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AUTHORS

Meike Vey

Nils Namockel

Oliver Ruhnau

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Institute of Energy Economics at the University of Cologne (EWI)
www.ewi.uni-koeln.de

Institute of Energy Economics
at the University of Cologne (EWI)

Alte Wagenfabrik
Vogelsanger Str. 321a
50827 Köln
Germany

Tel.: +49 (0)221 277 29-100
Fax: +49 (0)221 277 29-400
www.ewi.uni-koeln.de

CORRESPONDING AUTHOR

Meike Vey
meike.vey@web.de

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Green charged decision-making: How two-part remuneration, contract flexibility, and environmental nudging drive vehicle-to-grid participation

Meike Vey[a,*], Nils Namockel[a,b], Oliver Ruhnau[a,b]

[a] *Institute of Energy Economics at the University of Cologne, Vogelsanger Strasse 321a, 50827 Cologne, Germany.*
[b] *Chair of Energy Economics, University of Cologne, Vogelsanger Strasse 321a, 50827 Cologne, Germany.*

Abstract

Electric mobility and renewable energy play key roles in the global energy transition. In this context, vehicle-to-grid technology, which enables bidirectional energy flow between electric vehicles and the grid, could make electric vehicles usable as energy storage units, thus supporting grid stability and integration of renewable energy. However, the willingness of electric vehicle owners to participate in vehicle-to-grid contracts remains insufficiently understood, particularly regarding how they respond to specific contract attributes. This paper addresses this gap by conducting a discrete choice experiment to evaluate the preferences of current and potential future German electric vehicle drivers for various vehicle-to-grid contract alternatives. We find that cycle-based remuneration, flexible contract duration, and environmental nudging significantly enhance consumer acceptance. Conversely, a lower guaranteed battery level and longer minimum plug-in durations negatively impact participation. We also test how respondent characteristics influence participation and identify income-dependent preferences, such as lower-income individuals attributing a stronger preference to fixed daily payments than higher-income individuals. Our differentiated findings may be used to improve contract designs and marketing efforts to address the unique V2G preferences of various user segments.

Keywords: Vehicle-to-grid, Discrete choice experiment, Willingness to accept, Preferences, Bidirectional charging

JEL classification: C25, D12, Q42, Q48, Q51, Q58, R41

*Corresponding author, *email*: meike.vey@web.de.

1. Introduction

The rapid adoption of electric vehicles (EVs) will closely link the transportation sector to the electricity sector. For the example of Europe, EVs are projected to reach 60% of car sales by 2030, following the *Stated Policies* scenario [1]. On the one hand, this development may help decarbonize the transportation sector by using electricity from renewable energy sources (RES). On the other hand, flexible charging and discharging of EVs may help address challenges associated with the intermittency of the most prominent RES, namely wind and solar energy. In particular, vehicle-to-grid (V2G) technology[1], which enables bidirectional energy flow between EVs and the grid, holds the potential to leverage EVs as mobile energy storage, capable of absorbing surplus RES and discharging it back into the grid when RES are scarce, thereby reducing reliance on conventional power plants [3, 2].

The theoretical potential of V2G technology is substantial. With EVs parked approximately 97% of the time, their collective storage capacity offers a promising alternative to stationary storage systems [4, 5]. V2G technology provides several benefits, including economic savings on electricity bills and system costs, reductions in CO_2 emissions, and improved grid reliability [6, 7, 8]. For instance, a recent study [7] estimates that V2G can reduce the average price paid for EV charging by 28–67% versus unidirectional charging with a time-invariant tariff. While V2G technology comes at additional costs, car manufacturers are increasingly developing V2G-compatible vehicles, suggesting that benefits are expected to outweigh these costs [e.g. 9, 10, 11, 12].

Despite this theoretical potential, regulatory, technical, and socioeconomic barriers currently hinder the commercial viability of V2G. The utilization of V2G technology requires smart meters, which are still rare in some countries [13]. Regulation for feeding electricity into the grid, such as grid codes, has been developed for large power producers and may be unsuited for distributed V2G systems. Electricity taxes may make it uneconomical to sell energy back to the grid [14]. Finally, even when these issues are solved, V2G-capable charging infrastructure may be lacking [15].

While much of the existing research on V2G focuses on techno-economic aspects, consumer acceptance has remained underexplored. Between 2015 and 2017, only 3% of peer-reviewed studies on V2G addressed consumer acceptance [16]. Similarly, Park Lee [17] observed that socio-technical barriers receive insufficient attention in the literature, noting a lack of knowledge about the relationship between contracts, system operations, and actor behavior. Furthermore, a report by Everoze EVConsult [18] highlights that, while

[1] V2G is part of a broader suite of 'vehicle-to-x' technologies, including vehicle-to-home, where EVs supply power to homes, and vehicle-to-vehicle, where energy is shared between EVs [2].

98% of V2G projects focused on technical factors, only 27% considered social factors, leaving a significant gap in understanding consumer behavior.

This article aims to enhance the limited understanding of consumer preferences for V2G contracts with a discrete choice experiment (DCE) in the context of Germany. Within the DCE, we focus on the effects of flexible contract design, a remuneration scheme that combines fixed and variable payments, and environmental nudging on the willingness to participate in V2G. Furthermore, we differentiate consumer preferences by income. The results will inform economic modeling and practical applications, namely the effective design of contracts between EV owners and aggregators.

Our research contributes to two strands of the existing V2G literature: contract design and consumer acceptance. Within the first strand, some studies apply contract and game theory to determine the optimal design of contracts between aggregators and EV owners in V2G systems. For example, Gao et al. [19] demonstrate that aggregators can determine an optimal unit price for EV charging to maximize profits under asymmetric information. Similarly, Jember et al. [20] implement a non-cooperative Stackelberg game to identify an optimal pricing and discharging strategy, and Zhang et al. [21] model a system in which EVs can submit bids for charging and discharging to a profit-maximizing broker. Other studies derive contract designs from real-world applications. For instance, Guille and Gross [22] propose a framework in which aggregators manage EV batteries as controllable loads, offering charging discounts in exchange for scheduled grid connections. Jiao et al. [23] focus on revenue-sharing contracts between the aggregator, EV owner, and grid, aiming to maximize collective profit.

The second strand of literature evaluates consumer preferences in V2G contexts. A pioneering study by Parsons et al. [24] investigated different V2G remuneration models in combination with guaranteed minimum driving ranges and plug-in durations, finding that remuneration was the most influential attribute, with flexible performance-based payments or upfront discounts emerging as the most effective strategies to encourage participation. By contrast, more recent studies [25, 26, 27] find that concerns about vehicle availability and battery degradation often outweigh financial incentives when deciding on V2G participation. Huang et al. [27] identify fast-charging options as an effective countermeasure to availability concerns and show that V2G contracts with a pre-defined green electricity mix benefited from increased consumer acceptance.

We aim to make four significant contributions to this existing literature. First, we introduce an innovative remuneration structure, which combines a fixed per-day with a variable per-kWh component, and analyze the acceptance of these components depending on the participants' income. This approach may address battery degradation concerns as additional revenue is generated whenever the battery is used. Second, we propose V2G contracts that can be adjusted daily and compare their acceptance to monthly adjustable agreements. We argue that such contract flexibility could address availability concerns while providing certainty for aggregators relative to fast-charging options. Third, we update the findings of previous studies. In particular, we find that minimum battery levels may not be as important as previously thought, which we explain by technological progress in EV battery technology. Finally, we assess the influence of environmental nudging with an A/B test. Such nudging could leverage consumers' growing concern for sustainability to benefit V2G, similar to the positive effects found for other types of pro-environmental behavior [28, 29, e.g.].

This paper is structured as follows: Section 2 outlines the design and implementation of the DCE. Section 3 details the approach to estimating the willingness to participate in V2G contracts. Section 4 presents the findings, including statistical analysis and economic implications. Section 5 contextualizes the results within the existing literature. Section 6 summarizes the results, derives recommendations, and discusses further research.

2. Conceptualization of the DCE

This section outlines the design and implementation of the DCE. It starts with Subsection 2.1 defining the V2G contract attributes investigated in the DCE and continues with Subsection 2.2 describing the design and implementation of the DCE, including the nudging techniques used.

2.1. Definition of V2G contract attributes

Identifying the relevant attributes and their levels is crucial for designing an effective DCE. The challenge is representing all essential aspects of the decision while keeping the number of attributes and levels manageable to avoid overburdening participants. The following discusses how we derived our selection of attributes and levels based on recent literature. Additionally, we took practical considerations into account to ensure that the chosen levels are relevant in real-world conditions. Table 1 provides an overview of our selected attributes and levels.

Table 1: Summary of contract attributes and their levels

Attribute	**Levels**
Fixed remuneration	0 cents/day, 25 cents/day, 50 cents/day
Variable remuneration	5 cents/kWh, 10 cents/kWh, 15 cents/kWh
Contract flexibility	Daily, Monthly
Minimum plug-in duration	5 hours, 10 hours, 15 hours
Minimum battery level	35%, 50%, 70%

Remuneration: Remuneration is critical in determining whether EV owners will engage in V2G. In this study, two types of remuneration are included: a fixed payment, which rewards participants for making their vehicle available to the grid at rates of 0, 25, and 50 cents per day, and a variable payment, which rewards participants at rates of 5, 10, and 15 cents per kWh discharged to the grid. The fixed payment structure is based on capacity market models and is supported by previous literature on fixed monthly remuneration in similar markets [25]. The levels of the variable payments are derived from market benchmarks in peak shaving, similar to payments for photovoltaic operators [30, 31]. Higher remuneration in both schemes is expected to increase the willingness to participate.

