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Users' perspectives of bi-directional charging in public environments

Dr. Érika Martins Silva Ramos[1*], Dr. Thomas Lindgren[2], Dr. Jonas Andersson[1], Dr. Jens Hagman[1]

[1*]*RISE Research Institutes of Sweden, Lindholmspiren 7A, 417 56 Göteborg, erika.martins.silva.ramos@ri.se*

[1] *RISE Research Institutes of Sweden*

[2]*Volvo Cars AB*

Vehicle users' adoption of vehicle-to-grid (V2G) is essential for the system's ability to perform V2G grid services. What charging preferences, needs and routines do EV users have and why? What future expectations do EV users have for bi-directional charging? To answer these research questions, a multimethod study is performed (interviews and survey). The following themes were identified as critical for the acceptance of V2G technology in the everyday life of the interviewees: Convenient and resilient home, minimum range for emergencies, fear of battery degradation, trust in system providers, economic and social incentives, user preferences and need for control. Linear regression models identified associations between sociodemographic characteristics and evaluations of V2G in terms of sustainability and efficiency. The interest in creating resilient homes among certain consumers and EV drivers suggests a demand for services that integrate technologies for home energy efficiency and V2G.

Keywords: Electric Vehicles; Consumer behaviour; V2H&V2G; Social equity; Optimal charging locations

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1 Introduction

Vehicle-to-grid (V2G) has the potential to improve the energy demand between electric vehicles and the electricity system. The potential implications of V2G are reduced negative climate impact by increased use of renewable electricity, reduced electricity costs for users and decreased need for electricity network expansions by improved optimization of electricity usage.

Vehicle users' adoption of V2G is essential for the system's ability to perform many, if not all, of the potential V2G grid services. Important user behaviours for V2G include accepting to take part in V2G, plug-in probability, plug-in time and percentage of the battery capacity shared to V2G. Behaviours that in turn are dependent on users' knowledge, motivations and possible financial and non-financial incentives. Therefore, research on users' behaviour, needs and interconnections with other actors in the V2G ecosystem is important.

All these behavioural and psychological factors affect to what extent and at what pace the market for V2G will grow [1]. Therefore, the PEPP project (Public EV Power Pilots), funded by the Swedish Energy Agency, aims at understanding how the features of V2G and user's interaction with the technology should be designed to support the adoption of V2G.

1.1 Literature review

After a review of the recent publications in the field, three key aspects were found relevant to understand users' behaviors and needs in the context of V2G services in public spaces. The key aspects are the barriers faced by the users, what kind of incentives they are most influenced by, and the energy consumption behavior at the household level. Most of the studies use methods such as expert interviews, choice experiments, and surveys.

Barriers

Range anxiety has been listed as one of the main barriers for drivers to consider adopting V2G technology [1], since range concerns would decrease the willingness to share battery capacity through V2G. Other behavioral aspects also play a substantial role in the adoption of V2G, such as charging preferences, the desired state of charge, time constraints, minimum plug-in hours, driving range, and contract terms [2]–[6]. In terms of psychological aspects, the need for control, guilt-free mobility, hedonic aspects, gender roles, feeling of making a smart choice, perceived transparency of contract terms, and willingness to pay are among the psychological aspects to limit the use of V2G if the implementation is not tailored towards the users' needs and boundaries [7]. Other relevant barriers are double taxation, negative experiences with public charging point [8], lack of understanding and trust in the actors involved in V2G services and fears related to battery degradation [9].

Incentives

Using a self-report online survey conducted among 929 Norwegian car users in November 2021, a study examined how perceptions and beliefs about the V2G system influence both electric vehicle (EV) users and non-EV users (combustion engine car owners as potential future EV users) to utilize V2G technology. The main findings from the authors were that positive perceptions and beliefs about V2G technology significantly motivate users to adopt it, while concerns about the reliability and cost of V2G systems are major barriers to adoption. Younger users and those with higher environmental awareness are more likely to support V2G technology [10].

While several businesses have been emerging in the European and Nordic markets aiming at monetizing V2G services, some studies have identified other drivers for V2G participation, such as the idea of having a smart and resilient home. A Swedish study conducted an online questionnaire to gather data from Swedish EV drivers. Respondents were asked about their preferences and concerns related to V2X applications. The study found that Swedish EV drivers are more interested in V2H applications compared to V2G. V2H allows EVs to supply power to homes, which is seen as more beneficial by the respondents [11].

