protection	• Swedish TSO requirements • ALP • RfG • EIFS 2018:2 • SS-EN 50549-1	• Grid agreement • Customer agreement • Energy tax and VAT • TSO requirements		• Market regulations • Technical requirements for ancillary service • NIS2 requirements • Balancing rules		• Termination policies • Electrical safety requirements

Figure 4. V2G Service Blueprint

The Process Insights derived from the co-developed V2G Service Blueprint reveal critical interdependencies and considerations essential for successful service implementation and adoption. Key Synchronization Areas necessitate alignment between stakeholders regarding customer expectations, technical and regulatory pre-qualification criteria, installation prerequisites, data sharing agreements, and balancing customer needs with grid stability.

Supporting Facts & Metrics, drawn from both the project's workshops and wider V2G literature, highlight significant user challenges and behaviours. For instance, user awareness of V2G capabilities remains relatively low, with findings suggesting figures around 40% among EV drivers in some European contexts, including Sweden [16,17], necessitating clear value communication to maintain interest. User experience is paramount, with a strong preference for simplicity; some scholars indicated a desire for contracts readable in under five minutes by a large majority of potential users [18], aligning with broader findings emphasizing the need for user-friendly interfaces and processes to overcome perceived complexity [19]. Trust in the service provider emerges as a critical factor in adoption [20]. Technical prerequisites are strict, with grid connection permits often tied to specific, approved EV models and designated bidirectional chargers [21], and while some wall boxes are certified, compatibility remains a key consideration. Effective onboarding, boosted by guided tutorials, and positive first-week experiences are crucial for long-term retention [22]. Operational metrics show peak V2G participation often aligns with early evening grid needs, though energy return varies significantly based on user driving habits and dynamic grid requirements [23].

Several Potential Pitfalls were identified, including user misconceptions about battery degradation (often overstated compared to findings from managed charging studies [17,24]), uncertainties in connection timelines and financial returns, communication gaps during installation, unexpected performance issues, and inadequate customer support. To mitigate these, various Ideas & Opportunities were generated, such as co-branded marketing, transparent cost-benefit tools, real-time dashboards, performance-based rewards, community engagement, and streamlined offboarding.

3.2 Stakeholders' Interaction Analysis

An important contribution of the V2G service blueprint is its capacity for systematic role clarification within the complex stakeholder network. By assigning specific frontstage and backstage actions to each identified actor's lane, the blueprint moves beyond abstract stakeholder lists to provide a granular and unambiguous definition of who does what at each specific stage of the service lifecycle. This structured mapping details operational involvement, clarifying responsibilities in a way that verbal descriptions or high-level diagrams often fail to achieve. Furthermore, the blueprint visually maps the sequence, direction, and nature of interactions between these actors as the service unfolds over time. This interaction mapping is important for understanding the operational dynamics of V2G.

The blueprint can clearly delineate the Wallbox Installer's frontstage activities, such as the physical installation of the charging equipment at the customer's premises and the initial customer handover or training. Concurrently, it maps the Aggregator's backstage activities, which include receiving installation confirmation, remotely configuring the charger for V2G communication, registering the asset within their platform, and initiating communication exchanges with the relevant DSO or TSO systems to validate the grid connection point and perform initial eligibility checks. While some reports mention installers , they often lack this level of detail regarding specific interactions with other actors like Aggregators or DSOs during the setup phase. During ongoing V2G operation, the blueprint visualizes the EV owner interacting with a mobile app to set charging preferences or monitor performance (Customer Actions & Frontstage). Simultaneously, it shows the Aggregator's platform executing backstage actions: receiving real-time data (e.g., state-of-charge, connection status) from the EV/charger, processing grid signals (e.g., price fluctuations, frequency deviations, capacity requests), calculating optimal charging/discharging schedules based on algorithms that balance grid needs, user constraints, and economic incentives, and sending commands back to the charger. Critically, it also maps the essential backstage data exchanges between the Aggregator's platform and the systems of the DSO and TSO. These exchanges are vital for the Aggregator to understand grid conditions, for the DSO to manage potential local distribution network impacts, and for the TSO to procure and verify the delivery of ancillary services or flexibility. This detailed mapping provides empirical grounding derived from the service design itself, complementing and operationalizing insights from broader stakeholder analyses found in research. Studies identify the Aggregator as a key intermediary, managing fleets of EVs to participate in various energy markets and provide services. Research also highlights the crucial, and sometimes complex, coordination required between the Aggregator, the DSO (focused on distribution network integrity and local services), and the TSO (focused on transmission system balance, frequency control, and wholesale market operations). The blueprint allows for the visualization of specific interaction patterns reflecting different coordination models discussed in the literature, such as DSO-managed schemes versus more integrated TSO-DSO hybrid models [25,26]. To synthesize this information, the following table connects key V2G stakeholders identified in research with their roles and interactions as mapped within a detailed V2G Service Blueprint:

Table 1: Key V2G Stakeholders and Blueprint-Defined Interactions

	Primary Role	Key Frontstage Actions	Key Backstage Actions	Key Interactions
EV Owner	Provides vehicle/battery for V2G services; sets preferences; consumes energy; potentially earns revenue	Using app/interface; plugging/unplugging EV; contacting support; setting preferences.	N/A	Installer (during setup), Aggregator (via app/platform, support), Energy Supplier (billing).
Wallbox Installer	Installs and commissions V2G-capable charging equipment; provides initial customer guidance. (Role implied, less detailed in snippets)	Physical installation; testing connection; customer demonstration/handover.	Coordinating installation schedule; verifying site suitability; reporting installation completion to Aggregator/Supplier.	Customer, Aggregator (reporting), Energy Supplier or DSO (for connection procedures).
Aggregator	Manages fleet of EVs; optimizes charging/discharging; bids into energy/ancillary service markets; interfaces with grid operators	Providing app/platform interface; sending notifications; providing performance reports.	Receiving EV/user data; processing grid signals; running optimization algorithms; sending charge/discharge commands; performing V2G pre-qualification; managing market participation; data validation; settlement.	Customer (data/commands), Installer (setup info), DSO (local grid data/constraints), TSO (ancillary service signals/bids), BSPs, Energy Markets.
DSO	Manages local distribution network; ensures grid stability/safety at distribution level; may procure local flexibility services	N/A	Monitoring local grid conditions (voltage, load); validating grid connection points; setting operational boundaries for Aggregators; processing grid data; managing network constraints; clearing local flexibility markets.	Aggregator (data exchange, operational limits), TSO (coordination, information sharing), Installers (connection standards), Energy Supplier (metering data).
TSO	Manages high-voltage transmission system; ensures overall grid balance/frequency; procures ancillary services from market participants	N/A	Monitoring overall system state; issuing grid signals (e.g., frequency regulation needs); dispatching ancillary services; managing wholesale markets; coordinating with DSOs.	Aggregator/BSP (market participation, dispatch signals), DSO (coordination, data exchange).
Energy Supplier	Provides retail electricity; manages customer billing; may offer specific EV/V2G tariffs	Providing electricity tariff information; sending bills; offering V2G-specific plans.	Metering energy consumption/generation; managing customer accounts; settling V2G transactions with Aggregator.	Customer (billing, tariffs), Aggregator (settlement data), DSO (metering data).
BSP	May act as intermediary between Aggregator and TSO for specific balancing markets. (Role often combined with Aggregator)	N/A	Aggregating flexibility bids; interfacing with TSO market platforms.	Aggregator, TSO.

3.3 Communication Flows and Defining Interface Requirements

Effective communication and data exchange constitute the operational bedrock of V2G systems, enabling the intricate coordination and control required to leverage distributed EV battery capacity for grid stabilization and ancillary services. Service blueprinting provides a methodology to map and analyze these critical communication flows within the complex V2G ecosystem. This visualization encompasses not only communication acts, such as user interactions with interfaces or support personnel, but also data exchanges occurring within the backstage and support layers. These implicit flows, fundamental to V2G functionality yet typically invisible to the end-user, include EV telemetry transmission (e.g., state-of-charge, connection status) to aggregators, the dissemination of grid signals (e.g., pricing, frequency deviations, capacity requests) from TSOs and DSOs to aggregators, the issuance of control commands (e.g., charge/discharge instructions) from aggregators to EVs/chargers, and the exchange of settlement data among relevant parties. Analyzing these potential communication pathways via the blueprint facilitates a preliminary assessment of the V2G information architecture. It allows for the prelimnary definition of data exchange requirements, including the specific information content, the identities of the communicating entities (e.g., EV-Aggregator, Aggregator-DSO, TSO-Aggregator) and necessary performance characteristics such as reliability, throughput, and security. This process-grounded analysis is essential for identifying critical system interfaces, uncovering potential communication gaps or bottlenecks in the service design, and directly informing the technical requirements for the V2G communication infrastructure. Consequently, it provides the necessary context for specifying and implementing robust, interoperable communication protocols – such as ISO 15118 for high-level EV-EVSE communication including bidirectional power transfer and OCPP for EVSE-Central Management System interactions , alongside other relevant standards like, IEEE 2030.5 , OpenADR , or IEC 61850 depending on the specific interaction mapped – as well as defining standardized data formats, shared digital platforms or APIs , and implementing stringent cybersecurity measures across all communication channels to ensure operational integrity and data privacy.