Contract flexibility: Contract flexibility determines how easily EV owners can adapt their V2G contract to changing circumstances. We test two levels of contract flexibility: daily flexibility, meaning that the minimum plug-in duration and the minimum battery level can be adjusted daily or that the contract can be canceled or paused after any day, and monthly flexibility, meaning that these attributes are fixed for an entire month. This is much less than previous studies proposing contract durations of 6 to 48 months [26, 27]. We argue that such long durations may be impractical for many consumers and expect more flexible contracts (i.e., daily adjustability) to increase participation.

Minimum plug-in duration: The minimum plug-in duration, i.e., the minimum time an EV is connected to the grid, directly affects the ability of V2G systems to manage energy supply. Literature suggests that cars are parked for extended periods [32], which could make it feasible to require a minimum connection time. In this experiment, three levels of such a minimum plug-in duration are tested: 5, 10, and 15 hours per day. While longer durations increase the utility for aggregators, they are expected to reduce EV owners' willingness to participate in V2G due to the inconvenience of reduced vehicle availability.

Minimum battery level: The minimum battery level ensures EV owners retain sufficient charge for emergencies. For this study, three levels are chosen: 35%, 50%, and 70%. These levels account for emergencies on the one hand and aim to balance battery preservation with V2G participation on the other hand. Studies by the German Automobile Association suggest that a 25-kilometer round trip is sufficient to reach essential services like pharmacies [33]. This translates into a minimum battery level of approximately 12.5% in an EV with a 60 kWh capacity, based on an average consumption of 15 kWh per 100 km [34]. Moreover, battery health guidelines recommend maintaining a charge between 20% and 80% [35], which we assume should not be violated even after an emergency drive. Hence, we set the lowest minimum battery level to 35% (12.5% + 20% + 2.5% additional buffer). It is hypothesized that higher battery levels will increase the willingness to participate in V2G, allowing greater flexibility for vehicle use.

2.2. Design and implementation of the DCE

This subsection details the design and implementation of the DCE. It describes the way choice sets were determined, the environmental nudges incorporated to influence participant decision-making, and additional details regarding the implementation of the experiment.

2.2.1. Composition of choice sets

The design of the DCE requires balancing the statistical needs for reliable data analysis with the participant's cognitive load. Presenting too many choice sets can lead to respondent fatigue, while too few sets might fail to capture significant patterns. Presenting all possible combinations of attributes, i.e., a full factorial design, is deemed impractical due to the large number of attributes and levels, which would overwhelm participants [36]. Instead, a D-efficient design was chosen, which maximizes the statistical information from the choice sets [36, 37]. This method ensures a balance between comprehensiveness and respondent burden.

The software Ngene was used to generate the choice sets. Each choice set offers two V2G contract options and a no-choice option if participants do not wish to participate in either option. The design and the attributes with its levels are presented in Appendix A. The composition of the choice sets is based on utility functions, which were informed by general trends in the literature. Additionally, Ngene improves efficiency by using already known parameter values as starting values for the utility functions. These parameters could be derived from previous studies or pilot surveys [37]. For this study, we only integrated the basic tendency (whether participants value the change of an attribute as positive or negative). Otherwise, the differentiation between two different survey versions would lead to two different designs and could, therefore, lead to biased results. Several utility functions were tested, indicating that 15 choice sets allow for high statistical efficiency without overloading participants [38].

2.2.2. Environmental nudging

To examine the effect of environmental nudging, the survey was divided into two versions: A reference survey (ECON) and a survey containing the nudging measures (ENV). A single link was created to randomly redirect participants to the ECON and ENV survey with equal probability.

Both surveys comprised the same choice sets, but in the ENV survey, all V2G contract options were visually highlighted in green to frame them as environmentally positive. Examples for the choice sets in the ECON and the ENV surveys are presented in Appendix B. Furthermore, the participants were shown an introductory video explaining the concept of V2G, which differed by survey type. The video in the ECON survey focused on economic benefits, while the video in the ENV survey emphasized environmental advantages. Both videos have been created with ProCreate and Mango Whiteboard Animator and were roughly two minutes long.[2] For participants who could not listen to the video, the content was provided in written form. The hypothesis is that this pro-environmental nudging increases participants' willingness to engage in V2G programs, although we cannot distinguish the individual effects of the video or color.[3]

2.2.3. Further implementation details

Following the video and before answering the choice sets, participants were asked to assume they owned an EV with a 60 kWh battery, had access to a home charging station, and made decisions based on a typical workday. In addition to exploring V2G preferences through choice sets, the survey collected socio-demographic data and insights into participants' attitudes toward technology, EV ownership, and sustainability (see Appendix C).

The survey's target group includes all German individuals over 18 with a driver's license. The choice of distribution channels was optimized to primarily reach EV owners, EV drivers, and people interested in EVs. This choice was motivated by the assumption that these respondents can empathize with the choice situation in the V2G context. The survey was advertised in several EV internet forums and distributed via survey exchange groups and platforms, mailing lists, and personal networks. Furthermore, personal acquaintances were asked to participate and forward the survey to potentially interested individuals.

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[2] Link to the video with the economic focus: https://www.youtube.com/watch?v=PxwmE8lCvjU; Link to the video with the environmental focus: https://www.youtube.com/watch?v=sPSHiiHxrho

[3] In this study we use the term nudging to refer to our implemented non-coercive approaches to influence human behavior, as used in [29]. Alternatively, our implemented measures may also be referred to as framing.

3. Approach to estimate the willingness to participate

This section describes the two models used to derive preferences from stated choices and the underlying utility function.

3.1. Deriving preferences from stated choices

This study estimates preferences for different V2G contracts using choice models grounded in McFadden's Random Utility Theory [39]. This theory provides a robust theoretical framework for analyzing individual decision-making by assuming that individuals choose the option that maximizes their utility. The utility of a product or service is determined by its attributes, and the probability of selecting a specific option depends on its utility relative to other alternatives in the choice set.

We chose the Multinomial Logit (MNL) model and the Mixed Logit (MXL) model to estimate choice probabilities because of their complementary strengths in capturing consumer preferences and addressing the complexities of choice data. The MNL model, detailed in [40], is widely used for its simplicity, computational efficiency, and ease of interpretation. However, it assumes independence of irrelevant alternatives and identical preferences across individuals, which can limit its applicability. The MXL model, described extensively in [41, 40], addresses these limitations. It incorporates random taste variations and allows for correlation in the error term, enabling the capture of heterogeneity in individual preferences. By modeling parameters as random coefficients that follow a specified distribution, the MXL model provides a more flexible and realistic representation of decision-making behavior. MXL models are, however, significantly more complex. More precisely, overfitting and insufficient sample sizes can lead to unreliable results, and convergence issues may arise during estimation. To address these issues, we use the results of the MNL model as a benchmark to validate the robustness of the MXL model and as starting values for the MXL estimation process. Louviere [42] provides detailed derivations, assumptions, and examples that underpin the methodologies applied in this study.

In sum, using both MNL and MXL models allows for a comparative analysis that enhances the robustness and reliability of the results. While the MNL model provides a baseline for understanding general trends, the MXL model offers deeper insights into preference heterogeneity. This combination balances simplicity and the need to account for more complex decision-making patterns.

3.2. Definition of the utility function

The DCE was evaluated using the Biogeme software package in Python. Biogeme implements various analyses on DCEs, particularly using MNL and MXL models as considered in this study [43, 44]. More precisely, we employed the Newton algorithm with a trust region for simple bound constraints to estimate the MXL model [45].

To determine the impact of nudging, the data from both studies is merged, and a dummy variable is introduced. This variable is set to one if the participant completed the ENV survey. Otherwise, it was set to zero.

Subsequently, it was determined which socio-demographic factors to include in the model. To address potential collinearities, a variance inflation factor (VIF) test was conducted, where elevated VIF values indicate dependencies between variables. However, the VIF values for the variables in this study are significantly smaller than the commonly accepted threshold of ten [46]. Thus, sufficient independence between the parameters is assumed, allowing all characteristics to be retained in the analysis.

The response options were grouped into broader categories in some cases to enable statistical analysis, as otherwise there would be too few participants corresponding to each category. The relevant groupings are summarized in Appendix D.

As criteria for the evaluation of the goodness of fit of a model, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) [47] are used. Furthermore, for the MNL model, we evaluate the McFadden's R^2, which ranges from zero to one. A higher value indicates greater predictive power of the model, while typically, a McFadden's R^2 value between 0.2 and 0.4 is considered indicative of a good fit [39]. Comparing the AIC, BIC, and R^2 metrics, it is found that almost all parameters are best represented when using dummy variables, except the parameter for fixed remuneration, which can be effectively incorporated as a continuous linear term. The other parameters do not develop linearly, and, given only three data points, performing a meaningful function approximation is not feasible [48]. Possible explanations for this non-linearity are explored in Section 4. The reference categories are detailed in Table 2. For the contract attributes, the most attractive levels were selected as references.