In a study of how household values and attitudes towards automated electric vehicle (EV) charging systems influence the adoption and use of such technology, the authors identified that households prioritize environmental sustainability and express a strong preference for technologies that contribute to a cleaner planet. They also found that automated EV charging is seen as beneficial for reducing the environmental footprint and simplifying the charging process for their participants [12].

While non-monetary incentives, such as having a smart, sustainable and resilient household, may be an important driver for potential users of V2G services, the literature has also looked at the potential economic incentives and revenues for the users that could increase willingness to participate in V2G services.

A Norwegian study found that Norwegians require a financial compensation (FC) of $144 and a minimum state of charge (SoC) of 71% to use V2G services. The analysis revealed a reciprocal and negative relationship between FC and minimum SoC, both influenced by external factors. In a multi-equation equilibrium context, the marginal effects indicate that a one-unit increase in minimum SoC leads to a $5 reduction in the expected FC, all else being equal. Conversely, a $1 increase in FC results in a 0.05 decrease in the required minimum SoC, all else being equal [13].

The economic relationship between minimum SoC and FC is significantly affected by factors such as age, perceived usefulness of the V2G system, experience with EVs, and higher levels of trust in the V2G system. Specifically, individuals with high trust in V2G require less FC for a given amount of minimum SoC. Additionally, younger individuals (aged 18–22) tend to demand higher FC when minimum SoC is reduced.

Energy consumption at household level

Monetizing V2G services for the users is one of the challenges currently faced by the actors in the V2G ecosystem. Part of it is due to the high level of uncertainty from different actors, including users' charging behaviors. Another aspect of it is the tight relationship of users' charging behavior and their electricity consumption at the household level.

Typically, an EV tends to consume 50% of the electricity in a household, therefore the electricity contracts and other energy related appliances in the household are important factors in how much revenues users may have from V2G services, such as connecting solar PVs with V2G services. It's important to note that the variation in how financial incentives are perceived may be influenced by the type or design of these incentives. Different forms of incentives, such as tax credits, rebates, subsidies, or discounts on electricity bills, can have diverse effects on users' willingness to adopt V2G technology, and they vary across countries.

The V2G services connected to electricity contracts tend to work based on ToU (Time of Use) contracts, although variable rates for electricity consumption are not necessarily required for V2G. In Sweden, the electricity contracts can be hourly based or monthly based ToU contracts, or flat rate electricity contracts. Different electricity contracts can then be connected to different business models and offers for users, for example, ToU contracts can be connected to incentives that offer rewards or "wallets" for the users' revenues.

1.2 Research questions

Given the three key aspects identified in the literature to understand users' behaviors and needs related to V2G services – barriers, incentives and energy consumption at the household level – the following research questions were lifted for this study:

RQ 1. What charging preferences, real needs and routines do EV users have and why?

RQ 2. What future expectations do EV users have for bi-directional charging?

2 Method

To answer the research questions proposed for this study, two methods were applied. A qualitative study based on user-centered interviews and a survey. Mixed-method research has the potential to reduce common method bias, to answer research questions with a more comprehensive perspective and complement strengths. Moreover, the qualitative study had a more exploratory rationale, while the survey comprised more specific questions and a broader sample size. The commuting distances reported were classified into short (< 5km), medium (5 – 10 km) and long (> 10km).

2.1 Qualitative study: User-centered interviews

2.1.1 *Sample*

Eight EV drivers were interviewed, the age span was of 35 – 65, two interviewees were women, all except one participant lived in a detached house and had a parking space. Table 1 presents a summary of characteristics of the participants in terms of car ownership, household profiles, housing characteristics (type, electricity contracts and energy systems), charging patterns and locations, use of alternative modes of transport, concerns about battery degradation and overall self-evaluations of how much weather affects their travelling habits.

Table 1. Profiles of participants interviewed.

