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Coupling transport and electricity: How can vehicle-to-grid boost the attractiveness of carsharing?

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ABSTRACT

Combining carsharing and vehicle-to-grid could result in synergies for decarbonizing transport and electricity systems. For carsharing operators, often experiencing financial difficulties, vehicle-to-grid service provision could generate additional revenues while supporting the integration of renewable energy. However, extant research has not yet studied customers' interest in vehicle-to-grid carsharing. We therefore investigate whether and how vehicle-to-grid could improve the attractiveness of carsharing. Based on a stated-choice experiment in Germany and Switzerland, we compare the attractiveness of vehicle-to-grid, electric and conventional carsharing. We find that customers choose vehicle-to-grid over electric carsharing in 56.1% and over conventional carsharing in 74.2% of the choices. By estimating a multinomial, a mixed-logit, and a willingness-to-pay-space model, we find that costs show the highest relative importance for customers' utilities despite the early adopter sample. Access and egress times as the second most important service characteristics, combined with free-floating as the preferred scheme, highlight the relevance of charging infrastructure.

1. Introduction

The transport sector accounts for about 25% (IEA, 2020) of global direct CO_2 emissions from fuel combustion with almost 75% stemming from road transport (European Environment Agency, 2019). Cars account for about 45% of the road transport emissions (European Environment Agency, 2019) and two of the main strategies for their decarbonization are electrification and carsharing[1] (Transport and Environment, 2018). Emission reductions through electrification of cars are based on a high share of renewable electricity supply in the electricity mix. Intermittent renewable electricity however challenges the match of supply and demand and hence, increases the need for flexibility services in the electricity system (Kubli et al., 2018). In addition, electric vehicles (EVs) can challenge electric distribution grids due to the increased electricity demand load at already high peak demand times in the evening (McKenna et al., 2011; Neaimeh et al., 2015; Knezović et al., 2017; Muratori, 2018). Vehicle-to-grid (V2G) offers bidirectional electricity flows between the EVs and the electricity system (Weiller and Neely, 2014; Kempton and Tomić, 2005), which supports the integration of renewable electricity and EVs into the system by providing flexibility services[2] (Noel et al., 2017; Nguyen et al., 2015; Staudt et al., 2018; Wang et al., 2017; Kester et al., 2018; Hu et al., 2016). Examples of services include

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[1] Carsharing refers to a mobility service with the use of cars amongst members of a carsharing operator. Members can reserve and book cars according to their availabilities and locations. In comparison to rental cars, the booking can be spontaneous and for short time spans.

[2] V2G technology can provide flexibility services to the electricity system at distribution and transmission level, which we summarize as "V2G services".

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List of abbreviations

AICc	Akaike information criterion with correction for small sample sizes
ASC	Alternative specific constant
CO	Conventional car
Coef.	Coefficient
CSmemb	Current carsharing membership
DSO	Distribution System Operator
E	Electrical
EV	Electric vehicle
EVown	Electric vehicle ownership
FF	Free-floating
hhsize	Household size
LL	Log Likelihood
MNL	Multinomial logit
NOcar	No car ownership
Remun	Remuneration
SB	Station-based
SE	Standard error
Swiss	Residence Switzerland
TSO	Transmission System Operator
V2G	Vehicle-to-grid
V2Gfamil	V2G familiarity
V2Gright	V2G right position of choice set
WTP	Willingness-to-pay

frequency regulation, spinning reserves, congestion management, load shifting, and energy curtailment reduction (Arias et al., 2019). Despite an increasing number of pilot projects worldwide, commercial applications of V2G are still rare (Everoze and EVConsult, 2018). In contrast, carsharing has already been operated commercially for several years, but operators often experience financial difficulties due to high fixed costs and overestimated revenues despite increasing supply (Göddeke et al., 2021) and membership numbers (Cohen and Kietzmann, 2014; De Luca and Di Pace, 2015). Particularly, the high investment costs for EVs threaten the profitability of E-carsharing[3] (Fournier et al., 2014).

While E-carsharing is a key strategy for decarbonizing passenger transport, coupling carsharing with V2G technology has the potential to further strengthen the synergies between the transport and electricity systems. There are four main potential benefits of V2G carsharing. First, carsharing operators can gain additional revenue by providing V2G services to the electricity system when the cars are not booked, including at night (Fournier et al., 2014; Sovacool et al., 2020; Taiebat and Xu, 2019). Second, V2G could increase the attractiveness of carsharing as it has already been shown that E-carsharing is more popular than conventional carsharing[4] (Cartenì et al., 2016; Paundra et al., 2017; Schlüter and Weyer, 2019). These first two benefits could counteract financial difficulties for carsharing operators, particularly higher investment costs for E-carsharing. Third, V2G can support the electricity system in integrating more intermittent renewable electricity, which is also beneficial for the decarbonization of the transport system (Baumann et al., 2013). Using EVs as mobile batteries in the system can save investment costs in stationary battery storage for the electricity system (Noel et al., 2017; Everoze and EVConsult, 2018; Kempton and Dhanju, 2006). Fourth, V2G uptake could be accelerated as customers do not own the EVs and hence, do not worry about battery degradation, which is one of the main social barriers for V2G uptake (Sovacool et al., 2017a; Taiebat and Xu, 2019).

To leverage the aforementioned benefits, we need to understand customer preferences and acceptance of V2G carsharing. Ongoing pilot projects have already started to investigate V2G carsharing (e.g. Novatlantis (2020)), yet at a small scale with current insights remaining scarce (Cenex, 2019; Jin et al., 2020). As V2G might require adjustments to carsharing service characteristics, it is crucial to investigate induced changes to carsharing service characteristics due to V2G. In addition, customers' interest in V2G carsharing needs further evaluation as V2G can only realize financial benefits for carsharing operators if there is demand for V2G carsharing. In an ever more competing system of carsharing services among themselves as well as towards different transport services (e.g. e-scooters, ridepooling, etc.), carsharing operators need to make sure to directly address the customers' needs and wants in the best way possible. Extant literature has however focused on investigating V2G uptake with an ownership rather than sharing model (Geske and Schumann, 2018; Noel et al., 2019a; Parsons et al., 2014) or unidirectional E-carsharing (Cartenì

[3] E-carsharing refers to carsharing with uncontrolled unidirectional EV charging, not providing flexibility services to the electricity system.

[4] In this work, "conventional cars" refer to petrol and diesel cars.

et al., 2016; Wielinski et al., 2017; Mueller et al., 2015). We address this gap by asking whether and how V2G could improve the attractiveness of carsharing for customers and consequently, also for operators. By conducting a stated-choice experiment in Germany and Switzerland, we compare V2G carsharing to E- and conventional carsharing. We focus on this geographical scope because the largest number of V2G pilot projects is conducted in Europe, including first pilot projects that investigate V2G carsharing in Switzerland, (e.g. Novatlantis (2020)). Based on our survey results, we investigate how selected carsharing service characteristics impact the customers' choices. Understanding the most important characteristics is crucial to provide attractive mobility concepts that can support the decarbonization of both the transport and the electricity systems.

This work makes two contributions. First, to the authors' knowledge, this is the first study that evaluates customers' interest in V2G carsharing and compares customers' preferences between V2G and E- as well as conventional carsharing. Second, we investigate induced differences in other service characteristics to analyze how these changes affect customers' choices and to identify the most important service characteristics.

The remaining part of the paper is structured as follows. Section 2 provides an overview of the extant literature about V2G technology, its combination with carsharing, and customer perspectives, Section 3 explains our stated-choice experiment design, sample, and models, Section 4 analyzes and discusses results and derives implications, and Section 5 provides concluding remarks.

2. Electric vehicles with V2G technology

2.1. Background on V2G technology and its implementation status

V2G can support the energy transition by providing flexibility services while generating additional revenues for providers. Challenges and uncertainties however remain concerning technical, social, and regulatory aspects as well as future market developments. Technical challenges include potential battery degradation, charger and communication efficiency, and aggregation, affecting the economic value of V2G systems (Noel et al., 2019c). Regarding social aspects, V2G uptake and related concerns about potentially resulting mobility constraints need to be addressed (Sovacool et al., 2017b; Noel et al., 2019b). Concerning regulation, challenges include the difficult verification of many small and dispersed providers, large minimum bid sizes for electricity market participation, and long sale cycles that are inappropriate for cars[5] (Everoze and EVConsult, 2018; Kester et al., 2018; Noel et al., 2019b; Cenex, 2020; The Parker Project, 2019). Uncertainties in future market developments are particularly relevant at distribution level as service definitions as well as transparent revenue indications for providing services are missing (Knezović et al., 2017; Everoze and EVConsult, 2018).

To find solutions to these challenges, about 100 V2G projects have been implemented worldwide (V2G Hub, 2021), confirming the technical feasibility (Cenex, 2020) and indicating the economic attractiveness of V2G (The Parker Project, 2019). The implemented V2G applications vary in the car use types and services. 74% of the projects involve commercial vehicle fleets due to possible centralized approaches, which reduce installation and maintenance costs while offering a larger fleet of cars (Gschwendtner et al., 2021). 53% of the projects provide services at transmission level (Gschwendtner et al., 2021) with frequency response as one of the most frequently implemented V2G services (V2G Hub, 2021).

2.2. Combining V2G and carsharing

The combination of carsharing and V2G is currently tested in several pilot projects as fleets are particularly suitable for V2G uptake (Kester et al., 2018; Fournier et al., 2014) and the impact of future mobility concepts on V2G need further investigation (Taiebat and Xu, 2019; Sovacool et al., 2020). Table 1 provides an overview of exemplary V2G carsharing pilot projects. While most of these projects are still ongoing or have been completed recently, first results indicate the potential and challenges of combining carsharing and V2G. For instance, a plug-in time of about 60% – which might be increased with higher charger availability – indicates the promising V2G potential of carsharing fleets (Everoze and EVConsult, 2018). However, more than half of the users book the cars less than one hour in advance, which could be problematic for long-distance trips as sufficient range needs to be ensured (Roschewitz et al., 2020). Overall, the size of most pilot projects is small with a limited number and segment of potential customers and cars. As larger fleets can provide aggregation benefits for providing V2G services (Roschewitz et al., 2020), the scaling potential of V2G carsharing requires further investigation. As scaling depends on the interest in the service and number of customers, it is crucial to investigate the broader interest in V2G carsharing among potential customers.