Table 2: Reference levels

Category	**Reference level**
Variable remuneration	15 cents/kWh
Contract flexibility	Daily
Minimum plug-in duration	5 hours
Minimum battery level	70%
Age	55 years or older
Gender	Male
Level of education	School degree
Housing situation	Rent
Income	€3,000 or above
Comparing electricity tariffs	Compare
Technical interest	Not interested
Concerned about climate change	Not concerned
Car relationship	No corresponding relationship
Car usage	Frequently
Distance travelled	No distance
EV ownership	Interested
V2G familiarity	Not familiar
V2G concerns	No corresponding concern
Environmental nudging	No (ECON-survey and/or did not watch the video)
Attribute description	Read

In addition to the main effects, we tested for significant interaction effects. Only the interaction between remuneration schemes and income turned out to be significant and was, therefore, kept in the utility function. The final utility function with an alternative-specific constant (ASC) is presented in equation (1) for the example of one V2G contract option and the MNL model. The contract attributes from the choice sets and the interaction effects are framed in red and blue, respectively. The utility function for the MXL model excludes the interaction effect due to convergence issues, a frequent limitation of MXL models. The utility functions of all models and alternatives, including the option opt-out, can be found in Appendix E.

$$
\begin{aligned}
V1 = ASC_{V1} \\
&+\beta_{\text{FixRem}} \cdot \text{FixRem} \\
&+\beta_{\text{VarRem5c}} \cdot \text{VarRem}_{5c} + \beta_{\text{VarRem10c}} \cdot \text{VarRem}_{10c} \\
&+\beta_{\text{ChangeContractMonthly}} \cdot \text{ChangeContractMonthly} \\
&+\beta_{\text{MinPlugIn10h}} \cdot \text{MinPlugIn}_{10h} + \beta_{\text{MinPlugIn15h}} \cdot \text{MinPlugIn}_{15h} \\
&+\beta_{\text{MinBattery35p}} \cdot \text{MinBatteryLevel}_{35p} + \beta_{\text{MinBattery50p}} \cdot \text{MinBatteryLevel}_{50p} \\
&+ \beta_{\text{Age18-34}} \cdot \text{Age}_{18-34} + \beta_{\text{Age35-54}} \cdot \text{Age}_{35-54} \\
&+ \beta_{\text{Female}} \cdot \text{Female} + \beta_{\text{Diverse}} \cdot \text{Diverse} \\
&+ \beta_{\text{HigherDegree}} \cdot \text{HigherDegree} + \beta_{\text{HighestDegree}} \cdot \text{HighestDegree} \\
&+ \beta_{\text{HomeOwner}} \cdot \text{HomeOwner} \\
&+ \beta_{\text{IncomeBelow3,000}} \cdot \text{IncomeBelow3,000} + \beta_{\text{NoIncomeGroup}} \cdot \text{NoIncomeGroup} \\
&+ \beta_{\text{TariffCompareNotAtAll}} \cdot \text{TariffCompareNotAtAll} \\
&+ \beta_{\text{TechModeratelyInterested}} \cdot \text{TechModeratelyInterested} + \beta_{\text{TechVeryInterested}} \cdot \text{TechVeryInterested} \\
&+ \beta_{\text{ClimateModeratelyConcerned}} \cdot \text{ClimateModeratelyConcerned} + \beta_{\text{ClimateVeryConcerned}} \cdot \text{ClimateVeryConcerned} \\
&+ \beta_{\text{CarEmotional}} \cdot \text{CarEmotional} + \beta_{\text{CarNeutral}} \cdot \text{CarNeutral} + \beta_{\text{CarFunctional}} \cdot \text{CarFunctional} + \beta_{\text{CarRejecting}} \cdot \text{CarRejecting} \\
&+ \beta_{\text{InfrequentDrivers}} \cdot \text{InfrequentDrivers} + \beta_{\text{DoNotDrive}} \cdot \text{DoNotDrive} \\
&+ \beta_{\text{ShortDistances}} \cdot \text{ShortDistances} + \beta_{\text{LongDistances}} \cdot \text{LongDistances} \\
&+ \beta_{\text{EVOwner}} \cdot \text{EVOwner} + \beta_{\text{EVNotInterested}} \cdot \text{EVNotInterested} \\
&+ \beta_{\text{FamiliarWithV2G}} \cdot \text{FamiliarWithV2G} + \beta_{\text{VeryFamiliarWithV2G}} \cdot \text{VeryFamiliarWithV2G} \\
&+ \beta_{\text{BatteryDegradation}} \cdot \text{BatteryDegradation} + \beta_{\text{Complexity}} \cdot \text{Complexity} \\
&+ \beta_{\text{Duty}} \cdot \text{Duty} + \beta_{\text{RangeAnxiety}} \cdot \text{RangeAnxiety} \\
&+ \beta_{\text{NudgeEnv}} \cdot \text{NudgeEnv} \\
&+ \beta_{\text{SkimmedAttributes}} \cdot \text{SkimmedAttributes} \\
&+\beta_{\text{IncomeVarRem5ct/kWh}} \cdot \text{VarRem}_{5ct/kWh} \cdot \text{IncomeBelow3,000} \\
&+\beta_{\text{IncomeFixRem}} \cdot \text{FixRem} \cdot \text{IncomeBelow3,000}
\end{aligned} \tag{1}
$$

4. Results

This section presents the DCE's findings on the effects of selected contract attributes on the willingness to participate in V2G technology. First, a descriptive analysis is provided, followed by an assessment of the influence of contract attributes and nudging on participation probabilities using the MNL and MXL models. Finally, the willingness-to-accept (WTA) for various attributes is calculated to explore their economic implications.

4.1. Descriptive statistics

A total of 229 individuals participated in the survey. The dataset was cleaned following established procedures from Conrad et al. [49] and Leiner [50], excluding participants who completed the survey in less than 150 seconds. Furthermore, respondents who consistently selected "No participation in V2G" across all choice sets were excluded, as their responses offered no insights into the influence of contract attributes or nudging effects. After this filtering, 204 valid responses remained, comprising 100 participants who completed the ECON survey and 104 who completed the ENV survey.

Table 3 summarizes the socio-demographic characteristics of the participants that completed the ECON and ENV surveys, respectively. The final column includes average demographic data for Germany (2021–2022) to offer a benchmark for evaluating sample representativeness. Given the limited sample size for certain queries, some variables were grouped into broader categories to facilitate the analysis. The ungrouped socio-demographic statistics are detailed in Table D.1 in Appendix D.

Table 3: Socio-demographic characteristics of the sample and comparison with the German population

Category	**Specification**	**ECON %** (N=100)	**ENV %** (N=104)	**Germany %**
Age	18 to 34 years	41.00	45.19	24.72 [51]
	35 to 54 years	30.00	30.77	21.49 [51]
	55 years or older	29.00	24.04	53.79 [51]
Gender	Female	38.00	34.62	48.65 [51]
	Male	59.00	62.50	51.35 [51]
	Diverse	2.00	2.88	-
	No response	1.00	-	-
Level of education	School degree	5.00	4.81	18.3 [52]
	Higher degree [1]	80.00	81.73	70.2 [52]
	Highest degree[2]	13.00	11.54	11.1 [52]
	No response	2.00	1.92	-
Housing situation	Rent	51.00	47.12	58.2 [53]
	Ownership	47.00	50.96	41.8 [53]
	No response	2.00	1.92	-
Income	Below €3,000 net	51.00	50.96	70.02 [54]
	€3,000 net or above	42.00	37.50	15.37 [54]
	No response	7.00	11.54	0.21[3] [54]

[1] Includes bachelor's and master's degrees and vocational training.
[2] Includes doctoral degrees.
[3] Individuals without any salary were not considered.

Overall, socio-demographic distributions between the ECON and ENV groups are similar, with differences typically below 4%-points. However, certain deviations from national averages are notable. The sample is younger than the general population, which likely correlates with tech-savyness. Male participants were overrepresented compared to the general population, a trend often observed for surveys related to energy and EVs [55] [56]. While participants with higher degrees align closely with national averages, those with only school-level qualifications are underrepresented. The average proportion of renters in Germany is substantially higher. Related to this, the share of participants reporting monthly net incomes exceeding €3,000 is markedly above the national average. This is not surprising, as other studies report that current EV drivers have relatively high incomes [56]. While not fully representative of the general population, we argue that the sample offers valuable insights into a key target group for V2G contracts: individuals with driver's licenses and interest in V2G technologies.

Figure 1 illustrates participant responses to additional questions regarding EV ownership, car relationship, EV and technical interests, familiarity with V2G, concerns about V2G and climate change, car usage, and habits to compare electricity tariffs. Detailed numbers are presented in Table D.2 in Appendix D.