	J, male	D, male	A, female	JN, male	X, male	M, female	P, male	Z, male
Car ownership	Owner	Owner	Owner	Owner	Leased	Leased	Leased	Leased
Household	2 adults 3 children	2 adults	2 adults 2 children	1 adult	1 adult	2 adults	3 adults	3 adults
Housing type	House	House	House	House	Apartment	House	House	House
Energy contracts	ToU (Hourly based)	ToU (Hourly based)	ToU (Hourly based)	ToU (Hourly based)	NA	Fixed	ToU (Hourly based)	ToU (Monthly based)
House's energy system	Pellets	Heat pump, radiator and fireplace	Solar panels	Floor heating with an exhaust air heat pump	NA	NA	Solar panels	Heat pump
Commuting driving distances	Short	Long	Long	Long	Long	Long	Long	Long
Charging location and minimun SoC	Home mostly; 30% SoC	Home only; 60% SoC	Home mostly; 60% SoC	Home mostly; 40% SoC	Out of home, when possible; NA	Always plug in at home; NA	Home when sun is shining; NA	Always plug in at home; NA
Other modes of transport	Active travels to commute to work	None	Active travels to commute to work	None	None	None	Cycling	None
Battery degradation	Not much concern	Concerned	NA	Not much concerned	Concerned	Concerned if privatly owned	Some concerns	Not much concerned
Weather impact	Low impact	No impact	Some impact	No impact	NA	No impact	Some impact	No impact

2.1.2 *Instruments and procedures*

Based on ethnographic methodology, the setting for the user-centered interviews is an artifact that can allow presumptive V2G users to stage their daily lives in a playful setting to elicit user needs on future V2G human machine interaction. The interviews were recorded and transcribed. The participants answered a consent form before participating in the interview and after the interview session, they received a value card.

The hardware is composed of a smartphone, toy cars, a miniature wall box, and a layout with symbols for representing daily destinations (e.g., home, workplace, parking area). The software is an app prototype that allows the assessment of human-machine interaction, system dynamics and rules, and back-end functionality.

The app prototype was created using the Flutter cross-platform framework, which allows for greater flexibility and compatibility when it comes to choosing which hardware platform to run the app on (such as Android, iOS, and web). The choice of hardware can have an impact on how the test subject experiences the interface, due to factors such as screen size, refresh rate, color accuracy, etc.

2.1.3 *Data analysis*

The interview data was recorded using Microsoft Teams, and the recordings were uploaded to the Dovetail qualitative analysis platform and transcribed. In Dovetail, five tag groups were defined – *Individual values, Household characteristics, Daily/occasional routine, System level* and *Expectations on V2G*. In total, 45 tags were predefined in the four categories. The predefined tags were related to answering the research questions. The *Individual values* category contained aspects such as positive and negative attitudes, fears and uncertainties, pain points and potential positive outcomes. The *Household characteristics* category included demographic tags such as age, occupation, family, car brand and type of ownership, and what type of energy contract was used in the household. The *Daily/occasional routine* category contained behavioural tags connected to the daily life of the participants, how they charged their vehicles, how much, where and how they drive, what role the vehicle has in their daily life and for occasional trips. The *Expectations on V2G*, included tags on incentives, battery health, the need for minimum state-of-charge, and to what level of detail the participants require to control the charge/discharge algorithm and the related information flow. When the tags had been defined, three researchers coded the material independently and cross-checked each other's tagging for a consistent analysis. After the coding process was done, the material was clustered according to themes using the canvas function in the Dovetail software. Based on clusters the material was summarised. The major findings can be found in the results section.

2.2 Quantitative study: Survey

2.2.1 *Sample*

The majority of respondents were men (N = 452; 83.1%), among the age groups 36-45 years old (N = 160; 29.4%) and 46-55 years old (N = 202; 37.1%), with children in the household (N = 339; 62.3%).

2.2.2 *Instruments and procedures*

An online survey was sent out via intranet by one of the partners of the project between the 23rd October - 3rd November 2023. The final sample comprised 544 valid answers. The criterium to select the participants was employees that have a leasing contract of a Battery Electric Vehicle (BEV) or a Plug-in Hybrid Electric Vehicle (PHEV) provided by the organization. The data was analyzed by descriptive statistics and linear regression models.

The survey was composed of 25 questions, taking approximately 5 – 7 minutes to fill in. The questions comprised the following aspects: sociodemographic, household profile, travel behavior patterns, access to charging infrastructure, energy consumption behavior, attitudes towards V2G and willingness to use a vehicle that has the V2G functionality. The latent variables were measured by a 7-point Likert scale, which 1 means "totally disagree" and 7 means "totally agree".