A first indication of combining carsharing and V2G at large scale are existing E-carsharing schemes. Compared to conventional carsharing, E-carsharing operations are more complex due to charging requirements and additional investments, e.g. in EVs and charging infrastructure (Mueller et al., 2015; Jin et al., 2020; Bruglieri et al., 2014; Perboli et al., 2018; Liao and Correia, 2022; Xu et al., 2021). Real-world fully electric free-floating carsharing schemes however demonstrate that they can provide a similar service as conventional carsharing (Sprei et al., 2019; Taiebat and Xu, 2019). Depending on the available charging infrastructure and the operating scheme (round-trip, station-based or free-floating)[6], carsharing operators can relocate cars for charging (Seign and Bogenberger, 2012; Ran et al., 2021; He et al., 2017; Sprei et al., 2019), incentivize or oblige customers to park the cars at a charging station (Fournier et al., 2014; Ran et al., 2021; Illgen and Höck, 2018), or use a mix of both measures (Huang et al.,

[5] Some countries have started to address these issues by, e.g., decreasing bid sizes and shortening sale cycles (Gschwendtner et al., 2021).

[6] Explanations of carsharing schemes can be found in Table B.2.

Table 1
Overview of exemplary V2G carsharing pilot projects.

	Smart Solar Charging	City-Zen Smart City	Go-EV car share	Smart Mobility V2X	V2X Suisse
Country	Netherlands	Netherlands	UK	Switzerland	Switzerland
Timespan	2015 - ongoing	2014–2019	2021	2019–2021	2022 - ongoing
Size	22 chargers, scaling up to 1000 chargers	4 chargers	27 chargers	2 EVs	50 EVs
Areas/ customer types	5 areas, all combining renewable energy production with V2G chargers and carsharing: residential, school complex with Park&Ride, high density urban, and mixed area with transit hub	Urban area, diverse customers: commercial, individual and carsharing	10 chargers for carsharing scheme for residents and businesses	Residential area including multi-family houses	40 carsharing stations across Switzerland to cover rural and urban areas
Goals	Creating flexible storage capacity to reduce peak loads and releasing energy at high prices or during periods of network congestion	Testing V2G technology and services at distribution level to support grid stability; identifying social and regulatory barriers; testing aggregators and energy management systems for distribution grid congestion	Discharging EV batteries to optimize grid balancing and testing the optimization of solar charging for carsharing EVs	Investigating an intelligent regulation and tariff system with integrated energy management and E-carsharing to optimize the mobility behavior of residents and the buildings' PV self-consumption; demonstrating new business models for V2G service provision	Testing support of grid stability and increasing PV self-consumption; investigating the business potential of V2G carsharing; testing the competition between potential flexibility buyers (e.g. transmission and distribution level)
Website	Smart Solar Charging (2021) and V2G Hub (2021)	Bierman et al. (2016) and V2G Hub (2021)	Isles of Scilly (2020)	Novatlantis (2020)	Sun2wheel (2022)

2020; Folkestad et al., 2020; Seign and Bogenberger, 2012). Either option increases costs for operators compared to conventional carsharing services (Seign and Bogenberger, 2012). Additional costs arise from the initial investment costs for EVs (Brendel et al., 2018; Wappelhorst et al., 2014; Boyacı et al., 2017) and charging infrastructure (He et al., 2017) while customers are unlikely to pay a premium for E-carsharing compared to conventional carsharing (Seign and Bogenberger, 2012). Additional revenues from V2G services could compensate for these additional costs of E-carsharing and increase its profitability (Fournier et al., 2014; Taiebat and Xu, 2019; Zhang et al., 2021).

Several studies have investigated the combination of carsharing and V2G from an operator perspective. Kahlen et al. (2018) analyze the decision of a shared EV fleet operator to charge an EV, discharge for mobility, discharge to the grid or keep it idle. They show that participation of an EV fleet in the North European electricity spot market with V2G can be profitable and fleet owners can use geographical differences by participating in V2G during less popular times in certain areas, considering varying use patterns of carsharing services (Hu et al., 2018; Costain et al., 2012; Huo et al., 2020; Kahlen et al., 2018). For instance, most idle EVs appear in residential areas during the morning and in business areas before the evening rush hours (Zhang et al., 2021). Caggiani et al. (2021) suggest distributing cars at carsharing stations at the beginning of each day for a one-way station-based E-carsharing service to maximize the benefit of V2G while meeting carsharing customers' demand. Jiao et al. (2021) use real E-carsharing data to develop a control system for operators to integrate V2G while improving cost savings and reliability of the electricity grid. However, the attractiveness of V2G carsharing and the impact of customers' choices on V2G carsharing operations, such as desired charging levels, pricing schemes and potential remuneration, require more investigation (Jiao et al., 2021; Ren et al., 2019; Shen et al., 2019).

2.3. Customer perspectives on carsharing, E-carsharing, and V2G car ownership

While several studies have investigated the impact of service characteristics on the use of carsharing, their results are limited to conventional and E-carsharing services without additional features such as V2G. Table 2 summarizes the attributes that have been investigated in previous stated-choice experiments, distinguishing between conventional and E-carsharing. Table A.1 summarizes the attributes investigated in stated-choice experiments on V2G car ownership in a domestic context as no stated-choice experiments have been conducted on V2G carsharing to the authors' knowledge. We used this literature screening as a basis for selecting the attributes of our experiment (see Section 3).

Table 2 shows the similarities and differences between conventional and E-carsharing stated-choice experiments. The most frequently investigated attributes in both conventional and E-carsharing stated-choice experiments are costs, and access and egress times. The listed E-carsharing stated-choice experiments do not investigate E-carsharing as an alternative to conventional carsharing, but add the attribute 'car propulsion' to distinguish between conventional and E-carsharing (Cartenì et al., 2016; Rotaris et al., 2019; Yoon et al., 2017; Zoepf and Keith, 2016) or compare it to other modes, e.g. public transport or taxi (Caiati et al., 2020; Jin et al.,

Table 2
Overview of attributes investigated in previous stated-choice experiments on conventional and E-carsharing.

Investigated attributes	Conventional carsharing									E-carsharing					
	Carroll et al. (2017)	Guidon et al. (2020)	Ho et al. (2020)	Krauss et al. (2022)	Le Vine et al. (2014)	De Luca and Di Pace (2015)	Schmid et al. (2019)	Wu et al. (2019)	Zhou et al. (2020)	Caiati et al. (2020)	Cartenì et al. (2016)	Jin et al. (2020)	Rotaris et al. (2019)	Yoon et al. (2017)	Zoepf and Keith (2016)
Costs (e.g. per hour or min, subscription costs)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Access/egress time or distance	x			x	x	x	x	x			x	x	x	x	x
Travel time	x			x		x	x	x			x			x	
Car propulsion											x		x	x	x
Operation scheme (i.e. free-floating, station-based, round-trip)			x	x									x		
Kilometers or minutes included in monthly subscription		x								x	x				
Car size					x				x			x			
Waiting time	x								x						
Parking				x						x					
Remaining range												x			
Advance booking time			x												

2020). These experiments do therefore not cover induced changes to the carsharing service by offering EVs, e.g. due to charging requirements. Hence, customers' perceptions of the changes to the carsharing service due to EVs have not been investigated yet.

Previous stated-choice experiments indicate the importance of costs, access and egress times as well as operation schemes on customers' choices. Costs have been identified as important factor for customers' choices (De Luca and Di Pace, 2015), and customers value access time as more important than egress time (Jin et al., 2020; De Luca and Di Pace, 2015) although their impact decreases with increasing trip distances (Jin et al., 2020). Free-floating schemes are typically preferred over station-based or round-trip schemes (Rotaris et al., 2019) because they offer higher flexibility and hence, can be used for a higher variety of trip purposes compared to station-based carsharing (Becker et al., 2017). Balac et al. (2019) conclude that free-floating carsharing is more convenient and, thus, offers high potential for carsharing in general. However, each of the three schemes (round-trip, station-based and free-floating) might be better suited for a different setting or user-group (e.g. Becker et al. (2017), Yoon et al. (2017), Namazu and Dowlatabadi (2018) and Lempert et al. (2019)).

While previous studies have shown that E-carsharing is more popular than conventional carsharing, the importance of costs and range anxiety for customers could challenge E-carsharing services. Cartenì et al. (2016) show that the option of using an EV increases the probability of using carsharing. Schlüter and Weyer (2019) find that carsharing users would use EVs if provided and conclude that offering EVs can support acquiring new customer groups. Additionally, Paundra et al. (2017) find that EVs are more attractive in carsharing services because they might otherwise not be affordable for specific customer groups. Furthermore, costs are still very important for E-carsharing (Cartenì et al., 2016) and the desired range is longer than the actually needed range (Wielinski et al., 2017). As range anxiety is an issue for longer trips with EVs (Mueller et al., 2015), it is important to use the time when cars are not booked for charging.

As the potential for V2G service provision depends on plug-in behavior and charging locations, it is crucial to investigate the user acceptance of this technology (Sovacool et al., 2017b; Noel et al., 2019b). The results on V2G car ownership show that users are concerned about battery degradation, range anxiety, and inconvenience related to restrictions on the desired mobility behavior (Sovacool et al., 2017a; Karlsson, 2020). Users also dislike contractually required plug-in times or low guaranteed driving ranges (Parsons et al., 2014). If range anxiety and minimum range are however improved, high V2G uptake could be achieved even without remuneration (Geske and Schumann, 2018).

Although extant literature on conventional carsharing, E-carsharing, and V2G car ownership indicates that characteristics such as costs, access and egress times, range, and remuneration might be important for V2G carsharing, it is unknown how customers value these characteristics for V2G carsharing and how the induced changes to the service characteristics affect customers' choices. Particularly, the attractiveness of V2G carsharing compared to other carsharing services remains unclear. This study attempts to address these gaps by investigating customers' choices between V2G and E- as well as conventional carsharing and by determining the most important operating conditions from a customer perspective to inform the development of operation systems and ensure the attractiveness of carsharing while adding V2G.