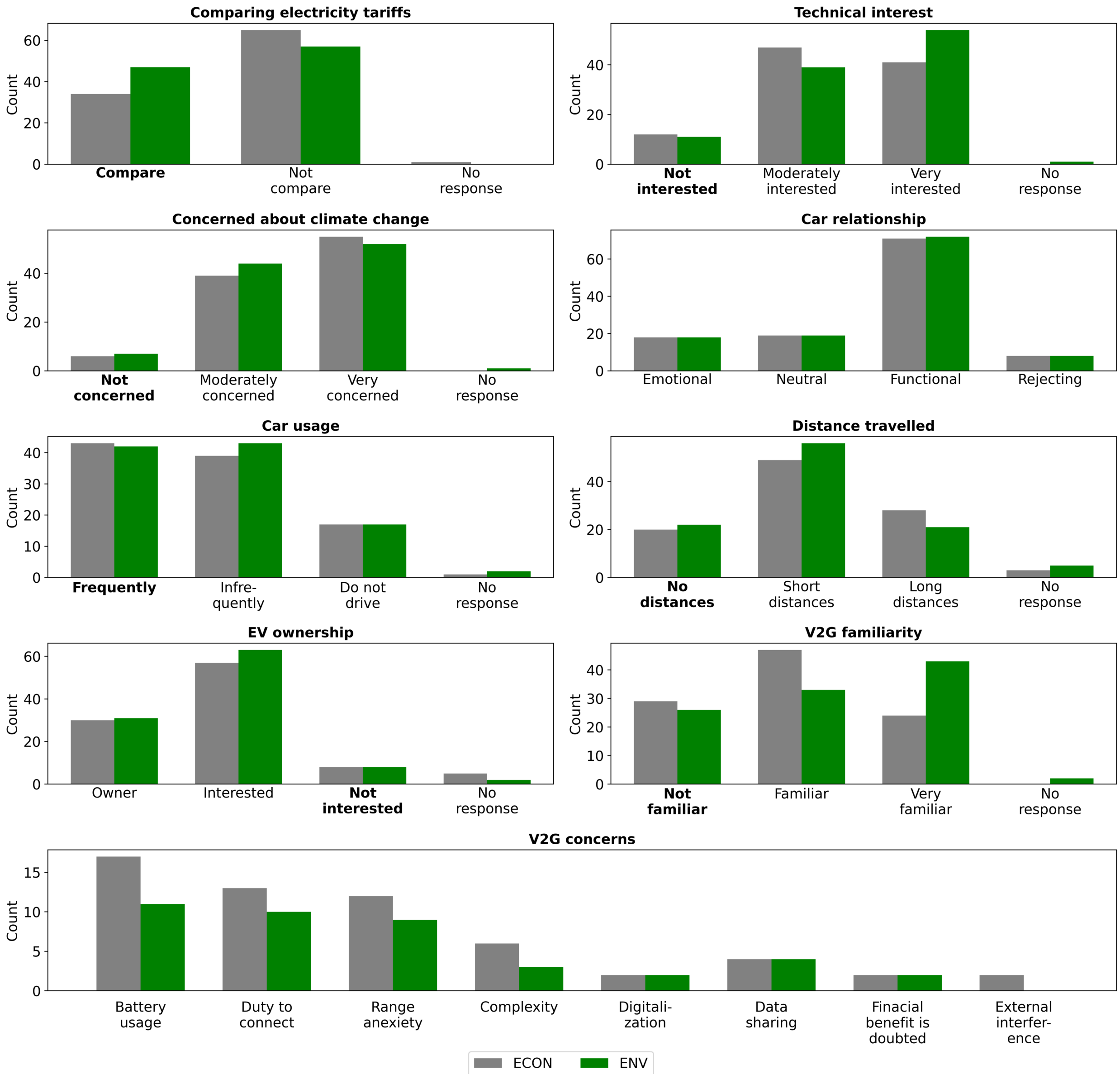

Figure 1: Participant responses to additional questions

Note: The reference levels are marked in bold letters.

Notably, the groups responding to the ECON and ENV surveys are similar across most characteristics, indicating a successfully randomized distribution. Nevertheless, participants in the ENV survey are relatively more familiar with V2G, have a higher technical interest, and more frequently check their electricity tariffs. These factors should be kept in mind when evaluating the effect of nudging. For the other factors, most participants stated having a functional relationship with their car and being interested in EVs, while only relatively few own one. They are most often very or moderately concerned about climate change. V2G concerns are relatively rare among participants, with battery degradation being the most common. Participants typically travel short distances and are evenly distributed between frequent and infrequent drivers.

4.2. Determinants of the willingness to participate in V2G systems

This section examines the influence of contract attributes, participant characteristics, and environmental nudging on willingness to participate in V2G systems. The results of the MNL and MXL models are summarized in Table 4. It includes the estimated coefficients of the utility function (denoted by β), robust standard errors (denoted by SE), and robust significant levels (denoted by Sig.) for all contract attributes and those participant characteristics that yielded significance levels below 0.05. Sensitivity analyses were conducted to assess the robustness of the results across various model configurations for both MNL and MXL models. The analyses included varying the order and combinations of attributes, testing different functional forms (e.g., linear, quadratic), using different starting values for the MXL model, exploring various distributional assumptions, and incorporating interaction variables. These analyses confirmed the consistency of model outcomes, demonstrating the models' stability across different specifications and robustness to assumptions changes. Additional results are included in Appendix F.

Table 4: Results of the estimation

Category	Reference	Variable	MNL Model			MXL Model		
			β	SE	Sig.	β	SE	Sig.
Fixed remuneration	-	Linear 0-50 cents/day	0.017	0.002	***	0.033	0.003	***
Variable remuneration	15 cents/kWh	10 cents/kWh	-0.078	0.089		-0.159	0.156	
		5 cents/kWh	-0.765	0.084	***	-0.780	0.202	***
Contract flexibility	Daily	Monthly	-0.374	0.050	***	-0.962	0.156	***
Minimum plug-in duration	5 hours	10 hours	-0.212	0.058	***	-0.125	0.143	*
		15 hours	-0.889	0.063	***	-2.001	0.274	***
Minimum battery level	70%	50%	-0.232	0.060	***	0.048	0.159	
		35%	-0.204	0.063	**	-0.586	0.174	***
Income	€3,000 or above	Below €3,000	0.519	0.191	**	0.528	0.166	**
		No income group	-0.435	0.205	*	-0.376	0.214	
Comparing electricity tariffs	Compare	Not compare	0.390	0.132	**	0.425	0.143	**
Car relationship	No	Neutral	0.777	0.216	***	0.944	0.244	***
		Rejecting	1.232	0.413	**	1.856	0.382	***
EV ownership	Interested	Owner	-0.700	0.154	***	-0.782	0.172	***
		Not interested in EV	-1.535	0.221	***	-1.724	0.248	***
V2G familiarity	Not familiar	Very familiar	0.470	0.203	*	0.473	0.211	*
V2G concerns	No	Battery degradation	-0.491	0.197	*	-0.426	0.224	*
		Complexity	-0.690	0.273	*	-1.096	0.346	*
		Range anxiety	-0.685	0.285	*	-0.853	0.328	**
Environmental nudging[1]	No	Yes	0.473	0.145	**	0.465	0.161	**
Interaction effects								
Income < €3,000		5 cents/kWh	0.374	0.116	**			
Income < €3,000		Fixed remuneration	0.005	0.002	*			
Model fit			**Value**			**Value**		
R^2			0.256					
AIC			5092			5009		
BIC			5369			5305		

Significance levels: *** p<0.001, ** p<0.01, * p<0.05.
[1] For calculating this coefficient, all the participants who reported not watching the video or reading the text, or spent less than 30 seconds on the corresponding page, were excluded.

Remuneration structure: Our analysis of the novel combination of fixed and variable remuneration reveals that both components significantly influence the willingness to participate. As expected, increasing fixed remuneration positively influences the willingness to participate, as reflected in both the MNL and MXL models. Similarly, decreasing variable remuneration negatively impacts the likelihood of V2G participation in both models. However, the estimated effect of reducing the variable remuneration from 15 to 10 cents per kWh is non-significant and disproportionately smaller than that of reducing the variable remuneration to 5 cents per kWh. This pattern suggests diminishing marginal utility, where increases in remuneration become less effective beyond a certain threshold. A range between 5 and 10 cents per kWh appears critical to making participation attractive. While the MNL model estimates similar effect sizes for changing fixed and variable remuneration from the best to the worst tested attribute level ($50 * 0.017 = 0.85 \simeq 0.765$), the MXL model attributes more weight to changing the fixed remuneration ($50 * 0.033 = 1.65 > 0.780$).

Nevertheless, both models emphasize the importance of both fixed and variable incentives in encouraging V2G engagement.

Contract flexibility: Reducing contract flexibility from daily to monthly adjustability negatively significantly decreases willingness to participate in both models. This confirms our hypothesis on participants' aversion to long-term commitments. While the MNL model suggests that the effect size of changing the contract flexibility from daily to monthly is somewhat smaller than that of the maximum considered change in fixed and variable remuneration, the MXL model ranks the effect size of the considered change in contract flexibility between those of fixed and variable remuneration. While this finding is consistent with previous studies finding preferences for shorter contract durations (e.g., one month contract duration is preferred over 48 months), it reveals the additional preference for greater flexibility even within shorter contract durations. Furthermore, one hypothesis was that contract flexibility might also increase the willingness for longer connection times or lower battery levels, as these constraints could then be adjusted on a short-term basis. However, no interaction effects were observed.

Minimum plug-in duration: As expected, longer minimum plug-in durations significantly reduce the willingness to participate in V2G programs. The results for a 10-hour duration are consistent across models, with relatively small coefficients of -0.212 (MNL) and -0.125 (MXL). These values are modest compared to those associated with other contract attributes, indicating a less pronounced influence on participants' willingness to participate. In contrast, the 15-hour duration exhibits notably larger negative coefficients, especially in the MXL model. This difference likely reflects the MXL model's capacity to account for random taste variation, capturing participants' stronger aversion to longer plug-in durations. The non-linear relationship suggests a steep increase in negative preferences between 10 and 15 hours, pointing to a potential threshold many participants find difficult to accept.

Minimum battery level: Reducing the minimum battery level yields mixed results. On the one hand, the MNL model suggests that reducing the minimum battery level from 70% to 50% or 35% has significant similarly large negative effects on V2G participation. On the other hand, the MXL model shows no significant coefficient for the 50% level, highlighting considerable heterogeneity in participant preferences. While some participants may strongly dislike a 50% minimum, others may find it acceptable. The negative effect of the 35% level is more pronounced in the MXL model, suggesting that individuals with strong preferences impose a substantial penalty on lower battery levels—a nuance that the MNL model smooths out under its homogeneity assumption. Still, the coefficients of minimum battery levels remain relatively small compared to those of other contract attributes.

Electricity tariffs: Participants who do not actively compare electricity tariffs demonstrate a significantly higher likelihood of participating in V2G programs in both models. This result may appear counterintuitive, as one could expect participants who make an effort to compare electricity tariffs to save money on electricity bills would also be more inclined to make an effort to participate in V2G to benefit financially. Further research may be needed to resolve this apparent contradiction.

Car relationship: A neutral relationship with cars is associated with a significantly higher likelihood of participation in both models. Surprisingly, a rejecting relationship with cars also positively influences participation. This could stem from environmental concerns, where the benefits of V2G make car usage more acceptable, or from infrequent car usage, where V2G provides an opportunity to utilize parked vehicles.

EV ownership: EV ownership significantly reduces the likelihood of participation in V2G programs compared to individuals who do not own an EV but express a general interest in them. This result holds across both models. We can think of two potential reasons for this result. First, EV owners may be reluctant to replace their current charging technology, which likely does not support V2G. Second, EV owners may weigh more on V2G concerns when deciding on V2G participation. Those uninterested in EVs are also less likely to engage in V2G, likely because they perceive a lack of relevance in the absence of EV ownership.