The survey was developed based on psychometric research. Psychometric research takes into consideration the cognitive process involved when people answer to surveys and therefore the design of psychological scales took into account these process (for an overview on psychometric research, see Krosnick, 1991, Krosnick, 1999).

Because the scale was developed to assess behaviors that have recently emerged, few tests of V2G have been run on field, the scale used in this study hasn't been applied in other studies yet. The items of the subscale were developed specifically to this study. All items were under scrutiny of researchers experts in the areas of energy, transport and charging behavior. Preliminary versions of the scale have been presented in conferences, workshops and project meetings with other stakeholders (such as representatives of OEMs, parking operators, electricity providers). The items were based on other studies that also have incorporated behavioral questions in their research questions. Below, each scale is presented, together with an example of an item and the reference to the literature in which the subscale was based.

Potential Outcomes was assessed by 10 items that aimed at capturing beliefs about the outcomes of bi-directional charging technology related to a more efficient use of resources (e.g. "*I believe that the need for energy production will decrease*"), sustainability (e.g. "*I believe that the use of renewable energy will increase*"), and uncertainties related to charging preferences, driving behaviors, routines and lifestyles (e.g. "*I fear that V2G will add complexity to planning the charging of my vehicle*").

3 **Results**

3.1.1 *Results Qualitative study – interviews*

The following themes were identified as critical for the acceptance of V2G technology in the everyday life of the interviewees: *Convenient and resilient home*, *minimum range for emergencies*, *fear of battery degradation*, *trust in system providers*, *economic and social incentives*, *user preferences and need for control*. Following, each theme is described and quotes are provided to exemplify the themes.

- Convenient and Resilient home

Most of the participants stated that home charging is their main way of charging. There are strong routines related to the commute journey and charging the car when coming home from work and it is important that the charging can be performed in a convenient way. Apparently, connecting the vehicle for short periods of charging e.g. at a supermarket does not seem to be needed or of interest for many of the participants, unless the vehicle SOC is very low. Home resilience, i.e. the idea of using the car as a source of backup electricity in case of power outages is also mentioned as an interesting and valuable feature, although very few have actually tried it in practice.

"We have a charging box at home. So we always charge at home. I've charged away from home once in a year, so I have the habit of plugging in and charging every time we come home." Participant M

"No, it's the same thing there. In that parking lot, there are charging stations, but since they are from an external provider, I feel it's too complicated for me to connect the car, charge it so that I maybe have a driving range of two miles. And then I go home again. It's way too complicated. So, I just park." Participant X

- Minimum range for emergencies

The minimum range left in the vehicle is an important concern for all participants. However, the number of kilometres varies greatly depending on the daily life of the vehicle owner and the family routines. For example, one participant mentions sick relatives in combination with living on the countryside as a concern with an impact on minimum range needed for potential emergencies. For others, a lower SOC level is acceptable, but can vary with weekly routines.

"If I'm driving only in the city, but still I will want to charge it when it's like close to 60-50km [Remaining range]. That's when I feel like I need to charge. But my husband usually let it go to like 30km. He said, "yeah, but we don't need to charge it". "Yes, we do."" Participant A

"That it never discharges more than 50% [Battery level]. But I could allow it to discharge down to 20%, provided that by the time I need to leave, it is back to at least 50%." Participant JN

- Fears of battery degradation

There is an apparent fear of economical loss related to the hypothetical question of possible battery degradation when increasing the number of charging cycles due to V2G services. The participants seem aware of the value of a non-degraded battery to maintain the vehicles value on the second-hand market. Different types of economical compensations for the battery degradation were discussed. Battery insurance from the V2G service provider was also suggested to reduce the fear of battery degradation by relieving the battery ownership responsibility. Another aspect mentioned is the possibility to sell the battery on the second life market.

"So, if I had owned the car, I would definitely have been more worried about the wear and tear on the battery. Eh, because then I would have invested in the car in a different way." Participant M

"I need to be sure somehow that doesn't affect too much, doesn't degrade too much." Participant D

- Trust in the system/providers

There are many actors in the V2G eco-system, such as electricity-, grid-, parking-, car leasing companies, etcetera. Some participants mention the need to have trust in the service providers and stakeholders setting the rules and prerequisites for V2G services. The vehicle owner's engagement is crucial for enabling V2G capabilities, and participants state a fear of being exploited, i.e. someone else making a profit on their engagement and effort, rather than contributing to the society and sustainable energy production.