3. Method

3.1. *Stated-choice experiment design*

Stated-choice experiments are a commonly used method to answer research questions about customers' preferences between alternatives and their attributes (Schmid et al., 2018). Particularly in the case of V2G carsharing, revealed preference data is currently very limited due to few pilot projects of small size (see Table 1). Therefore, we designed a stated-choice experiment embedded in an online survey. The descriptions of the alternatives V2G, E- and conventional carsharing are provided in Table B.1. To select important attributes, we screened the literature on conventional and E-carsharing (see Table 2) and V2G car ownership (see Table A.1) as no stated-choice experiments on V2G carsharing have been conducted yet to the authors' knowledge. We developed our experiment design based on a combination of carsharing and V2G attributes to reflect the potential impact of V2G on the carsharing service.

Consequently, we selected six attributes, listed in Table 3. The respective descriptions provided to the survey respondents can be found in Table B.2. To establish a comparable and relatable choice situation for respondents, we included a specified trip length (20 km, 50 km, or 100 km) for each choice set, which remained the same across alternatives within one choice set. In addition, the respondents were instructed to decide on the basis of their (potential) main trip purpose for carsharing, which they previously stated in the survey.

As first attribute, we included 'minimum range' because more time is available for providing V2G services if people accept relatively low EV ranges, due to fewer requirements for instant charging. Furthermore, less required charging time increases possible bookings with a given car fleet, which is the primary source of revenue. In addition, it is unlikely that customers are willing to choose an EV that does not cover the trip length because they would need to charge on their way, potentially several hours, while they have booked and thus are paying for the car. Extant literature already indicates that the desired range is higher than the needed range (Geske and Schumann, 2018; Jin et al., 2020; Meijssen, 2019; Zonneveld, 2019) and users show a high willingness-to-pay (WTP) for additional range (Noel et al., 2019a). Therefore, we stated the minimum range in percent of the given trip length, which was always covered.

Table 3
Overview of the attributes and respective levels for the stated-choice experiment.

Attribute	V2G	EV	CO
Minimum range [% of trip length]	125, 150, 200	125, 150, 200	125, 150, 200
Cost per hour (beforeremuneration) [EUR or CHF]	7, 12, 18	7, 12, 18	7, 12, 18
Remuneration [% of total trip costs]	5, 10, 30	5, 10, 30	n/a
Scheme	Free-floating, Station-based, Roundtrip	Free-floating, Station-based, Roundtrip	Free-floating, Station-based, Roundtrip
Access time [min]	3, 8, 15	3, 8, 15	3, 8, 15
Egress time [min]	3, 8, 15	3, 8, 15	3, 8, 15

Concerning the cost levels, we drew on comparable designs (Zoepf and Keith, 2016; Rotaris et al., 2019; Wu et al., 2019) and actual prices in Germany ("Stadtmobile", "ShareNow") and Switzerland ("Mobility"). The remuneration attribute functions as a discount provided by the operator if the customers plug the car into a charging station at their destination. Therefore, this attribute was only valid for V2G and E-carsharing. Plug-in time is crucial to ensure that V2G-enabled EVs can provide flexibility services to the electricity system (IRENA, 2019). In addition, customers might expect the carsharing operators to forward some of the additional revenues from V2G service provision to the customers when they plug-in the EVs. Despite not providing a remuneration for conventional carsharing, it is priced below V2G in some choice sets, which ensures that respondents need to trade off.

The attribute 'scheme' is important because it impacts charging infrastructure requirements and potential additional efforts to ensure that EVs are plugged-in when they are not used for mobility services. Existing literature on carsharing shows that free-floating schemes tend to be preferred over station-based and round-trip schemes (Rotaris et al., 2019; Becker et al., 2017; Balac et al., 2019). However, ensuring that EVs are plugged-in will be easier if customers prefer station-based or round-trip carsharing schemes because they allow the independence of public chargers and do not require staff to relocate vehicles for charging. Nevertheless, we include the attribute level free-floating to investigate its importance and account for a potential future situation in which public (bidirectional) charging stations are available and used or provided by carsharing operators.

Lastly, we added access and egress times as attributes as they might increase when searching for a charging station to plug-in the car after its use (Le Vine et al., 2014; Wu et al., 2019; De Luca and Di Pace, 2015; Yoon et al., 2017; Ghamami et al., 2020). Table 2 also demonstrates that most studies include these attributes and that they are considered to have a high impact on people's choices (e.g. De Luca and Di Pace (2015)).

To answer our research question regarding the attractiveness of V2G carsharing, we compared it to E- and conventional carsharing. We decided to present two alternatives to the respondents as we found during the pre-test that the choice tasks would have otherwise been too complex. We randomly split the sample into one sub-sample choosing between V2G and E-carsharing, and another sub-sample choosing between V2G and conventional carsharing (see choice set examples in Figs. B.1 and B.2) to reduce response burden. The alternatives were labeled according to the respective service to account for label effects. To reduce bias due to the positioning of the alternatives, the order was varied on the inter-individual level (50% of respondents saw V2G carsharing as first and 50% as second alternative) but constant on the intra-individual level to avoid misunderstandings.

We used the software Ngene (ChoiceMetrics, 2018) to create a block design with 40 rows and 5 blocks for each sub-sample, i.e. each respondent saw eight choice tasks, to account for potential cognitive burden (Bech et al., 2011). We applied a D-efficient MNL design and excluded strictly dominant and redundant choice sets to force respondents to trade off and increase the amount of preference information (Rose and Bliemer, 2009). We checked trade-off values of the designs, which showed satisfying patterns. To get meaningful and realistic designs, we additionally applied two conditions. First, egress time for V2G is always larger or the same compared to conventional carsharing due to the additional distance to the less densely distributed charging stations compared to gasoline stations. Second, the remuneration for E-carsharing could only be as high as for V2G carsharing as providers generate additional revenue with V2G.

In the survey,[7] we collected further information on the respondents, such as socio-demographic characteristics, familiarity with V2G, environmental attitude, carsharing use, and ownership of different car types to support interpretations and enable the integration of interactions between parameters in the models.

Before the public survey distribution, we conducted a pre-test with 29 respondents, including survey, stated-choice, carsharing, and V2G experts as well as a diverse group of non-experts in these topics to cover a wide range of eligible respondents and ensure that the survey and choice experiment are clear to all of them. After the respondents filled-in the survey individually and provided written feedback, we interviewed the respondents to test how they understood the attributes of the alternatives and the choice settings, particularly related to the novel technology V2G. Based on the feedback, we improved the description of the attributes, shortened the survey to reduce cognitive burden, and clarified misleading questions.

[7] The survey is provided in the supplementary material of this paper. Although this includes the entire survey, we used branching and random selection in the actual survey for respondents.

Table 4
Sample characteristics.

Characteristic	Value	% N = 308
Car ownership	Only EV	0.2
	EV and conventional car	24.6
	Only conventional car	35.0
	No car	40.0
	Car with other propulsion	0.1
Previous experience with driving an EV	Negative	6.0
	Positive or neutral	55.6
	No previous experience	31.5
Carsharing use	Membership	33.2
	No membership but used before	18.2
	Never used	48.6
Purpose of carsharing use	Commute	10.0
	Leisure	39.5
	Shopping/Moving goods	50.5
Attitude towards carsharing	Negative	6.5
	Positive or neutral	93.5
Familiarity with V2G	Unfamiliar	34.0
	Familiar or neither (un)familiar	66.0
Importance of the environment	Unimportant	2.0
	Important or neither (un)important	98.0

3.2. Sample recruitment and description

People owning a driver's license and currently living in Germany or Switzerland were eligible respondents. We offered the survey in both English and German and used manifold distribution channels between April and May 2020. In total, we approached the largest 19 carsharing operators in Germany and Switzerland with one operator forwarding the survey to their customers. Moreover, we posted the survey in two university mailing lists, five forums, three Facebook-groups, approached nine newsletters, and used LinkedIn and Twitter.

Out of the 454 responses, we could use 308 responses with $n = 2464$ observations for analyses. We only included complete responses, excluded responses with too short response times, and investigated the excluded responses to ensure that no specific demographic groups have been excluded. Instead of aiming for a representative sample for the German or Swiss population, we aimed at balancing our respondents amongst different car ownership profiles, carsharing users, and familiarity with V2G (see Table 4). These characteristics are difficult to cover in a random sample but important for analyzing customers' choices. Our sample represents potential early adopters (Plötz et al., 2014; Helmus et al., 2020; Liao and Correia, 2022; Kramer et al., 2014) as middle-aged men with high education and full-time employment, attributing high importance to the environment, dominate the sample (see Table C.1). In addition, 93.5% of the sample indicate a generally positive attitude towards carsharing. The small share of people only owning an EV[8] (0.2%, see Table 4) can be explained by the observation that initially, many people owning an EV also own a conventional car (Skippon and Garwood, 2011). While the high share of people with previous EV driving experience in our sample suggests that they could relate to the hypothetical experiment, there is also a potential positive bias towards EVs in our sample.

3.3. Model specifications

We estimated two models to investigate the robustness of our findings against model assumptions and further parameterized a model in WTP-space to estimate the distributions of WTP values directly and avoid dividing by distributed cost coefficients (Daly et al., 2011). We estimated a multinomial logit (MNL) (McFadden, 1978) and a mixed-logit model (Train, 2009; Schmid et al., 2019; Hensher and Greene, 2003). While the MNL model provides the basis, the mixed-logit model accounts for preference heterogeneity and other behavioral aspects, which impact the overall level of correlation between decision-making factors[9] (Hess and Train, 2017). Preference heterogeneity allows to account for different decision-making factors and different sensitivities for the same decision-making factors amongst respondents (Arunotayanun and Polak, 2011). The respective utility functions for each model and alternative are specified in Appendix D. All models were estimated in R, using the MIXL-package (Molloy et al., 2021).