V2G familiarity: High familiarity with V2G significantly increases participants' willingness to engage, as shown in both models. This finding aligns with research by Kester et al. [57], which suggests that knowledge about V2G systems enhances their acceptance.

V2G concerns: Concerns about battery degradation, process complexity, and range anxiety each negatively and significantly affect willingness to participate. Addressing these concerns through targeted information and marketing strategies could play a critical role in increasing acceptance and participation.

Nudging effect: Environmental nudging demonstrates a significant and positive effect on the willingness to participate in both models. Participants exposed to the ENV survey, which emphasized environmental benefits in the introductory video and through green highlighting, are more inclined to engage in V2G than those exposed to the ECON survey. The size of the nudging effect is within the range of previously discussed contract attributes, which underlines its relevance. Some participants reported not watching their assigned video or spent insufficient time on the introduction page. Still, we cannot distinguish the effect of the video from that of the green highlighting due to the small sample size. For our main results, participants who reported not watching their assigned video or spent insufficient time on the introductory page were excluded, but a sensitivity run without this exclusion yielded similar results. Notably, this nudging effect is significant after controlling for participant characteristics like V2G familiarity and technical interest. Hence, we eliminate the risk that our finding on nudging is biased by these characteristics not being perfectly balanced between the ENV and ECON respondents. Furthermore, interaction terms between these characteristics were non-significant, suggesting that the effect of nudging does not depend on prior traits.

Interaction effects: The interaction effect between a lower income and a variable remuneration of 5 cents per kWh is significant and positive. This indicates that lower-income participants are more sensitive to this remuneration scheme than higher-income participants, with a stronger preference for even small compensation amounts. In contrast, the difference in participation between 10 and 15 cents per kWh for lower-income participants is non-significant, suggesting that once a higher remuneration is offered, lower-income individuals may become more indifferent to further increases in variable remuneration.

Similarly, the interaction effect between lower income and fixed remuneration is also significant and positive, indicating a higher value placed on fixed payments by lower-income participants. This may be because fixed remuneration provides certainty, unlike variable payments that depend on usage. This assumption is supported by Holt and Laury [58], who found that income is negatively correlated with risk aversion, meaning lower-income individuals may be more risk-averse and place less importance on uncertain remuneration per kWh. Furthermore, for higher-income groups, the value of earnings from V2G participation is relatively small compared to their total income, potentially leading them to pay less attention to them.

Non-significant parameters: We do not find significant effects of age, gender, education, concerns about climate change, a functional or emotional relationship with cars, and driving behavior on the willingness to participate in V2G. Additionally, the sample sizes for participants expressing concerns about digitization, data sharing, financial benefit doubts, or external interference were too small for statistical evaluation.

4.3. Willingness to accept changes in contract attributes

This section translates the previous estimates into the WTA for a deterioration in the different V2G contract attributes. Given the previously found significant interaction terms between income and remuneration, we calculate distinct WTAs for participants earning below and above €3,000 per month net. Participants who did not disclose income information were excluded due to the small sample size of this subgroup.

To this end, the parameters were re-estimated for the different income groups using the MNL model exclusively. The decision to omit the MXL model is justified by the similarity in parameter estimates between the MNL and MXL models, suggesting that the MXL model's additional complexity is unnecessary for the WTA analysis. Furthermore, we excluded the 15-hour minimum plug-in duration from the WTA analysis due to the previously found strong negative effect suggesting the impracticality of such long plug-in durations. The results are summarized in Appendix G.

The WTA for each significant contract attribute was calculated as the negative ratio of the attribute's coefficient to the fixed remuneration coefficient, representing the marginal rate of substitution:

$$WTA = -\frac{\beta_a}{\beta_{FixRem}}, \tag{2}$$

where β_a denotes the coefficient of the attribute of interest and β_{FixRem} represents the coefficient of fixed remuneration. This quotient indicates the additional income required to compensate for the negative effects of an attribute's deterioration.

The results are summarized in Table 5 and reveal that participants in the lower-income group consistently exhibit lower WTA values than their higher-income counterparts. This suggests that lower-income individuals attribute greater importance to fixed income and are willing to accept reductions in variable remuneration and comfort for comparatively smaller increments in fixed remuneration.

Table 5: Willingness to accept relative to fixed remuneration

Attribute	**Attribute change**	**Income < €3,000** **Cents/day WTA**	**Income ≥ €3,000** **Cents/day WTA**
Variable remuneration	15 cents/kWh to 5 cents/kWh	17.26	51.08
Contract flexibility	Daily to monthly	15.54	26.95
Minimum plug-in duration	5 hours to 10 hours	8.74	/
Minimum battery level	70% to 35%	/	22.47
Minimum battery level	70% to 50%	9.45	17.31

Variable remuneration: Reducing variable remuneration from 15 to 5 cents per kWh would require an increase in fixed remuneration of 17.26 cents per day for the lower-income group and 51.08 cents per day for the higher-income group to accept the change. This demonstrates that the higher-income group is significantly more sensitive to changes in variable remuneration. This finding aligns with previous research suggesting that income negatively correlates with risk aversion [58, e.g.]. In other words, the lower the income, the higher the risk aversion and the higher the value from additional income. In the context of this experiment, this means that individuals pay a higher importance to the fixed remuneration per day.

Contract flexibility: The lower-income group places a value of 15.54 cents per day on transitioning from daily to monthly contracts, whereas the higher-income group assigns a value of 26.95 cents per day to the same change. This results indicates that both groups value contract flexibility. Furthermore, it questions the future relevance of monthly fixed contracts, as the benefits of longer fixed terms may not sufficiently offset the required increase in financial incentives.

Minimum plug-in duration: The lower-income group requires an additional 8.73 cents per day to accept an increase in the plug-in duration from 5 to 10 hours. This change has no significant impact on the higher-income group. Conversely, for the higher-income group, the lack of significant effect may stem from the fact that people with a higher income use EVs more often as a second vehicle [59]. Thus, the minimal plug-in duration might be less important for them.
Minimum battery level: For the higher-income group, reducing the minimum battery level from 70% to 35% is valued at 22.47 cents per day, while a reduction from 70% to 50% is worth 17.31 cents per day. In contrast, the same reduction from 70% to 50% is only valued at 9.45 cents per day by the lower-income group. The reduction from 70% to 35% is only significant in the high-income group. This might be due to the fact that people with a higher income tend to drive more kilometers on average [60], hence this group exhibits greater sensitivity to reductions in the minimum battery level.

The WTA analysis reveals distinct differences in how income groups value the selected contract attributes. Participants with a net income below €3,000 per month prioritize fixed remuneration and can be more easily incentivized to alter their behavior through fixed payments. Conversely, participants earning €3,000 or more per month place greater importance on variable remuneration, contract flexibility, and minimum battery level. These findings underscore the existence of two distinct target groups, which can be addressed through tailored strategies to enhance grid utility effectively.

5. Discussion

This section contextualizes the findings of our study within the existing literature and discusses limitations. Four main distinctions are identified: we examine the combination of fixed and variable remuneration, introduce and test the concept of contract flexibility, update previous findings on further contract attributes like minimum battery levels, and investigate the effect of environmental nudging. Not least, we differentiate our findings by income groups.
While previous studies only considered fixed remuneration (see Appendix H), we find that both fixed and variable remuneration significantly affect the willingness to participate. The two remuneration components yield the highest WTA among our considered contract attributes and levels across income groups. However,

our results suggest that lower-income participants prefer fixed remuneration, and those with higher incomes favor variable remuneration.[4]

Without previous research on sub-monthly contract flexibility, we can use earlier studies that investigated contract durations between six and 48 months for comparison (see Appendix H). Our results suggest that increasing contract flexibility from monthly to daily significantly increases the willingness to participate in V2G systems. Contract flexibility even yields the third-highest WTA among our considered contract attributes—less than the remuneration components but more than the minimum plug-in duration and battery level. This finding differs from Kubli et al. [26], who find that contract duration is less important than minimum battery levels. The higher importance of contract flexibility might be explained by a decreasing marginal effect of commitment duration, be it short-term contract flexibility or more long-term contract duration. Supporting this notion, Huang et al. [27] show minimal differentiation in participant preferences between 6- and 24-month contracts.

Furthermore, we update previous findings on other contract attributes, namely minimum plug-in duration and battery level, and differentiate these findings by income. On the one hand, previous studies suggest greater importance of minimum plug-in durations and minimum battery levels than our results (see Appendix H). These differences could be attributed to technological progress and model mis-specifications. Technological progress has enabled rapidly increasing EV battery capacities over the last few years, which could explain the reducing relevance of minimum battery levels, particularly when compared to older studies [24, 25]. Moreover, the choice of minimum battery levels seems crucial, as the levels considered in some studies would not be sufficient for emergencies or could damage the battery, thereby fostering a strong negative effect on the entire attribute [25, 27]. Finally, the same studies did not dummy-code the plug-in durations [25, 27]. This can potentially distort the results by failing to capture preference thresholds, like the one we identified between 10 and 15 hours minimum plug-in duration.

The significant impact of environmental nudging, which operates independently of the contract attributes, represents a novel finding in the field of V2G. Still, our result aligns well with previous studies finding positive effects for other types of pro-environmental behavior. For instance, Wee et al. [29] analyzed 37 articles and found that nudging was effective in 64.86% of cases. Our research supports the hypothesis that environmental nudging is also effective for V2G and quantifies the effect relative to other contract attributes.

[4] Note that Huang et al. [27] also discuss a "variable" remuneration component, but this rewards participants for additional plug-in time as opposed to the V2G activation in our case.

When interpreting the results of our study, two main limitations should be kept in mind. First, the reliance on stated preference data introduces inherent limitations. Participants are not exposed to the real-world consequences of their choices, which may lead to underestimating the importance of certain attributes or overstating hypothetical preferences. Nevertheless, in the context of V2G, stated preferences offer a valuable preview of consumer preferences before the new technology is deployed at scale. Second, while the sample size of 204 participants is sufficiently large to derive statistically significant results, generalizability is naturally limited. From the demographic characteristics of our sample, we can conclude that our results are not representative of the German population. However, through dissemination channels like EV internet forums, we may have reached survey participants who are also more likely to use V2G systems, which could also increase the relevance of our results.