Table 2: V2G Communication Protocols and Blueprint Relevance

Protocol	Function	Key Interacting Entities	Relevant Blueprint Stages/Interactions
ISO 15118	High-level communication between EV and EVSE; enables V2G (bidirectional power flow), Plug & Charge, smart charging negotiation.	EV Communication Controller (EVCC), Supply Equipment Communication Controller (SECC)	*Usage Phase:* Interactions involving EV connection, authentication, negotiation of charging/discharging parameters (power, energy, time) directly between EV and smart charger.
OCPP	Communication between EVSE (Charge Point) and Central Management System (CMS/CPMS); remote control, monitoring, billing, smart charging.	EVSE (Charge Point), CMS/CPMS (often Aggregator/CPO)	*Installation/Configuration Phase:* Remote configuration of EVSE. *Usage Phase:* Sending start/stop commands, receiving meter values, managing reservations, updating firmware, transmitting V2G schedules received from Aggregator CMS to the EVSE.
IEEE 2030.5	Application layer protocol for utility management of end-user energy resources; supports DR, DER, EV integration.	Utility/Aggregator Server, Client Devices (EVSE, DER)	*Usage Phase:* Exchanging demand response signals, pricing information, load control commands, and DER status updates between utility/Aggregator systems and end devices participating in grid programs.
OpenADR	Standard for automated demand response communication; exchange of price, reliability, and DR event signals.	Utility/Aggregator (VTN), End Device/Aggregator (VEN)	*Usage Phase:* Communicating dynamic pricing or DR event signals from utility/Aggregator to EVSE/Aggregator platform to influence charging/discharging behavior based on grid needs or economic opportunities.
IEC 61850	Provides retail electricity; manages customer billing; may offer specific EV/V2G tariffs	Providing electricity tariff information; sending bills; offering V2G-specific plans.	*Backstage/Support Processes:* Use for communication between DSO/TSO control centers and aggregated DER resources (represented by Aggregator) for grid monitoring and control, especially for larger-scale V2G deployments integrated with distribution automation systems.

4 Discussion

This study contributes to the field of NSD by applying service design principles, specifically service blueprinting, to the complex, emerging domain of V2G services. Grounded in the theoretical understanding that NSD encompasses the entire process from idea to market launch and that service design plays a crucial role in defining the service concept to meet customer needs while aligning with strategic intent, this research focused on developing a V2G service concept operationalized through a detailed Service Blueprint. The co-design methodology employed aligns with the emphasis in service design on user orientation and stakeholder involvement to bridge the gap between the strategic goals of V2G providers (e.g., grid stabilization, renewable integration) and the needs and expectations of customers (e.g., financial benefits, ease of use, reliability). The primary outcome, the V2G Service Blueprint developed for the Swedish context (Figure 4), summarizes the core results of this research. It systematically maps the customer journey through distinct service phases, from initial awareness and contracting to ongoing usage and potential termination. Crucially, it visualizes the corresponding frontstage and backstage actions undertaken by a diverse network of stakeholders – including the Customer, Wallbox Installer, Aggregator, DSO, TSO, Energy Supplier, and BSPs. This detailed mapping illuminated the intricate web of interactions and dependencies required for service delivery. The analysis further distilled key process insights, highlighting critical synchronization areas, potential pitfalls derived from user experience data and operational constraints (pending placeholder citations), and opportunities for service improvement. Furthermore, the blueprint facilitated the analysis of essential communication flows and the identification of requirements for underlying technical protocols (like ISO 15118 and OCPP) that enable the necessary data exchange between entities.

These findings directly address the challenges identified in the Introduction regarding the complexity of coordinating multiple actors, integrating technology, navigating regulations, and ensuring a positive user experience in V2G deployment. While the technical feasibility of V2G is increasingly demonstrated, this work underscores that operational success hinges on managing the sociotechnical system as a whole. The blueprint provides the structured, holistic view necessary for this, moving beyond high-level conceptual models (like Figure 1) to detail the operational reality. It makes explicit the often-invisible backstage processes and support systems critical for delivering the service, clarifying the roles and interactions of key players like the Aggregator, DSO, and TSO in managing energy flows and grid services. As highlighted by Shostack and Bitner et al., blueprinting acts as a practical technique for service innovation; here, it proves particularly valuable for visualizing and managing the inherent complexity of a multi-actor energy service ecosystem.