For each of the models, we applied pooled estimation for the V2G parameters because V2G was included in both sub-experiments. We therefore include a scale parameter ζ in the V2G utility function to account for different error variances between the two datasets (Swait and Louviere, 1993). Alternative specific constants (ASCs) are included in the utility functions for E- and conventional carsharing (with V2G as reference). We present the mixed-logit model with 5000 draws for simulating the distributions of random

[8] "EV ownership" refers to battery, hybrid, and plug-in hybrid electric vehicles in this work.
[9] Decision-making factors are represented in the parameters of the utility functions.

components due to stable parameters from 5000 draws onwards. We add trip length as context parameter and single interaction terms for the socio-demographic characteristics listed in Table 4 and Table C.1. We selected those interaction effects that statistically improve the model (AICc served as the determining factor). We did not include higher than single interaction terms since previous studies found those explain only additional 10%–15% of the variance in the data (Louviere et al., 2000). As we varied the position of alternatives between respondents, we also accounted for left–right bias in the model estimations. We further performed post-estimation analyses to discuss part-worth utilities, and marginal probability effects.

4. Results and discussion

4.1. Model estimations and analyses

We find that V2G carsharing is chosen over E-carsharing in 56.1% and over conventional carsharing in 74.2% of the choices. Table 5 summarizes the estimated coefficients, which represent the impact of the service attributes and socio-demographic characteristics on respondents' utilities. The scale parameter for pooled estimation ζ ranges from 0.97 to 1.00, indicating similar variances of the two data sets. For the post-estimation analyses, part-worth utilities and marginal probability effects, we focus on the more advanced mixed-logit model because it provides a better fit (see AICc).

All significant coefficients show the expected sign. While costs, access and egress times show a negative sign, meaning an increase in these attributes makes the alternatives less attractive, scheme (free-floating and station-based with round-trip as reference) and range are significantly positive.

The mixed-logit model includes the preference heterogeneity for the alternatives σ_{CO} and σ_{V2G} (σ_{EV} is normalized to zero (Walker, 2001)) and for the investigated attributes. These parameters represent the variation amongst respondents and are significant for conventional and V2G carsharing, the former showing a higher value. The highest variation occurs for the attributes remuneration and scheme, indicating that these attributes are valued differently amongst respondents. By conducting post-estimation analyses, we take potential individual variations into account.

The included socio-demographic parameters show that no car ownership, EV ownership, and familiarity with V2G technology significantly affect the choice of V2G over conventional carsharing. Reasons for these findings could be that people owning an EV or no car care about the environment.[10] Familiarity increases confidence or trust in EVs because EV use typically implies a positive experience, as shown in Table 4.

The part-worth utilities shown in Fig. 1 provide information about the relative importance of the service attributes for the respondents' choices. Respondents evaluate costs as most important for their utility. Although extant literature on E-carsharing also indicates that costs remain a crucial attribute (Cartenì et al., 2016), it should be noted that costs are most important despite the early-adopter characteristics of our sample. As costs are most and remuneration least important for the utilities, it might be more effective to integrate the discount directly into the costs of the service. Besides loss aversion (Tversky and Kahneman, 1991), reasons for this could be that respondents find it difficult to evaluate remuneration as percentage of total costs or they might prefer a guaranteed remuneration independent of the condition to plug-in the car after use.

Egress and access times follow costs in their importance for the respondents' utilities, as Fig. 1 shows. The difference between the part-worth utilities of egress time for conventional carsharing compared to V2G and E-carsharing reflects the negative impact of potentially higher egress times for plugging-in the cars after use, which has been incorporated in the design of the experiment. As Fig. 2 and Table E.1 show, the WTP for 1 min decrease in access time is on average 0.43 EUR for V2G carsharing, 0.49 EUR for E-carsharing, and 0.35 EUR for conventional carsharing. While the WTP for 1 min decrease in egress time is slightly higher for V2G (0.49 EUR) and E-carsharing (0.53 EUR), slightly lower values apply for conventional carsharing (0.33 EUR). These results demonstrate that the WTP for decreased access and egress times is higher for the electrified alternatives, which is particularly relevant because access and egress times might increase due to limited charging station availability.

Free-floating and station-based schemes perform substantially better than round-trip (as reference) with free-floating as the most attractive option for all alternatives. Fig. 2 demonstrates the WTP for free-floating with a mean of 4.91 EUR for V2G, 7.06 EUR for EV, and 2.11 EUR for conventional carsharing. This indicates that respondents are willing to pay a higher hourly price for a free-floating scheme. Consequently, in the case of V2G and E-carsharing, respondents do not want to be forced to return the car at the pick-up station to facilitate the charging process of the cars.

Although additional range is valued significantly positive even if the trip length is covered, the relative importance of range compared to the other attributes is rather low. As the coefficient for range is significantly positive, offering larger ranges to potential customers has a positive impact on their utility even if the trip length would be covered with a smaller range. However, the part-worth analysis shows that range is the second least important attribute.

Table 6 presents marginal probability effects for the mixed-logit model. Increasing costs for V2G carsharing lead to a substantial decrease (−14.78%) in choice probability. However, increasing costs for E- or conventional carsharing show smaller negative marginal probability effects (−6.54% and −4.71%, respectively). An increase in access and egress times for V2G carsharing by 1 min shows negative effects on V2G carsharing choices (−5.11% and −5.06%, respectively).

Our results show similar customer preferences compared to extant literature on E- and conventional carsharing. In line with previous studies finding that the option of using an EV increases the interest in carsharing (Cartenì et al., 2016; Mueller et al.,

[10] We did not include environmental attitude as a separate parameter in our models because it affects other parameters included in the models. As 98% of our sample attribute high importance to the environment, this attitude can help to interpret the reasons behind our results.

Table 5
Model estimation results with robust standard errors in brackets.

Parameter		MNL Coef. (SE)	Mixed-logit Coef. (SE)
Cost	[EUR]	−0.13*** (0.01)	−0.30*** (0.04)
Cost & trip purpose leisure	[EUR]	−0.05** (0.02)	−0.09** (0.05)
Remuneration	[%-pts.]	−0.75 (1.29)	−0.29 (2.41)
Remuneration & household size	[%-pts.]	0.87* (0.49)	1.44 (0.89)
Access time	[min]	−0.07*** (0.01)	−0.15*** (0.02)
Egress time	[min]	−0.07*** (0.01)	−0.14*** (0.02)
Free-floating (round-trip as reference)		0.74*** (0.11)	1.60*** (0.27)
Station-based (round-trip as reference)		0.28*** (0.10)	0.65*** (0.21)
Trip length	[km]		1.12 (0.96)
Range	[%-pts.]	0.26** (0.11)	0.45** (0.22)
Alternative specific constants (V2G as reference)			
ASC_{EV}		0.46 (0.42)	0.82 (0.74)
V2G familiarity		−0.04 (0.04)	−0.05 (0.08)
Trip purpose leisure		−0.27 (0.19)	−0.44 (0.36)
Household size		−0.05 (0.10)	−0.14 (0.19)
EV ownership[a]		−0.30 (0.28)	−0.39 (0.56)
No car ownership[a]		−0.45** (0.21)	−0.73* (0.41)
Current carsharing membership		0.13 (0.19)	0.30 (0.36)
Residence Switzerland		0.16 (0.19)	0.25 (0.37)
V2G right position of choice set		−0.24 (0.19)	−0.48 (0.37)
ASC_{CO}		−0.60 (0.53)	−1.24 (1.12)
V2G familiarity		−0.15** (0.06)	−0.31** (0.14)
Trip purpose leisure		0.27 (0.25)	0.54 (0.57)
Household size		0.08 (0.15)	0.11 (0.32)
EV ownership[a]		−0.97** (0.39)	−2.66*** (0.97)
No car ownership[a]		−0.55** (0.25)	−1.11* (0.59)
Current carsharing membership		−0.11 (0.26)	−0.24 (0.62)
Residence Switzerland		0.23 (0.25)	0.32 (0.59)
V2G right position of choice set		0.16 (0.26)	0.32 (0.64)
Scale parameter pooled estimation (ζ)		0.97 (0.07)	1.00 (0.00)

(*continued on next page*)

Table 5 (*continued*).

Parameter	MNL Coef. (SE)	Mixed-logit Coef. (SE)
Preference heterogeneity parameters		
V2G (σ_{V2G})		1.63***
		(0.28)
CO (σ_{CO})		2.11***
		(0.54)
Cost (σ_{cost})		0.23***
		(0.04)
Remuneration ($\sigma_{remuneration}$)		5.47***
		(1.86)
Access time (σ_{access})		0.16***
		(0.03)
Egress time (σ_{egress})		0.03
		(0.04)
Free-floating ($\sigma_{free-floating}$)		1.68***
		(0.34)
Station-based ($\sigma_{station-based}$)		1.55***
		(0.32)
Range (σ_{range})		0.02
		(0.13)
Respondents	308	308
Choice observations	2464	2464
Draws		5000
LL(null)	−1707.91	−1707.91
LL(choicemodel)	−1266.25	−1122.96
AICc	2594.32	2332.93

*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.
[a]The reference category is that the respondent owns a conventional car but no EV.