6. Conclusion

In the context of transport electrification, V2G technology can potentially support balancing the electricity systems. However, the successful implementation of V2G depends significantly on understanding the willingness of EV owners to participate and designing effective contracts to facilitate engagement. This study contributes to this understanding by investigating the willingness of current and potential future German EV drivers to participate in V2G through a DCE.

We identify the effects of specific contract attributes, participant characteristics, and environmental nudging on the willingness of EV owners to participate in V2G. Besides fixed remuneration, we find that the newly investigated contract attributes of variable remuneration and contract flexibility positively and significantly influence participation. Conversely, attributes such as a lower guaranteed battery level and high minimal plug-in duration negatively impacted willingness to participate, especially when thresholds were exceeded. In addition to contract attributes, our study highlights the great potential of environmental nudging in increasing participation rates. Interestingly, we find that those participants who currently own an EV are less likely to participate in V2G programs than individuals who report being interested in owning an EV in the future.

We also identified income-specific preferences. Participants with a net income below €3,000 per month prioritized fixed remuneration, the minimum plug-in duration significantly influenced participation, but the minimum battery level was insignificant. In contrast, participants with a net income of €3,000 or more placed greater importance on variable remuneration and considered minimum battery level more critical than plug-in duration.

Several practical recommendations can be drawn from our results. For businesses, our differentiated findings on V2G preferences underscore the value of customizing contract designs and marketing efforts to address the unique needs of various user segments, particularly those with different incomes. Furthermore, companies may consider a hybrid remuneration structure to address diverse preferences, offer flexible contract durations to accommodate consumer preferences for spontaneity, and leverage our positive results on nudging by emphasizing environmental benefits in their marketing efforts. To address challenges in meeting plug-in duration requirements, businesses may explore solutions that do not necessitate prolonged home parking. Additionally, setting default minimum battery levels at 35% may prevent participants indifferent to battery levels from opting for higher thresholds, thus optimizing the grid's usable capacity.
Policymakers may also play a role in improving V2G familiarity and raising awareness of V2G's environmental benefits. Information campaigns and public education could emphasize how V2G supports grid stability, integrates RES, and reduces environmental impact. Policymakers may also support research and pilot projects to collect further data on user preferences, refine contract designs, and eventually promote broader V2G participation.

Further research could build on and expand our research in several relevant areas. First, to improve the design efficiency of DCEs, future studies could incorporate the coefficients identified in this research as prior estimates. Adjustments, such as reducing the number of attributes, alternatives, or choice sets, could also enhance efficiency. For more granular insights, attribute levels could be tested with finer increments, and differences between weekday and weekend behaviors could be explored. Second, as pilot projects expand, future studies could employ revealed preference methods to validate and refine the findings from studies based on stated preferences like ours. Third, future research may conduct further segmented analyses, which could enable V2G offerings that are more precisely tailored to specific user groups. In particular, our findings encourage a more detailed analysis of the potential impact of variable remuneration adjustments on higher-income groups, as these changes could be highly influential.

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Abbreviations

Table 6: Table of abbreviations

AIC	Akaike information criterion	MNL	Multinomial Logit
ASC	Aternative-specific constant	MXL	Mixed Logic
BIC	Bayesian information criterion	RES	Renewable energy source
DCE	Discrete choice experiment	SE	Standard errors
ECON	Economical	V2G	Mobility cluster
ENV	Environmental	VIF	Variance inflation factor
EV	Electric vehicle	WTA	Willingness to accept

Appendices

A. Design of choice sets

In this section, table A.1 presents the design produced by Ngene. It contains 15 choice sets, as indicated by the row "choice set". The rows of alternative 1 describe the first contract offered, whereas the columns of alternative 2 describe the second contract offered. They are divided in the different contract attributes. The numbers from 0 to 2 indicate the corresponding attribute level as defined in table A.2.

Table A.1: Design of choice sets

Choice Set	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
A1: Fixed remuneration	2	0	0	2	2	1	1	2	1	2	1	0	1	0	0
A1: Variable remuneration	1	1	1	0	0	0	1	2	2	2	0	2	2	0	1
A1: Contract flexibility	1	0	1	0	0	1	1	0	0	1	1	1	0	0	0
A1: Min. plug-in duration	2	0	1	2	1	1	0	0	0	0	2	2	1	2	1
A1: Min. battery level	0	1	2	0	2	1	0	1	2	2	2	0	1	1	0
A2: Fixed remuneration	0	1	1	1	0	0	2	0	2	1	2	1	0	2	2
A2: Variable remuneration	0	2	0	2	2	1	2	0	1	1	2	1	0	1	0
A2: Contract flexibility	0	1	0	1	0	1	0	1	1	0	0	0	1	0	1
A2: Min. plug-in duration	1	2	0	1	0	2	2	1	2	2	1	0	0	1	0
A2: Min. battery level	1	0	0	2	1	2	2	0	1	1	0	2	2	0	1

Note: The abbreviation A1 and A2 correspond to the different alternatives of the DCE.

Table A.2: Attributes and Attribute Levels

Level	**Attribute**	**Attribute Level**
0		0 cents/day
1	Fixed remuneration	25 cents/day
2		50 cents/day
0		5 cents/kWh
1	Variable remuneration	10 cents/kWh
2		15 cents/kWh
0	Change of contract	Daily
1		Monthly
0		5 hours
1	Plug-in duration	10 hours
2		15 hours
0		35%
1	Minimal battery level	50%
2		70%

B. Example of the choice sets

Erklärung der Vertragsbestandteile

	1. Vertrag	2. Vertrag	Keine Teilnahme an V2G
1. Mindestanschlusszeit	15 Stunden	10 Stunden	
2. Minimales Batterielevel während V2G	35 %	50 %	
3. Änderung der Vertragskonditionen	Monatlich möglich	Täglich möglich	
4. Variable finanzielle Entlohnung	10 Cent/kWh	5 Cent/kWh	
5. Fixe finanzielle Entlohnung	50 Cent/Tag	0 Cent/Tag	

1. Welchen Vertrag präferieren Sie?

Wenn keiner der Verträge Sie überzeugt, wählen Sie bitte „Keine Teilnahme an V2G“

1. Vertrag | 2. Vertrag | Keine Teilnahme an V2G

Figure B.1: The choice sets as presented in the reference survey (ECON)

Erklärung der Vertragsbestandteile

	1. Vertrag	2. Vertrag	Keine Teilnahme an V2G
1. Mindestanschlusszeit	15 Stunden	10 Stunden	
2. Minimales Batterielevel während V2G	35 %	50 %	
3. Änderung der Vertragskonditionen	Monatlich möglich	Täglich möglich	
4. Variable finanzielle Entlohnung	10 Cent/kWh	5 Cent/kWh	
5. Fixe finanzielle Entlohnung	50 Cent/Tag	0 Cent/Tag	

1. Welchen Vertrag präferieren Sie?

Wenn keiner der Verträge Sie überzeugt, wählen Sie bitte „Keine Teilnahme an V2G“

1. Vertrag | 2. Vertrag | Keine Teilnahme an V2G

Figure B.2: The choice sets with the green-colored V2G contract options (ENV)

C. Survey questions

This section contains a list of all survey question categories followed by a list of all survey questions and answer options.

Question Categories:

- Age
- Gender
- Country
- Housing situation
- Educational attainment
- Net income
- Car relation
- Electricity tariff control
- Perceived threat from climate change
- Interest in technical topics
- V2G knowledge
- Concerns regarding V2G (Battery degradation, Range, Commitment obligation, Complex process, Digitization of car usage, Data privacy)
- Explanation of contract components was read
- Explanation of V2G was watched
- Frequency of car usage
- Average kilometers on a working day
- Electric car ownership

Questions:

1. How old are you? (18 to 24 years old; 25 to 34 years old; 35 to 44 years old; 45 to 54 years old; 55 to 64 years old; 65 years old or older)
2. What is your gender? (Female; Male; Diverse)
3. In which country are you living right now? (Germany; Austria; Switzerland; Another country)
4. What is your current living situation? (Renting an apartment; Renting a house; Owner of an apartment; Owner of a house; Other)
5. What is your highest level of education? (Currently a pupil; Finished school without a degree; School degree; Completed vocational training; University degree; Doctoral degree; Other degree)

6. What is approximately your monthly net income? (Less than €500; €500 to less than €1,000; €1,000 to less than €3,000; €3,000 to less than €5,000; €5,000 and more)
7. How would you describe your relationship to cars? (Emotional; Neutral; Functional; Rejecting; Other)
8. Have you ever checked if you could get better terms by changing your electricity contract? (Yes, regularly; Yes, occasionally; No; I don't take care of the electricity bill)
9. I perceive climate change as a threat (5 options ranging from 'not at all' to 'very'; 'climate change does not exist')
10. I have an interest in technical subjects (5 options ranging from 'not at all' to 'very')
11. I was familiar with the Vehicle to Grid concept before this survey (5 options ranging from 'not at all' to 'very')
12. Did you read the explanation about the contract components? (Yes, thoroughly; Yes, skimmed; No)
13. Did you watch the explanation about V2G in this experiment? (Video and/or text form) (Yes; Yes, but stopped/skimmed; No)
14. Do you have concerns about using V2G? (Yes; No)
    (a) If yes: what are your main concerns?
        i. The battery will be weakened by the additional charging cycles
        ii. The range might not be sufficient
        iii. An obligation to connect arises
        iv. The process is complex
        v. The use of the car is too digitalized
        vi. Data, e.g., about charging behavior, is shared
        vii. Other
    (b) Else: Nothing
15. How often do you use the car on a weekly average? (Several times a day; Once a day; 3 to less than 7 times a week; 1 to less than 3 times a week; Not at all)
16. How many kilometers do you usually drive on an average weekday? (0 km; 1 km to less than 50 km; 50 km to less than 200 km; more than 200 km)
17. Do you own an electric car? (Yes (owned/leased); No, but I plan to buy one; No, I don't plan to buy one but do not exclude it for the future; No, and I do not want one; Other)

D. Socio-demographic and characteristic values

This section contains a detailed listing of the socio-demographic responses in absolute numbers and percentages. Table D.1 shows the socio-demographic details, table D.2 provides information on the relationship with cars and EVs and related aspects and also further opinions and behaviors regarding the environment and cars.