Critically reflecting on this study, its strength lies in the application of a collaborative, co-design approach to develop the blueprint. This ensured that the perspectives and operational realities of various key stakeholders within the Swedish V2G ecosystem were incorporated, lending practical relevance to the resulting model. The visual nature of the blueprint itself is a key strength, providing a common language to facilitate communication and understanding across disciplines (e.g., energy, automotive, IT), which is essential in the nascent V2G field. However, the study has limitations. Its findings are rooted in the specific context of Sweden and focus on privately owned EVs; generalizability to other regulatory environments, market structures, or V2G applications (e.g., commercial fleets) requires careful consideration. The comprehensiveness of the blueprint is also dependent on the specific stakeholders engaged in the co-design workshops; perspectives not represented might lead to omissions. Furthermore, the blueprint represents a service *design* – actual implementation may uncover unforeseen operational challenges or require further iteration. The reliance on several placeholder references in the current draft's process insights section is also a limitation needing resolution.

The theoretical implications of this work lie in its empirical demonstration of service blueprinting's utility in a technologically complex, multi-stakeholder, ecosystem-level service context. It reinforces the value of service design tools, traditionally applied to more conventional customer-facing services, in tackling the challenges of NSD for critical infrastructure services like V2G. It highlights the necessity of mapping not just customer actions but the intricate backstage coordination and technical communication layers essential for service functionality. This case provides a concrete example of how blueprinting can operationalize a service concept within a sociotechnical system, bridging strategic intent with practical implementation needs.

From a practical standpoint, the implications are significant. The developed blueprint offers a tangible framework for organizations planning or implementing V2G services, particularly in Sweden and EU.

It clarifies roles, responsibilities, and critical interdependencies between stakeholders, aiding in partnership development and process definition. By identifying potential pitfalls (e.g., communication gaps during installation, user misconceptions) and synchronization areas, it enables proactive risk management and operational planning. The analysis of communication flows and interfaces directly informs technical architecture design and the selection of appropriate standards, promoting interoperability. Ultimately, the blueprint serves as a valuable tool for enhancing cross-disciplinary communication, aligning stakeholder activities, and designing a more robust and user-centric V2G service experience, thereby helping to bridge the gap between V2G's potential and its successful, scaled deployment.

5 Conclusion & Future Work

This study addressed the inherent complexity of deploying Vehicle-to-Grid (V2G) services by employing a collaborative, co-design methodology to develop a detailed Service Blueprint tailored to the Swedish context for privately owned EVs. The resulting blueprint provides a crucial, structured visualization of the entire V2G service ecosystem, mapping the customer journey, stakeholder actions (frontstage and backstage), critical touchpoints, and underlying support processes. By clarifying roles, interactions, operational requirements, and potential pitfalls, this research demonstrates the value of service blueprinting as a practical tool to facilitate shared understanding, manage complexity, and support the planning and implementation of robust, user-centric V2G services. Future work should focus on validating and refining this blueprint through pilot implementations and further iterative feedback cycles with stakeholders. Comparative studies applying this methodology in different national contexts or to varying V2G applications (e.g., commercial vehicle fleets) would be valuable to assess the framework's adaptability and generalizability. Further research is also warranted to delve deeper into specific challenges highlighted by the blueprint analysis, such as developing effective strategies to enhance user engagement and trust, refining technical interface standards for seamless data exchange between all actors, and exploring solutions to the identified regulatory hurdles. Finally, integrating the qualitative insights from the blueprint with quantitative modeling could provide deeper understanding of the economic viability and grid impact of different V2G service configurations.

Acknowledgments

This project was made possible through funding from Vinnova (Ref. No. 2023-00785) as part of the initiative *Implementation of Vehicle-to-Grid Services in Sweden*. We acknowledge the valuable collaboration of project partners—Polestar Performance AB, Vattenfall, Göteborg Energi, Svenska kraftnät (Swedish National Grid), Easee, and Chalmers University of Technology—in advancing sustainable energy solutions.

References

[1] Mwasilu, F., Justo, J. J., Kim, E. K., Do, T. D., & Jung, J. W. (2014). Electric vehicles and smart grid interaction: A review on vehicle to grid and renewable energy sources integration. *Renewable and sustainable energy reviews*, *34*, 501-516.

[2] İnci, M., Savrun, M. M., & Çelik, Ö. (2022). Integrating electric vehicles as virtual power plants: A comprehensive review on vehicle-to-grid (V2G) concepts, interface topologies, marketing and future prospects. *Journal of Energy Storage*, *55*, 105579.