2015), our results indicate a preference for V2G carsharing. Our part-worth analysis reveals that customers evaluate costs as most important for their utilities, which aligns with extant literature, showing that costs remain important for E-carsharing (De Luca and Di Pace, 2015; Cartenì et al., 2016). The willingness to accept additional access and egress time ranges from 0.33 EUR (Curtale et al., 2021) to 0.12 EUR (Brendel et al., 2016) and 0.27 USD (Wu et al., 2020) per walking minute. Our results show similar values for conventional carsharing but higher values for V2G and E-carsharing. Similar to extant literature, we find that free-floating schemes are likely to be preferred over station-based and round-trip schemes (Rotaris et al., 2019; Becker et al., 2017; Balac et al., 2019). Ho

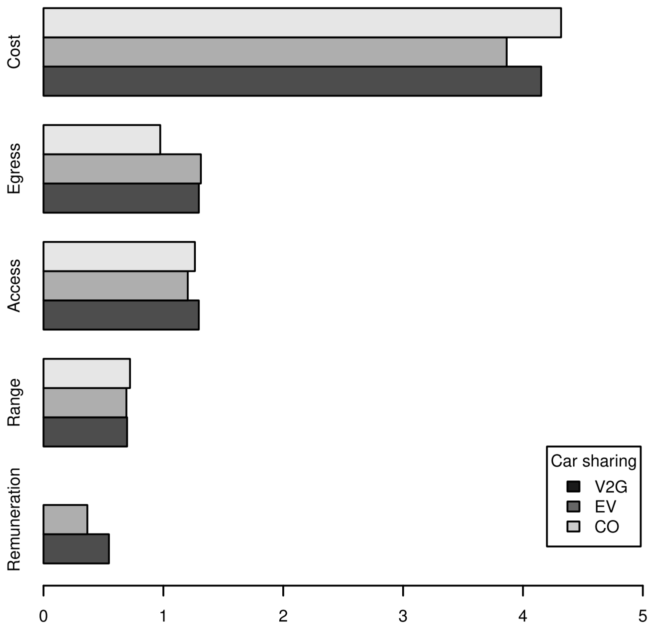

Fig. 1. Part-worth utilities; Relative importance of single attributes on decision-making in the mixed-logit model.

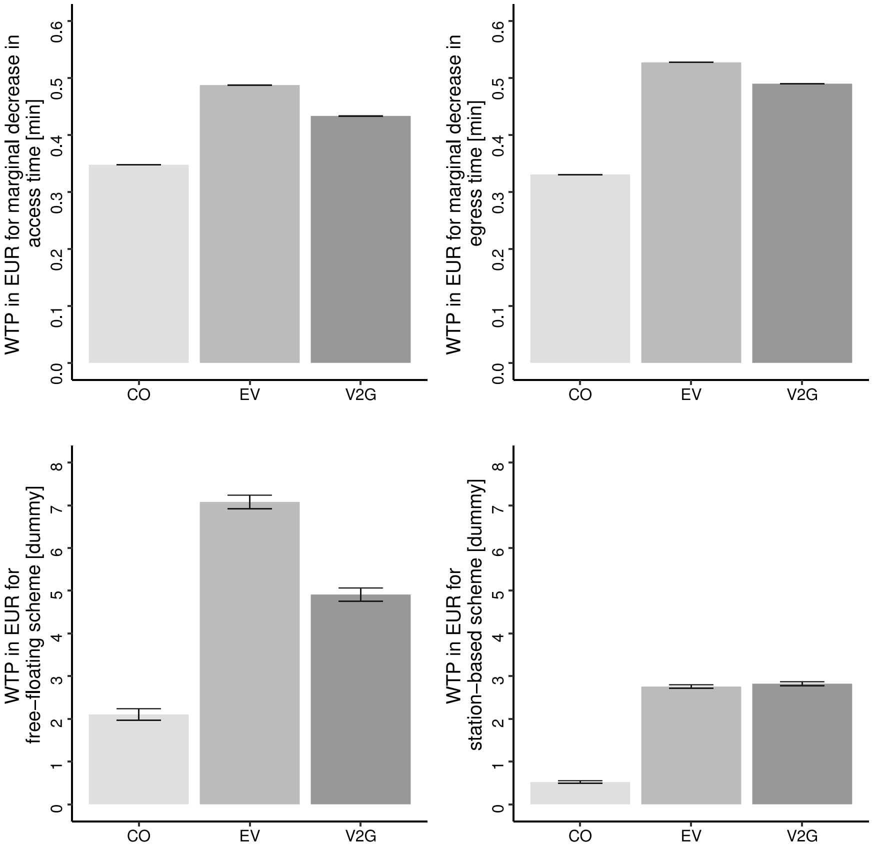

Fig. 2. WTP with 95%-confidence intervals.

et al. (2020) find a WTP of 5.28 GBP (95% Confidence Interval = [4.81 GBP, 5.74 GBP]) for an hour use of one-way carsharing, which aligns with our values of 4.91 EUR for free-floating V2G carsharing. Concerning range, our results confirm that providing longer ranges than required for the trip (as all attribute levels covered the whole trip) increases the attractiveness of carsharing (Wielinski et al., 2017; Jin et al., 2020).

The above analyses show that, overall, V2G is preferred over E-carsharing and particularly over conventional carsharing. However, costs, as well as access and egress times highly impact customers' choices. It should be noted that costs demonstrate the highest relative importance for customers' utilities despite the early-adopter characteristics of our sample, attributing high importance to the environment. Customers cannot be expected to sacrifice convenience as they are likely to prefer free-floating schemes for V2G and E-carsharing as has been found for conventional carsharing (Rotaris et al., 2019; Becker et al., 2017; Balac

Table 6
Marginal probability effects for selected parameters in the mixed-logit model.

Parameter	Change in	Unit	V2G	EV	CO
Cost	V2G	[EUR/h]	−14.78	7.34	7.43
Cost	EV	[EUR/h]	6.54	−6.54	–
Cost	CO	[EUR/h]	4.71	–	−4.71
Remuneration	V2G	[%-pts.]	1.61	−1.21	−0.39
Remuneration	EV	[%-pts.]	−0.87	0.87	–
Access	V2G	[min]	−5.11	2.86	2.25
Access	EV	[min]	2.41	−2.41	–
Egress	V2G	[min]	−5.06	2.41	2.65
Egress	EV	[min]	2.88	−2.88	–
Range	V2G	[%-pts.]	2.72	−1.57	−1.15
Range	EV	[%-pts.]	−1.62	1.62	–
Range	CO	[%-pts.]	−1.19	–	1.19
Free-floating	V2G		11.50	−6.73	−4.76
Station-based	V2G		4.96	−3.03	−1.92

et al., 2019). The high importance of access and egress times, in combination with free-floating as the preferred scheme, might be challenging for V2G carsharing as the cars need to be plugged-in to provide the expected additional revenue. Furthermore, large ranges are preferred even if the trip length would be covered with a smaller range. In addition to the service attributes, socio-demographic characteristics impact customers' choices. V2G carsharing benefits from customers' familiarity with V2G, EV ownership, and no car ownership.

4.2. Implications

From these results, we can derive four main implications for both carsharing operators and policy makers. First, despite higher infrastructure costs, V2G carsharing should be offered to a similar price as E- and conventional carsharing. It might be beneficial to forward some of the additional revenue from providing V2G services by directly integrating the discount into the costs rather than awarding them after using the service and plugging-in the car. The costs for V2G-enabled EVs, charging infrastructure, and potential remuneration for customers to plug-in the cars need to be compared to the additional revenue resulting from V2G service provision to the electricity system, considering future V2G service demand and cost developments. As the revenues of some flexibility services depend on local grid conditions, carsharing operators should investigate the extent of required V2G services in their operating area. In addition, policy makers could consider subsidizing V2G-enabled EVs and infrastructure to support their uptake and consequently, synergies between decarbonizing transport and electricity.

Second, access and egress times as the second most important service characteristics, in combination with free-floating as the preferred scheme, highlight the high relevance of charging infrastructure. Carsharing operators need to consider the interplay of public charging infrastructure and chargers in their depots. As it is crucial that EVs are plugged-in after their use to enable V2G service provision, short egress times combined with free-floating schemes depend on a well-functioning public charging network. While public chargers might reduce the costs for investing in operator-owned chargers, public chargers also increase the dependence of V2G carsharing on potentially uncertain public investments. Additionally, different ownership and payment structures of chargers might complicate their use (Sovacool et al., 2020). However, in contrast to E-carsharing, V2G service provision could regain potential additional costs resulting from required staff or incentives to plug-in cars after use in a free-floating scheme.

Third, as familiarity with EVs and V2G increase customers' interest in V2G carsharing, policy makers could consider supporting V2G awareness and education in society, for instance, with V2G carsharing pilot projects to increase all actors' experience. In addition, policy makers need to enable and support V2G and carsharing services in the first place. There are still regulatory barriers for V2G commercialization (Everoze and EVConsult, 2018) and entry-barriers for carsharing services, which could be reduced by free carsharing subscription periods or free parking space for shared cars (Sprei et al., 2019), for instance.

Fourth, carsharing operators have to consider in their charging strategies that customers are likely to request a substantially higher range than needed for the booked trip. If a carsharing operator's fleet shows a high utilization rate for mobility, it is difficult to extend the plug-in time beyond the required charging time. Depending on the utilization for mobility of specific car models in their fleets, carsharing operators could consider to purchase V2G-enabled EVs only for car models that are less frequently booked but still crucial to be offered in their fleets. The long plug-in times of these car models increase their possible use for V2G services to generate additional revenue.

5. Conclusion

Based on the $n = 2464$ observations in our stated-choice experiment and the estimated MNL, mixed-logit and WTP-space models, this work makes two contributions. First, we evaluate customers' interest in V2G carsharing and compare customers' preferences between V2G and E- as well as conventional carsharing. Second, we investigate induced differences in service characteristics to analyze how these changes impact customers' choices and to identify resulting customer needs.

Customers prefer V2G over conventional carsharing, mostly due to the comparable service V2G carsharing offers and the higher environmental standard it claims. More specifically, we can make four conclusions. First, costs show the highest relative importance for customers' utilities despite the early-adopter characteristics of our sample, attributing high importance to the environment. Directly integrating the discount into the costs might therefore be a better way of forwarding some of the additional revenue from V2G service provision than awarding the discount after using the service and plugging-in the car. Carsharing operators should compare additional costs for V2G-enabled EVs and infrastructure, including future cost developments, to the additional revenues from V2G services in their operating area, depending on the electricity system's (future) demand for V2G services. Second, our results regarding access and egress times as well as free-floating schemes highlight the importance of charging infrastructure. To avoid increases in access and egress times resulting from plugging-in EVs, carsharing operators need to account for the interplay of public charging infrastructure and chargers in their depots, considering V2G service provision could regain potential additional costs resulting from remunerations or required staff to plug-in cars after use in a free-floating scheme. Third, socio-demographic characteristics such as EV ownership and familiarity with V2G increase the preference for V2G carsharing, indicating a role for policy to support awareness and education for all involved actors. Fourth, although the available range always covered the trip length in our experiment, customers prefer longer ranges, which carsharing operators must consider in their charging strategies, potentially applying V2G only to car models with lower utilization rates for mobility.