Table D.1: Socio-demographic details

Response Option	**Grouped Category**	**ECON (N = 100)**		**ENV (N = 104)**	
		N	%	N	%
Age					
18 to 24 years	18 to 34 years	8	8.0	9	8.7
25 to 34 years	18 to 34 years	33	33.0	38	36.5
35 to 44 years	35 to 54 years	14	14.0	11	10.6
45 to 54 years	35 to 54 years	16	16.0	21	20.2
55 to 64 years	55 years or older	20	20.0	17	16.3
65 years or older	55 years or older	9	9.0	8	7.7
Gender					
Female	Female	38	38.0	36	34.6
Male	Male	59	59.0	65	62.5
Diverse	Diverse	2	2.0	3	2.9
No response	No response	1	1.0	-	-
Level of education					
Completed apprenticeship	Higher degree	17	17.0	21	20.2
School graduation	School degree	4	4.0	5	4.8
University degree	Higher degree	63	63.0	64	61.5
Other degree	Other degree	3	3.0	2	1.9
Doctorate	Highest degree	11	11.0	11	10.6
No response	No response	2	2.0	1	1.0
Housing situation					
Rented (apartment)	Rent	46	46.0	44	42.3
Rented (house)	Rent	3	3.0	4	3.8
Living with parents	Rent	2	2.0	1	1.0
Own apartment	Ownership	4	4.0	9	8.7
Own house	Ownership	43	43.0	44	42.3
No information	No information	2	2.0	2	1.9
Income					
Less than €500	Below €3,000	2	2.0	4	3.8
€500 to under €1,000	Below €3,000	5	5.0	15	14.4
€1,000 to under €3,000	Below €3,000	44	44.0	34	32.7
€3,000 to under €5,000	€3,000 or above	24	24.0	23	22.1
€5,000 and more	€3,000 or above	18	18.0	16	15.4
No response	No response	7	7.0	12	11.5

Table D.2: Car and EV relationship, V2G concerns and behavior

Response Option	Grouped Category	ECON (N = 100)		ENV (N = 104)	
		N	%	N	%
Comparing electricity tariffs					
Yes, regularly	Compare	34	34.0	47	45.2
Yes, rarely	Not compare	41	41.0	36	34.6
No	Not compare	22	22.0	15	14.4
I don't handle the electricity bill	Not compare	2	2.0	6	5.8
No response	No response	1	1.0	-	-
Technical Interest					
Not at all	Not interested	3	3.0	1	1.0
2	Not interested	9	9.0	10	9.6
3	Moderately interested	16	16.0	12	11.5
4	Moderately interested	31	31.0	27	26.0
Very	Very interested	41	41.0	54	51.9
No response	No response	-	-	1	1.0
Concerned about climate change					
Not at all	Not concerned	2	2.0	3	2.9
2	Not concerned	4	4.0	4	3.8
3	Moderately concerned	11	11.0	5	4.8
4	Moderately concerned	28	28.0	39	37.5
Very	Very concerned	55	55.0	52	50.0
No response	No response	-	-	1	1.0
Car relationship (multiple responses possible)					
Emotional	Emotional	18	18.0	18	17.3
Neutral	Neutral	19	19.0	19	18.3
Functional	Functional	71	71.0	72	69.2
Rejecting	Rejecting	8	8.0	8	7.7
Car usage					
Several times a day	Frequently	22	22.0	18	17.3
Once a day	Frequently	21	21.0	24	23.1
3 to under 7 times a week	Infrequently	11	11.0	22	21.2
1 to under 3 times a week	Infrequently	28	28.0	21	20.2
Not at all	Do not drive	17	17.0	17	16.3
No response	No response	1	1.0	2	1.9
Distance travelled					
0 km	No distances	20	20.0	22	21.2
1 km to under 50 km	Short distances	49	49.0	56	53.8
50 km to under 200 km	Long distances	28	28.0	21	20.2
No response	No response	3	3.0	5	4.8
EV Ownership					
Yes (owned/ leased/ company car)	Owner	30	30.0	31	29.8
No, but I plan to buy one	Interested	10	10.0	11	10.6
No, I don't plan to, but I don't rule it out	Interested	47	47.0	52	50.0
No, and I don't want one	Not interested	8	8.0	8	7.7
No response	No response	5	5.0	2	1.9
V2G familiarity					
Not at all	Not familiar	29	29.0	26	25.0
2	Familiar	11	11.0	7	6.7
3	Familiar	8	8.0	7	6.7
4	Familiar	28	28.0	19	18.3
Very well	Very familiar	24	24.0	43	41.3
No response	No response	-	-	2	1.9
V2G concerns (multiple responses possible)					
Battery usage	Battery usage	17	17.0	11	10.6
Duty to connect	Duty to connect	13	13.0	10	9.6
Range anxiety	Range anxiety	12	12.0	9	8.7
Complexity	Complexity	6	6.0	3	2.9
Digitization	Digitization	2	2.0	2	1.9
Data sharing	Data sharing	4	4.0	4	3.8
Financial benefit is doubted	Financial benefit is doubted	2	2.0	2	1.9
External interference/ loss of control	External interference	2	2.0	-	-

E. Utility functions

This section presents the utility functions formulated for the Multinomial Logit (MNL) model in detail. This is followed by the utility functions for the Mixed Logit (MXL) model.

E.1. Multinomial Logit Model

```
V1 = ASC_V1 + bMinPlugIn_10h * MinPlugIn_10h1 + bMinPlugIn_15h * MinPlugIn_15h1  \
   + bChangeContractFlexibly * ChangeContractFlexibly1 \
   + bMinBattlevel_35p * MinBattlevel_35p1 + bMinBattlevel_50p * MinBattlevel_50p1 \
   + bVarRem_5c * VarRem_5c1 + bVarRem_10c * VarRem_10c1   \
   + bIncome_VarRem_5c * VarRem_5c1 * IncomeBelow3000 \
   + bIncome_FixRem * FixRem1 * IncomeBelow3000 \
   + bFixRem * FixRem1 \
   + bFemale * Female + bDiverse * Diverse \
   + bAge_18_34 * Age_18_34 + bAge_35_54 * Age_35_54 \
   + bInfrequentDrivers * InfrequentDrivers + bDoNotDrive * DoNotDrive \
   + bShortDistances * ShortDistances + bLongDistances * LongDistances \
   + bHigherDegree * HigherDegree + bHighestDegree * HighestDegree \
   + bOwner * Owner + bEV_NotInterested * EV_NotInterested \
   + bIncomeBelow3000 * IncomeBelow3000  + bNoIncomeGroup * NoIncomeGroup \
   + bSkimmedContractAttributes * SkimmedContractAttributes \
   + bCompareTariffNotAtAll * CompareTariffNotAtAll  \
   + bModeratelyInterested * ModeratelyInterested + bVeryInterested * VeryInterested \
   + bFamiliarWithV2G * FamiliarWithV2G + bVeryFamiliarWithV2G * VeryFamiliarWithV2G \
   + bModeratelyConcerned * ModeratelyConcerned + bVeryConcerned * VeryConcerned \
   + bOwnership * Ownership \
   + bEmotional * Emotional \
   + bNeutral * Neutral \
   + bFunctional * Functional \
   + bRejecting * Rejecting \
   + bBatteryDegradation * BatteryDegradation \
   + bComplexity * Complexity \
   + bDuty * Duty \
   + bRangeAnxiety * RangeAnxiety \
   + bNudge_Env * Nudge_Env \
   + bNudge_Familiar * Nudge_Env * FamiliarWithV2G

V2 = ASC_V2 + bMinPlugIn_10h * MinPlugIn_10h2 + bMinPlugIn_15h * MinPlugIn_15h2 \
   + bChangeContractFlexibly * ChangeContractFlexibly2 \
   + bMinBattlevel_35p * MinBattlevel_35p2 + bMinBattlevel_50p * MinBattlevel_50p2 \
   + bVarRem_5c * VarRem_5c2 + bVarRem_10c * VarRem_10c2 \
   + bIncome_VarRem_5c * VarRem_5c2 * IncomeBelow3000 \
   + bIncome_FixRem * FixRem2 * IncomeBelow3000 \
   + bFixRem * FixRem2  \
   + bFemale * Female + bDiverse * Diverse \
   + bAge_18_34 * Age_18_34 + bAge_35_54 * Age_35_54 \
   + bInfrequentDrivers * InfrequentDrivers + bDoNotDrive * DoNotDrive \
   + bShortDistances * ShortDistances + bLongDistances * LongDistances \
   + bHigherDegree * HigherDegree + bHighestDegree * HighestDegree \
   + bOwner * Owner + bEV_NotInterested * EV_NotInterested \
   + bIncomeBelow3000 * IncomeBelow3000  + bNoIncomeGroup * NoIncomeGroup \
   + bSkimmedContractAttributes * SkimmedContractAttributes \
   + bCompareTariffNotAtAll * CompareTariffNotAtAll  \
   + bModeratelyInterested * ModeratelyInterested + bVeryInterested * VeryInterested \
   + bFamiliarWithV2G * FamiliarWithV2G + bVeryFamiliarWithV2G * VeryFamiliarWithV2G \
   + bModeratelyConcerned * ModeratelyConcerned + bVeryConcerned * VeryConcerned \
   + bOwnership * Ownership \
   + bEmotional * Emotional \
   + bNeutral * Neutral \
   + bFunctional * Functional \
   + bRejecting * Rejecting \
   + bBatteryDegradation * BatteryDegradation \
   + bComplexity * Complexity \
```

```
   + bDuty * Duty \
   + bRangeAnxiety * RangeAnxiety \
   + bNudge_Env * Nudge_Env \
   + bNudge_Familiar * Nudge_Env * FamiliarWithV2G

V3 = ASC_no + 0
```