[3] Yilmaz, M., & Krein, P. T. (2012, September). Review of benefits and challenges of vehicle-to-grid technology. In *2012 IEEE Energy Conversion Congress and Exposition (ECCE)*(pp. 3082-3089). IEEE.

[4] Mojumder, M. R. H., Ahmed Antara, F., Hasanuzzaman, M., Alamri, B., & Alsharef, M. (2022). Electric vehicle-to-grid (V2G) technologies: Impact on the power grid and battery. *Sustainability*, *14*(21), 13856.

[5] Ravi, S. S., & Aziz, M. (2022). Utilization of electric vehicles for vehicle-to-grid services: Progress and perspectives. *Energies*, *15*(2), 589.

[6] Nord Pool. (2024). *Day-ahead market prices – 2024*. https://www.nordpoolgroup.com/en/Market-data1/Dayahead/Area-Prices/

[7] Goldstein, S. M., Johnston, R., Duffy, J., & Rao, J. (2002). The service concept: the missing link in service design research?. *Journal of Operations management*, *20*(2), 121-134.

[8] Malakhatka, E., Sopjani, L., & Lundqvist, P. (2021). Co-Creating Service Concepts for the Built Environment Based on the End-User's Daily Activities Analysis: KTH Live-in-Lab Explorative Case Study. *Sustainability*, *13*(4).

[9] Lynn Shostack, G. (1982). How to design a service. *European journal of Marketing*, *16*(1), 49-63.

[10] Bitner, M. J., Ostrom, A. L., & Morgan, F. N. (2008). Service blueprinting: a practical technique for service innovation. *California management review*, *50*(3), 66-94.

[11] da Silva, A., & Cardoso, A. J. M. (2024). Navigating the digital shift: a service blueprint for coopetition technology-enabled networks. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, *22*(5), 1138-1146.

[12] A. Arshad and F. Loi, "Driving the Grid: The Role of V2G in Modern Energy Ecosystem," Master's thesis, University of Gothenburg, Gothenburg, Sweden, 2024.

[13] Willmott, T. J., Hurley, E., & Rundle-Thiele, S. (2022). Designing energy solutions: a comparison of two participatory design approaches for service innovation. *Journal of Service Theory and Practice*, *32*(3), 353-377.

[14] Campbell, R., Goodman-Williams, R., Feeney, H., & Fehler-Cabral, G. (2020). Assessing triangulation across methodologies, methods, and stakeholder groups: The joys, woes, and politics of interpreting convergent and divergent data. *American Journal of Evaluation*, *41*(1), 125-144.

[15] Edvardsson, B., & Olsson, J. (1996). Key concepts for new service development. *Service Industries Journal*, *16*(2), 140-164.

[16] Majerowska, E., & Jasik, H. (2024). Demand for electric cars in the context of sustainable development-a model approach for selected markets. *Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie*, (205).

[17] Kester, J., de Rubens, G. Z., 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.

[18] Mahler, M., & Murphy, A. (2024). Risk of desirable user experiences: insights from those who create, facilitate and accept mobile payments. *Electronic Commerce Research*, 1-22.

[19] Ghotge, R., Nijssen, K. P., Annema, J. A., & Lukszo, Z. (2022). Use before you choose: What do EV drivers think about V2G after experiencing it?. *Energies*, *15*(13), 4907.

[20] Noel, L., de Rubens, G. Z., Kester, J., & Sovacool, B. K. (2019). Navigating expert skepticism and consumer distrust: Rethinking the barriers to vehicle-to-grid (V2G) in the Nordic region. *Transport Policy*, *76*, 67-77.

[21] Das, H. S., Rahman, M. M., Li, S., & Tan, C. W. (2020). Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review. *Renewable and Sustainable Energy Reviews*, *120*, 109618.

[22] Bertana, A. (2022). *Designing an informative visual tool to explain the application of Vehicle to Grid (V2G) in business parks* (Bachelor's thesis, University of Twente).

[23] Kadu, R. (2024). Impact of User-Driven Charging Behaviors and V2G Integration on the Dutch Low Voltage Grid.

[24] Adegbohun, F., von Jouanne, A., Agamloh, E., & Yokochi, A. (2024). A review of bidirectional charging grid support applications and battery degradation considerations. *Energies*, *17*(6), 1320.

[25] Nguyen, H., Nguyen, P., & Kok, K. (2025). A comparative study of different TSO-DSO coordination in the reserve market. *arXiv preprint arXiv:2502.08782*.

[26] Wang, Y., Qiu, D., Teng, F., & Strbac, G. (2024). Two-Stage TSO-DSO Services Provision Framework for Electric Vehicle Coordination. *IEEE Transactions on Power Systems*.