Overall, V2G carsharing could increase the attractiveness of carsharing and might be an attractive option to gain additional revenues while carsharing vehicles are not booked or charged. Considering the higher investment costs for EVs, the potential financial benefits of providing V2G services could support carsharing operators in decarbonizing their fleets, assuming future cost decreases of V2G infrastructure. As V2G services can support the integration of more renewable electricity, V2G carsharing could be an attractive mobility concept supporting the decarbonization of both transport and electricity systems.

This study finds itself limited in certain dimensions. We conducted a stated-choice experiment based on a hypothetical situation. Therefore, results might differ from observed preference experiments, which are however difficult to conduct in this context, as V2G carsharing is not yet widely commercially available. In addition, we forced our respondents to choose between two carsharing service types and did not provide a "none" option. Therefore, some respondents might not use carsharing in the first place. Moreover, respondents were contacted without giving them a prior opt-in or opt-out opportunity, which might lead to a self-selection bias that makes the survey more attractive to people generally interested in the topic. Furthermore, the sample represents well-educated men more than other parts of the population, which might limit the applicability of the results to the early adopters that are typically more optimistic about new technologies than the average population.

Further research could conduct similar stated-choice experiments with a different geographical focus to account for local differences in travel behavior and preferences. Moreover, different types of remuneration could be investigated, such as bonus points accumulating to a free carsharing trip, for instance. In addition, further research could conduct financial analyses in collaboration with carsharing operators to investigate the required (future) investment costs for V2G infrastructure and the resulting annual revenues from V2G services, depending on the (future) requirements of the electricity system and the car utilization rates for mobility. Further research could also investigate the additional value of public charging infrastructure compared to limiting the charging opportunities to the carsharing operators' depots. Additionally, further research could analyze the specific effect of V2G carsharing on moving away from car ownership, potentially in comparison to carsharing with other vehicle technologies.

CRediT authorship contribution statement

Christine Gschwendtner: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Konstantin Krauss:** Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Literature review

Table A.1
Overview of attributes investigated in previous stated-choice experiments on V2G car ownership in a domestic context.

Investigated attributes	Geske and Schumann (2018)	Hidrue and Parsons (2015)	Kubli et al. (2018)	Meijssen (2019)	Noel et al. (2019c)	Parsons et al. (2014)	Zonneveld (2019)
Guaranteed minimum driving range on V2G contract	x	x	x	x		x	x
Fixed remuneration (monthly or annual)	x	x	x	x		x	x
Required plug-in time per day	x	x		x		x	x
Charging speed		x				x	x
Driving range on full battery		x			x	x	
Acceleration compared to preferred conventional gasoline vehicle		x				x	x
Full vehicle purchase price		x			x	x	
Discharging cycles			x	x			x
Contract duration			x	x			x
Premium for buying a car	x						
Pollution compared to preferred conventional gasoline vehicle						x	
Variable remuneration (depending on additional plug-in time)				x			
Number of days drawn to the guaranteed minimum battery level (per month)				x			
Fuel type (i.e. renewable energy or fossil fuels)					x		

Appendix B. Experimental design

The following descriptions of the alternatives and attributes were attached to the choice sets.

Table B.1
Alternatives and descriptions.

Alternative	Description
Petrol-/Diesel-carsharing	This alternative is a carsharing system using conventional vehicles with petrol or diesel engines.
E-carsharing	This alternative is a carsharing system using electric vehicles (EV) with standard charging technology.
V2G carsharing	This alternative is a carsharing system using cars with a vehicle-to-grid (V2G) charging function. This enables to not only charge but also discharge the vehicle battery when it is connected to a charging station. As V2G can support the electricity grid to integrate more renewable energy and potentially avoid expensive electricity network reinforcement, the car owner can earn some revenue for providing V2G services to the grid. Therefore, the carsharing service with V2G function can be offered cheaper.

Choice 1	E-car sharing	V2G-car sharing
Trip length	100 km	100 km
Minimum range	200 %	125 %
Cost per hour before remuneration	7 € or CHF	7 € or CHF
Remuneration of total trip costs	10 %	10 %
Scheme	Free-floating	Roundtrip
Access time	15 min	3 min
Egress time	15 min	8 min

Fig. B.1. Example of choice situation: V2G vs. E-carsharing.

Choice 1	Petrol-/ Diesel-car sharing	V2G-car sharing
Trip length	50 km	50 km
Minimum range	200 %	125 %
Cost per hour (before remuneration)	7 € or CHF	7 € or CHF
Remuneration of total trip costs	/	30 %
Scheme	Station-based	Free-floating
Access time	15 min	3 min
Egress time	15 min	15 min

Fig. B.2. Example pf choice situation: V2G vs. conventional carsharing.

Table B.2
Attributes of the alternatives and descriptions.

Attribute	Description
Trip length in kilometers:	Total distance you travel in each of the following choice tasks and is the same for both carsharing alternatives.
Minimum range in percentage of trip length:	Minimum distance you can drive the car with the current battery charge level. The minimum range is always larger than the trip length. E.g. if the trip length is 50km and the minimum range is 200%, you can drive the car for 100km without charging.
Cost per hour before remuneration in EUR or CHF:	Price you have to pay per hour for using the car. It includes all kilometers traveled and all costs related to the car including maintenance, insurance, and electricity.
Remuneration in percentage of total trip costs:	Discount you receive on the total trip costs for plugging-in the vehicle to a charging station at your destination.
Scheme:	Way in which you can access and return the car. There are three options: **Station-based** means that you have to access and return the car at a station of the provider, but not necessarily at the same station. **Round-trip** means that you have to access and return the car at the same station of the provider. **Free-floating** means that you can access and return the car anywhere within the area of operation of the provider (locations of the cars can be found online). Station-based and free-floating schemes allow one-way trips, which are not allowed in roundtrip schemes.
Access time in minutes:	Time you need to get from the origin of your trip (e.g. leaving home) to the car you booked.
Egress time in minutes:	Time you need to get from the parked car to the destination of your trip. If you plug-in your vehicle to a charging station, egress time might increase to find a suitable charging station. In return, you receive remuneration for plugging-in your vehicle.

Appendix C. Sample characteristics

Table C.1
Socio-demographic characteristics of the sample.

Characteristic	Value	% N = 331
Country	Germany	58.4
	Switzerland	35.4
	Other	6.2
Residential area	Rural	26.4
	Suburban	22.7
	Urban	50.8
Age	<20 years	0.6
(Mean = 40, SD = 15.4)	20–29 years	36.2
	30–39 years	23.3
	40–49 years	10.5
	50–59 years	14.5
	60–69 years	10.4
	70–79 years	3.3
	≥ 80 years	0.00
Gender	Female	21.7
	Male	75.0
	Other/Not specified	3.3
Education	High school diploma or equivalent	2.4
	Qualif. for university entrance	11.5
	Completed vocational training	11.5
	University/College degree	74.7
Occupation	Full-time employed	72.0
	Part-time employed	5.9
	Housewife/-husband	0.9
	Student	11
	Retired	9.4
	Unemployed	0.9
Income per year	<10,000 CHF or EUR	7.9
	10,000–50,000 CHF or EUR	34.9
	50,000–100,000 CHF or EUR	47.6
	>100,000 CHF or EUR	9.7

(*continued on next page*)

Table C.1 (*continued*).

Characteristic	Value	% N = 331
Household size (Mean = 2.54, SD = 1.11)	1 person	13.5
	2 persons	46.3
	3 persons	19.9
	4 persons	12.6
	5 or more persons	7.6
Number of children under 18 years living in the household (Mean = 0.33, SD = 0.74)	No children	80.8
	1 child	8.4
	2 children	7.9
	3 or more children	2.9%

Appendix D. Mathematical formulation of utility functions

In the following, we state the utility functions per model and alternative for each respondent n with β as coefficient for the respective attribute, α as coefficient of the alternative specific constants, ζ as scale for the pooled estimation, σ as preference heterogeneity parameters, η as the Sobol draws from the respective distribution, ASC as alternative-specific constant, and ϵ as random error term.

MNL model

$$\begin{aligned} U_{MNL_{V2G,n}} =& \zeta_{pooled} * \Big(\beta_{range} * \frac{range_{V2G}}{100} + \beta_{cost,n} * cost_{V2G} + \\ & \beta_{remun,n} * \frac{remun_{V2G}}{100} + \beta_{FF} * FF_{V2G} + \beta_{SB} * SB_{V2G} + \\ & \beta_{access} * access_{V2G} + \beta_{egress} * egress_{V2G} \Big) + \epsilon_{V2G,n} \end{aligned} \tag{D.1}$$

with

$$\beta_{cost,n} = \beta_{cost} + \beta_{cost_{leisure}} * leisure$$
$$\beta_{remun,n} = \beta_{remun} + \beta_{remun_{hhsize}} * hhsize$$

$$\begin{aligned} U_{MNL_{EV,n}} =& ASC_{EV} + \beta_{range} * \frac{range_{EV}}{100} + \beta_{cost,n} * cost_{EV} + \\ & \beta_{remun,n} * \frac{remun_{EV}}{100} + \beta_{FF} * FF_{EV} + \beta_{SB} * SB_{EV} + \\ & \beta_{access} * access_{EV} + \beta_{egress} * egress_{EV} + \epsilon_{EV,n} \end{aligned} \tag{D.2}$$

with

$$\begin{aligned} ASC_{EV,n} =& ASC_{EV} + \alpha_{leisure_{EV}} * leisure_{EV} + \alpha_{V2Gfamil_{EV}} * V2Gfamil_{EV} + \\ & \alpha_{hhsize_{EV}} * hhsize_{EV} + \alpha_{EVown_{EV}} * EVown_{EV} + \\ & \alpha_{NOcar_{EV}} * NOcar_{EV} + \alpha_{CSmemb_{EV}} * CSmemb_{EV} + \\ & \alpha_{Swiss_{EV}} * Swiss_{EV} + \alpha_{V2Gright_{EV}} * V2Gright_{EV} \end{aligned}$$