E.2. Mixed Logit Model

```
V1 = ASC_V1 + bMinPlugIn_10h_RND * MinPlugIn_10h1 + bMinPlugIn_15h_RND * MinPlugIn_15h1  \
   + bChangeContractFlexibly_RND * ChangeContractFlexibly1 \
   + bVarRem_5c_RND * VarRem_5c1 + bVarRem_10c_RND * VarRem_10c1   \
   + bFixRem_RND * FixRem1 \
   + bMinBatterylevel_35p_RND * MinBatterylevel_35p1 \
   + bMinBatterylevel_50p_RND * MinBatterylevel_50p1 \
   + bFemale * Female + bDiverse * Diverse \
   + bAge_18_34 * Age_18_34 + bAge_35_54 * Age_35_54 \
   + bOwner * Owner + bEV_NotInterested * EV_NotInterested \
   + bIncomeBelow3000 * IncomeBelow3000  + bNoIncomeGroup * NoIncomeGroup \
   + bSkimmedContractAttributes * SkimmedContractAttributes \
   + bCompareTariffNotAtAll * CompareTariffNotAtAll  \
   + bModeratelyInterested * ModeratelyInterested + bVeryInterested * VeryInterested \
   + bFamiliarWithV2G * FamiliarWithV2G + bVeryFamiliarWithV2G * VeryFamiliarWithV2G \
   + bModeratelyConcerned * ModeratelyConcerned + bVeryConcerned * VeryConcerned \
   + bOwnership * Ownership \
   + bEmotional * Emotional \
   + bNeutral * Neutral \
   + bFunctional * Functional \
   + bRejecting * Rejecting \
   + bBatteryDegradation * BatteryDegradation \
   + bComplexity * Complexity \
   + bDuty * Duty \
   + bRangeAnxiety * RangeAnxiety \
   + bNudge_Env * Nudge_Env

V2 = ASC_V2 + bMinPlugIn_10h_RND * MinPlugIn_10h2 + bMinPlugIn_15h_RND * MinPlugIn_15h2  \
   + bChangeContractFlexibly_RND * ChangeContractFlexibly2 \
   + bVarRem_5c_RND * VarRem_5c2 + bVarRem_10c_RND * VarRem_10c2   \
   + bFixRem_RND * FixRem2 \
   + bMinBatterylevel_50p_RND * MinBatterylevel_50p2 \
   + bMinBatterylevel_70p_RND * MinBatterylevel_70p2 \
   + bFemale * Female + bDiverse * Diverse \
   + bInfrequentDrivers * InfrequentDrivers + bDoNotDrive * DoNotDrive \
   + bShortDistances * ShortDistances + bLongDistances * LongDistances \
   + bHigherDegree * HigherDegree + bHighestDegree * HighestDegree \
   + bAge_18_34 * Age_18_34 + bAge_35_54 * Age_35_54 \
   + bOwner * Owner + bEV_NotInterested * EV_NotInterested \
   + bIncomeBelow3000 * IncomeBelow3000  + bNoIncomeGroup * NoIncomeGroup \
   + bSkimmedContractAttributes * SkimmedContractAttributes \
   + bCompareTariffNotAtAll * CompareTariffNotAtAll  \
   + bModeratelyInterested * ModeratelyInterested + bVeryInterested * VeryInterested \
   + bFamiliarWithV2G * FamiliarWithV2G + bVeryFamiliarWithV2G * VeryFamiliarWithV2G \
   + bModeratelyConcerned * ModeratelyConcerned + bVeryConcerned * VeryConcerned \
   + bOwnership * Ownership \
   + bEmotional * Emotional \
   + bNeutral * Neutral \
   + bFunctional * Functional \
   + bRejecting * Rejecting \
   + bBatteryDegradation * BatteryDegradation \
   + bComplexity * Complexity \
   + bDuty * Duty \
   + bRangeAnxiety * RangeAnxiety \
   + bNudge_Env * Nudge_Env

V3 = ASC_no + 0
```

F. Complete list of socio-demographic and characteristic influences

This section presents the influence of all socio-demographic factors and characteristics on the willingness to participate in V2G. Therefore, also non-significant influences are shown in Table F.1.

Table F.1: Socio-demographic and characteristic influences

		MNL Model			MXL Model		
Category	**Variable**	**β-value**	**Rob. SE**	**Sig.**	**β-value**	**Rob. SE**	**Sig.**
Age	18-34	0.126	0.247		0.306	0.262	
	35-54	-0.211	0.155		-0.127	0.166	
Gender	Female	0.028	0.169		-0.082	0.182	
	Diverse	-0.556	0.406		-0.511	0.432	
Level of education	Higher Degree	0.124	0.297		0.102	0.258	
	Highest Degree	-0.122	0.320		-0.047	0.294	
Housing situation		-0.237	0.199		-0.263	0.219	
Income	Below €3,000	0.519	0.191	**	0.528	0.166	**
	No income group	-0.435	0.205	*	-0.376	0.214	
Car relationship	Emotional	0.153	0.193		0.258	0.212	
	Neutral	0.777	0.216	***	0.944	0.244	***
	Functional	0.179	0.185		0.294	0.207	
	Rejecting	1.232	0.413	**	1.856	0.382	***
Comparing electricity tariffs	Not compare	0.390	0.132	**	0.425	0.143	**
Technical Interest	Moderately interested	0.041	0.227		-0.108	0.236	
	Very interested	0.217	0.276		0.104	0.287	
Concerned about climate change	Moderately concerned	0.087	0.254		0.065	0.258	
	Very concerned	0.095	0.253		0.107	0.252	
Car usage	Infrequently	-0.184	0.154		0.213	0.135	
Distance travelled	Short distances	-0.297	0.225		-0.095	0.178	
	Long distances	-0.264	0.238		-0.108	0.208	
EV ownership	Owner	-0.700	0.154	***	-0.689	0.167	***
	Not interested in EV	-1.535	0.221	***	-1.504	0.237	***
V2G familiarity	Familiar	0.174	0.181		0.240	0.168	
	Very familiar	0.470	0.203	*	0.473	0.211	*
Concerns	Battery degradation	-0.491	0.197	*	-0.426	0.224	
	Complexity	-0.690	0.273	*	-1.096	0.346	**
	Range anxiety	-0.685	0.285	*	-0.853	0.328	**
	Duty	0.373	0.328		0.596	0.365	
Attribute description	Skimmed	-0.024	0.130		-0.025	0.143	

Significance levels: *** $p<0.001$, ** $p<0.01$, * $p<0.05$

G. MNL results for both income groups

To isolate group-specific differences, separate MNL models were estimated for each income group. The results are summarized in Table G.1.

Table G.1: Results of the MNL model: Willingness to accept

Attribute	Level	Income < €3,000/month net			Income ≥ €3,000/month net		
		β-value	Rob. SE	Sig.	β-value	Rob. SE	Sig.
Fixed remuneration	0-50 cents/day	0.023	0.002	***	0.016	0.002	***
Variable remuneration	5 cents/kWh	-0.394	0.081	***	-0.822	0.094	***
	10 cents/kWh	-0.038	0.089		-0.104	0.102	
Contract flexibility	Monthly	-0.355	0.068	***	-0.434	0.082	***
Minimum plug-in duration	10 hours	-0.199	0.080	*	-0.175	0.094	
Minimum battery level	35%	-0.111	0.087		-0.362	0.102	***
	50%	-0.216	0.084	*	-0.279	0.096	***
Model Fit		**Value**			**Value**		
R^2		0.335			0.233		
AIC		2361			2128		
BIC		2574			2332		

Significance levels: *** p<0.001, ** p<0.01, * p<0.05

H. Attributes from literature

Table H.1 summarizes the properties and key assumptions of the four main relevant choice studies in the context of V2G.

Table H.1: Overview of choice studies

	Country	Remuneration	Min. range/ battery level	Plug-in duration	No. of Cycles	Contract Duration	Order of the Attributes Importance
Parsons et al. (2014)	US	\$500/year \$1,000/year \$2,000/year \$3,000/year \$4,000/year \$5,000/year	25 miles 75 miles 125 miles 175 miles	5 hours/day 10 hours/day 15 hours/day 20 hours/day			1. Remuneration 2. Min. range/ battery level 3. Plug-in duration
Geske and Schumann (2018)	DE	€15/month €30/month €45/month €60/month	10 km 20 km 30 km 40 km 50 km	0 hours/day 5 hours/day 7 hours/day 10 hours/day 14 hours/day			1. Min. range/ battery level 2. Plug-in duration 3. Remuneration
Kubli et al. (2018)	CH	Cost reduction of: CHF60/month CHF40/month CHF20/month	40% 60% 80% 100%		0/day 1/day 3/day Unlimited	0 months 12 months 24 months 48 months	1. Remuneration 2. Min. range/ battery level 2. Discharging cycles 4. Contract duration
Huang et al. (2021)	NL	€20/month €60/month €100/month €0/extra hour €0.15/extra hour €0.30/extra hour	10% 30% 50%	5 hours/day 10 hours/day 15 hours/day	1/session 4/session 7/session	6 months 12 months 24 months	1. Min. range/ battery level 2. Plug-in duration 3. Fixed remuneration 4. Discharging cycles