$$\beta_{cost,n} = \beta_{cost} + \beta_{cost_{leisure}} * leisure$$
$$\beta_{remun,n} = \beta_{remun} + \beta_{remun_{hhsize}} * hhsize$$

$$\begin{aligned} U_{MNL_{CO,n}} =& ASC_{CO} + \beta_{range} * \frac{range_{CO}}{100} + \beta_{cost,n} * cost_{CO} + \beta_{FF} * FF_{CO} + \\ & \beta_{SB} * SB_{CO} + \beta_{access} * access_{CO} + \\ & \beta_{egress} * egress_{CO} + \epsilon_{CO,n} \end{aligned} \tag{D.3}$$

with

$$\begin{aligned} ASC_{CO,n} =& ASC_{CO} + \alpha_{leisure_{CO}} * leisure_{CO} + \alpha_{V2Gfamil_{CO}} * V2Gfamil_{CO} + \\ & \alpha_{hhsize_{CO}} * hhsize_{CO} + \alpha_{EVown_{CO}} * EVown_{CO} + \\ & \alpha_{NOcar_{CO}} * NOcar_{CO} + \alpha_{CSmemb_{CO}} * CSmemb_{CO} + \\ & \alpha_{Swiss_{CO}} * Swiss_{CO} + \alpha_{V2Gright_{CO}} * V2Gright_{CO} \end{aligned}$$

$$\beta_{cost,n} = \beta_{cost} + \beta_{cost_{leisure}} * leisure$$

Mixed-logit model

$$
\begin{aligned}
U_{mixed-logit_{V2G,n}} =&\zeta_{pooled} * \Big(ASC_{V2G,n} + \beta_{range,n} * \frac{range_{V2G}}{100} + \\
&\beta_{cost,n} * cost_{V2G} + \beta_{remun,n} * \frac{remun_{V2G}}{100} + \\
&\beta_{FF,n} * FF_{V2G} + \beta_{SB,n} * SB_{V2G} + \beta_{access,n} * access_{V2G} + \\
&\beta_{egress,n} * egress_{V2G} + \beta_{triplength} * triplength_{V2G} \Big) + \epsilon_{V2G,n}
\end{aligned} \tag{D.4}
$$

with

$ASC_{V2G,n} = 0 + \eta_{V2G,n} * \sigma_{V2G}$ with $\eta_{V2G,n} \sim N(0,1)$
$\beta_{range,n} = \beta_{range} + \eta_{range,n} * \sigma_{range}$ with $\eta_{range,n} \sim N(0,1)$
$\beta_{cost,n} = \beta_{cost} + \beta_{cost_{leisure}} * leisure + \eta_{cost,n} * \sigma_{cost}$ with $\eta_{cost,n} \sim N(0,1)$
$\beta_{remun,n} = \beta_{remun} + \beta_{remun_{hhsize}} * hhsize + \eta_{remun,n} * \sigma_{remun}$
with $\eta_{remun,n} \sim N(0,1)$
$\beta_{FF,n} = \beta_{FF} + \eta_{FF,n} * \sigma_{FF}$ with $\eta_{FF,n} \sim N(0,1)$
$\beta_{SB,n} = \beta_{SB} + \eta_{SB,n} * \sigma_{SB}$ with $\eta_{SB,n} \sim N(0,1)$
$\beta_{access,n} = \beta_{access} + \eta_{access,n} * \sigma_{access}$ with $\eta_{access,n} \sim N(0,1)$
$\beta_{egress,n} = \beta_{egress} + \eta_{egress,n} * \sigma_{egress}$ with $\eta_{egress,n} \sim N(0,1)$

$$
\begin{aligned}
U_{mixed-logit_{EV,n}} =&ASC_{EV,n} + \beta_{range,n} * \frac{range_{EV}}{100} + \beta_{cost,n} * cost_{EV} + \\
&\beta_{remun,n} * \frac{remun_{EV}}{100} + \beta_{FF,n} * FF_{EV} + \\
&\beta_{SB,n} * SB_{EV} + \beta_{access,n} * access_{EV} + \\
&\beta_{egress,n} * egress_{EV} + \beta_{triplength} * triplength_{EV} + \epsilon_{EV,n}
\end{aligned} \tag{D.5}
$$

with

$$
\begin{aligned}
ASC_{EV,n} =&ASC_{EV} + \alpha_{leisure_{EV}} * leisure_{EV} + \alpha_{V2Gfamil_{EV}} * V2Gfamil_{EV} + \\
&\alpha_{hhsize_{EV}} * hhsize_{EV} + \alpha_{EVown_{EV}} * EVown_{EV} + \\
&\alpha_{NOcar_{EV}} * NOcar_{EV} + \alpha_{CSmemb_{EV}} * CSmemb_{EV} + \\
&\alpha_{Swiss_{EV}} * Swiss_{EV} + \alpha_{V2Gright_{EV}} * V2Gright_{EV}
\end{aligned}
$$

$\beta_{range,n} = \beta_{range} + \eta_{range,n} * \sigma_{range}$ with $\eta_{range,n} \sim N(0,1)$
$\beta_{cost,n} = \beta_{cost} + \beta_{cost_{leisure}} * leisure + \eta_{cost,n} * \sigma_{cost}$ with $\eta_{cost,n} \sim N(0,1)$
$\beta_{remun,n} = \beta_{remun} + \beta_{remun_{hhsize}} * hhsize + \eta_{remun,n} * \sigma_{remun}$
with $\eta_{remun,n} \sim N(0,1)$
$\beta_{FF,n} = \beta_{FF} + \eta_{FF,n} * \sigma_{FF}$ with $\eta_{FF,n} \sim N(0,1)$
$\beta_{SB,n} = \beta_{SB} + \eta_{SB,n} * \sigma_{SB}$ with $\eta_{SB,n} \sim N(0,1)$
$\beta_{access,n} = \beta_{access} + \eta_{access,n} * \sigma_{access}$ with $\eta_{access,n} \sim N(0,1)$
$\beta_{egress,n} = \beta_{egress} + \eta_{egress,n} * \sigma_{egress}$ with $\eta_{egress,n} \sim N(0,1)$

$$
\begin{aligned}
U_{mixed-logit_{CO,n}} =&ASC_{CO,n} + \beta_{range,n} * \frac{range_{CO}}{100} + \beta_{cost,n} * cost_{CO} + \\
&\beta_{FF,n} * FF_{CO} + \beta_{SB,n} * SB_{CO} + \beta_{access,n} * access_{CO} + \\
&\beta_{egress,n} * egress_{CO} + \beta_{triplength} * triplength_{CO} + \epsilon_{CO,n}
\end{aligned} \tag{D.6}
$$

with

$$
\begin{aligned}
ASC_{CO,n} =&ASC_{CO} + \alpha_{leisure_{CO}} * leisure_{CO} + \alpha_{V2Gfamil_{CO}} * V2Gfamil_{CO} + \\
&\alpha_{hhsize_{CO}} * hhsize_{CO} + \alpha_{EVown_{CO}} * EVown_{CO} + \\
&\alpha_{NOcar_{CO}} * NOcar_{CO} + \alpha_{CSmemb_{CO}} * CSmemb_{CO} +
\end{aligned}
$$

$$\alpha_{Swiss_{CO}} * Swiss_{CO} + \alpha_{V2Gright_{CO}} * V2Gright_{CO} + \eta_{CO,n} * \sigma_{CO}$$

with $\eta_{CO,n} \sim N(0,1)$

$$\beta_{range,n} = \beta_{range} + \eta_{range,n} * \sigma_{range} \text{ with } \eta_{range,n} \sim N(0,1)$$
$$\beta_{cost,n} = \beta_{cost} + \beta_{cost_{leisure}} * leisure + \eta_{cost,n} * \sigma_{cost} \text{ with } \eta_{cost,n} \sim N(0,1)$$
$$\beta_{FF,n} = \beta_{FF} + \eta_{FF,n} * \sigma_{FF} \text{ with } \eta_{FF,n} \sim N(0,1)$$
$$\beta_{SB,n} = \beta_{SB} + \eta_{SB,n} * \sigma_{SB} \text{ with } \eta_{SB,n} \sim N(0,1)$$
$$\beta_{access,n} = \beta_{access} + \eta_{access,n} * \sigma_{access} \text{ with } \eta_{access,n} \sim N(0,1)$$
$$\beta_{egress,n} = \beta_{egress} + \eta_{egress,n} * \sigma_{egress} \text{ with } \eta_{egress,n} \sim N(0,1)$$

Model in WTP-space

$$\begin{aligned} U_{WTP_{V2G,n}} =&\zeta_{pooled} * \Bigg[ASC_{V2G,n} + \beta_{cost,n} * \Bigg(\beta_{range,n} * \frac{range_{V2G}}{100} + \\ &\beta_{remun,n} * \frac{remun_{V2G}}{100} + \beta_{FF,V2G,n} * FF_{V2G} + \beta_{SB,V2G,n} * SB_{V2G} + \\ &\beta_{access,V2G,n} * access_{V2G} + \beta_{egress,V2G,n} * egress_{V2G} + \\ &\beta_{triplength} * triplength_{V2G} + cost_{V2G}\Bigg)\Bigg] + \epsilon_{V2G,n} \end{aligned} \tag{D.7}$$

with

$$ASC_{V2G,n} = 0 + \eta_{V2G,n} * \sigma_{V2G} \text{ with } \eta_{V2G,n} \sim N(0,1)$$
$$\beta_{range,n} = \beta_{range} + \eta_{range,n} * \sigma_{range} \text{ with } \eta_{range,n} \sim N(0,1)$$
$$\beta_{cost,n} = \beta_{cost} + \beta_{cost_{leisure}} * leisure + \eta_{cost,n} * \sigma_{cost} \text{ with } \eta_{cost,n} \sim N(0,1)$$
$$\beta_{remun,n} = \beta_{remun} + \beta_{remun_{hhsize}} * hhsize + \eta_{remun,n} * \sigma_{remun}$$

with $\eta_{remun,n} \sim N(0,1)$

$$\beta_{FF,V2G,n} = \beta_{FF,V2G} + \eta_{FF,V2G,n} * \sigma_{FF} \text{ with } \eta_{FF,V2G,n} \sim N(0,1)$$
$$\beta_{SB,V2G,n} = \beta_{SB,V2G} + \eta_{SB,V2G,n} * \sigma_{SB} \text{ with } \eta_{SB,V2G,n} \sim N(0,1)$$
$$\beta_{access,V2G,n} = \beta_{access,V2G} + \eta_{access,V2G,n} * \sigma_{access} \text{ with } \eta_{access,V2G,n} \sim N(0,1)$$
$$\beta_{egress,V2G,n} = \beta_{egress,V2G} + \eta_{egress,V2G,n} * \sigma_{egress} \text{ with } \eta_{egress,V2G,n} \sim N(0,1)$$

$$\begin{aligned} U_{WTP_{EV,n}} =&ASC_{EV,n} + \beta_{cost,n} * \Bigg(\beta_{range,n} * \frac{range_{EV}}{100} + \\ &\beta_{remun,n} * \frac{remun_{EV}}{100} + \beta_{FF,EV,n} * FF_{EV} + \beta_{SB,EV,n} * SB_{EV} + \\ &\beta_{access,EV,n} * access_{EV} + \beta_{egress,EV,n} * egress_{EV} + \\ &\beta_{triplength} * triplength_{EV} + cost_{EV}\Bigg) + \epsilon_{EV,n} \end{aligned} \tag{D.8}$$

with

$$\begin{aligned} ASC_{EV,n} =&ASC_{EV} + \alpha_{V2Gfamil_{EV}} * V2Gfamil_{EV} + \alpha_{EVown_{EV}} * EVown_{EV} + \\ &\alpha_{NOcar_{EV}} * NOcar_{EV} \end{aligned}$$

$$\beta_{range,n} = \beta_{range} + \eta_{range,n} * \sigma_{range} \text{ with } \eta_{range,n} \sim N(0,1)$$
$$\beta_{cost,n} = \beta_{cost} + \beta_{cost_{leisure}} * leisure + \eta_{cost,n} * \sigma_{cost} \text{ with } \eta_{cost,n} \sim N(0,1)$$
$$\beta_{remun,n} = \beta_{remun} + \beta_{remun_{hhsize}} * hhsize + \eta_{remun,n} * \sigma_{remun}$$

with $\eta_{remun,n} \sim N(0,1)$

$$\beta_{FF,EV,n} = \beta_{FF,EV} + \eta_{FF,EV,n} * \sigma_{FF} \text{ with } \eta_{FF,EV,n} \sim N(0,1)$$
$$\beta_{SB,EV,n} = \beta_{SB,EV} + \eta_{SB,EV,n} * \sigma_{SB} \text{ with } \eta_{SB,EV,n} \sim N(0,1)$$
$$\beta_{access,EV,n} = \beta_{access,EV} + \eta_{access,EV,n} * \sigma_{access} \text{ with } \eta_{access,EV,n} \sim N(0,1)$$
$$\beta_{egress,EV,n} = \beta_{egress,EV} + \eta_{egress,EV,n} * \sigma_{egress} \text{ with } \eta_{egress,EV,n} \sim N(0,1)$$

$$U_{WTP_{CO,n}} =ASC_{CO,n} + \beta_{cost,n} * \Bigg(\beta_{range,n} * \frac{range_{CO}}{100} +$$

$$\beta_{FF,CO,n} * FF_{CO} + \beta_{SB,CO,n} * SB_{CO} + \\ \beta_{access,CO,n} * access_{CO} + \beta_{egress,CO,n} * egress_{CO} + \\ \beta_{triplength} * triplength_{CO} + cost_{CO} \Big) + \epsilon_{CO,n} \tag{D.9}$$

with

$$ASC_{CO,n} = ASC_{CO} + \alpha_{V2Gfamil_{CO}} * V2Gfamil_{CO} + \alpha_{EVown_{CO}} * EVown_{CO} + \\ \alpha_{NOcar_{CO}} * NOcar_{CO} + \eta_{CO,n} * \sigma_{CO}$$

with $\eta_{CO,n} \sim N(0,1)$

$$\beta_{range,n} = \beta_{range} + \eta_{range,n} * \sigma_{range} \text{ with } \eta_{range,n} \sim N(0,1)$$
$$\beta_{cost,n} = \beta_{cost} + \beta_{cost_{leisure}} * leisure + \eta_{cost,n} * \sigma_{cost} \text{ with } \eta_{cost,n} \sim N(0,1)$$
$$\beta_{FF,CO,n} = \beta_{FF,CO} + \eta_{FF,CO,n} * \sigma_{FF} \text{ with } \eta_{FF,CO,n} \sim N(0,1)$$
$$\beta_{SB,CO,n} = \beta_{SB,CO} + \eta_{SB,CO,n} * \sigma_{SB} \text{ with } \eta_{SB,CO,n} \sim N(0,1)$$
$$\beta_{access,CO,n} = \beta_{access,CO} + \eta_{access,CO,n} * \sigma_{access} \text{ with } \eta_{access,CO,n} \sim N(0,1)$$
$$\beta_{egress,CO,n} = \beta_{egress,CO} + \eta_{egress,CO,n} * \sigma_{egress} \text{ with } \eta_{egress,CO,n} \sim N(0,1)$$

Utility functions used in Ngene code

$$U_{V2G} = b_1 * length[20,50,100] + b_2 * range[125,150,200] + b_3 * cost[7,12,18] + b_4 * remun[5,10,30] + \\ b_{5_{dummy}} * scheme_1[1,0] + b_{6_{dummy}} * scheme_2[1,0] + b_7 * access[3,8,15] + b_8 * egress[3,8,15] + \\ b_9 * length * length + b_{10} * range * range + b_{11} * cost * cost + b_{12} * remun * remun + \\ b_{13} * access * access + b_{14} * egress * egress \tag{D.10}$$

$$U_{EV} = b_{15} * range[125,150,200] + b_{16} * cost[7,12,18] + b_{17} * remun[5,10,30] + b_{18_{dummy}} * scheme_1[1,0] + \\ b_{19_{dummy}} * scheme_2[1,0] + b_{20} * access[3,8,15] + b_{21} * egress[3,8,15] + b_{22} * range * range + \\ b_{23} * cost * cost + b_{24} * remun * remun + b_{25} * access * access + b_{26} * egress * egress \tag{D.11}$$

$$U_{CO} = b_{27} * range[125,150,200] + b_{28} * cost[7,12,18] + b_{29_{dummy}} * scheme_1[1,0] + b_{30_{dummy}} * scheme_2[1,0] + \\ b_{31} * access[3,8,15] + b_{32} * egress[3,8,15] + b_{33} * range * range + b_{34} * cost * cost + \\ b_{35} * access * access + b_{36} * egress * egress \tag{D.12}$$

Appendix E. WTP-space model estimation results

Table E.1
WTP-space model estimation results with robust standard errors in brackets.

Parameter		WTP Coef. (SE)
Cost	[EUR]	−0.27*** (0.04)
Cost & trip purpose leisure	[EUR]	−0.07* (0.04)
Remuneration	[%-pts.]	−3.54 (6.55)
Remuneration & household size	[%-pts.]	−2.81 (2.42)
Access time		
Access time V2G	[min]	0.43*** (0.07)
Access time EV	[min]	0.49*** (0.10)
Access time CO	[min]	0.35*** (0.13)

(continued on next page)

Table E.1 (*continued*).

Parameter		WTP Coef. (SE)
Egress time		
Egress time V2G	[min]	0.49*** (0.08)
Egress time EV	[min]	0.53*** (0.09)
Egress time CO	[min]	0.33*** (0.09)
Free-floating (round-trip as reference)		
Free-floating V2G		−4.91*** (0.92)
Free-floating EV		−7.06*** (1.33)
Free-floating CO		−2.11** (1.03)
Station-based (round-trip as reference)		
Station-based V2G		−2.82*** (0.80)
Station-based EV		−2.76** (1.15)
Station-based CO		−0.52 (1.10)
Trip length	[km]	0.11 (0.12)
Range		0.26** (0.11)
Range V2G	[%-pts.]	−0.99 (0.97)
Range EV	[%-pts.]	−1.63* (0.92)
Range CO	[%-pts.]	−2.59** (1.14)
Alternative specific constants (V2G as reference)		
ASC_{EV}		0.34 (0.51)
V2G familiarity		−0.04 (0.07)
EV ownership[a]		−0.43 (0.44)
No car ownership[a]		−0.40 (0.31)
ASC_{CO}		−0.68 (0.66)
V2G familiarity		−0.21** (0.10)
EV ownership[a]		−2.07*** (0.73)
No car ownership[a]		−0.66 (0.46)
Scale parameter pooled estimation (ζ)		0.90 (0.07)
Preference heterogeneity parameters		
V2G (σ_{V2G})		1.33*** (0.23)
CO (σ_{CO})		1.32*** (0.44)
Cost (σ_{cost})		0.20*** (0.03)
Remuneration ($\sigma_{remuneration}$)		10.25* (6.02)
Access time (σ_{access})		0.04 (0.08)
Egress time (σ_{egress})		0.01 (0.03)
Free-floating ($\sigma_{free-floating}$)		4.13***

(*continued on next page*)

Table E.1 (*continued*).

Parameter	WTP Coef. (SE)
	(0.91)
Station-based ($\sigma_{station-based}$)	2.02*
	(1.17)
Range (σ_{range})	0.05
	(0.12)
Respondents	308
Choice observations	2464
Draws	5000
LL(null)	−1707.91
LL(choicemodel)	−1141.09
AICc	2369.20

*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.
[a]The reference category is that the respondent owns a conventional car but no EV.

Appendix F. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.trd.2022.103261. This includes the entire survey for this experiment while we used branching and random selection in the actual survey.

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