"It's less likely that they're going to be working [Public charging]. So you run into ones where the screen doesn't work or the payment system doesn't work and you have to download a new app and it's kind of frustrating thing." Participant J

"Yeah, because I mean, that from, I think that is one if you look at the society as a whole and then, the aspect of bidirectional becomes more relevant to me if it's clear how it's being used and if it's being used as a benefit to society, then I would be more likely to use it rather than if I just, ok, it's some electrical company who has some sort of gain, then I would be less interested for my liking" Participant Z

- Economic and social incentives

Most participants express economical incentives as a key driver to become involved in V2G services. Incentives of interest can be purely economic, as in getting paid for the energy fed back to the grid or the power used for frequency balancing. Other economic rewards can also be cut in parking costs. There are also an interest in convenience rewards such as a parking spot closer to the office building. Social incentives are also mentioned as an important driver, e.g. helping the grid from a societal or environmental perspective.

"One would like to see perhaps the needs of the grid if one can somehow predict it. When will the next need arise? Uh, in time, so one might be able to adapt oneself. Okay. Yes, but then one might be able to park here and help out, right?" Participant P

"And then it is the case that when I have looked at charging in places other than at home, I have never seen dynamic prices there, but it is the same price regardless of when I would charge. And since those prices are significantly higher than what I charge at home, it is not interesting because it [home charging] take me back and forth. It is more of an emergency solution." Participant JN

- User preferences and need for control of V2G services

Everyone expressed some basic needs for charging status at a glance and controls to be able to set up their preferences for the type of charging and minimum charge level. Some expressed a need for more detailed information on the energy flow, historically, now and as forecast. This was mentioned to be needed to be able to build trust in the service or provide fun facts about the usage.

"I want to see the numbers and the values and build trust for the numbers and the estimations. And when I get an idea of how much error there is in the estimations" Participant D

"I always sort of connect [Charging cable] and then normally it will be used either as a vehicle to grid or charging or whatever. Yeah. As long as it doesn't go below my threshold [minimum battery level]. But I always want the possibility to say, ah, today I want something else." Participant Z

3.1.2 *Results Quantitative study – survey*

The results of the quantitative study is dived in two subsections. First, a factor analysis was performed to identify the underlying factors that build the evaluation of V2G by the EV users. Three factors were identified: Sustainability, Efficiency and Uncertainties. This result is presented under the subsection *Factor analysis*. Following, these three factors were used as outcomes variables in multiple linear regressions in which the sociodemographic variables were used as predictors. The objective of this analysis was to identify societal groups that could be associated with the different factors of evaluation of V2G. For example, with these regressions, one may identify associations between different types of household profiles and in what extent they value the sustainability of V2G; or for example, identify if there are certain groups that have higher levels of uncertainties towards V2G. These results are presented in of *Linear regression models*.

- *Factor analysis*

Three components were extracted in a Principal Component Analysis (PCA) with Oblimin rotation; RMSR = 0.03; TLI = 0.93; RMSEA = 0.076, with 90% CI [0.058, 0.094]. The three components accounted to 61% of the total variance. The scale of expected outcomes was then defined into the factors of Sustainability (items ppo1 and ppo2), Efficiency (items ppo3, ppo4 and ppo5) and Uncertainties (items unc1 to unc5). All three dimensions presented satisfactory levels of reliability. The items, components' loadings after rotation, and reliability tests (Cronbach's alpha, α) are shown in Table 2.

Table 2. Obliquely (oblimin) rotated principal components loadings of ratings of Sustainability, Efficiency and Uncertainties evaluations of V2G.

	Sustainability (std. α = 0.77)	Efficiency (std. α = 0.85)	Uncertainties (std. α = 0.85)
"I believe that the use of renewable energy will increase"	**0.58**	0.22	-0.09
"I believe that parked cars will be better used if connected to V2G"	**0.96**	0.25	-0.11
"I believe that the energy prices on the market will decrease"	0.24	**0.80**	-0.16
"I believe that the risk of power outages will decrease"	0.25	**0.81**	-0.15
"I believe that the need for energy production will decrease"	0.11	**0.71**	-0.01
"I would fear that I would not have sufficient range to complete my transport needs"	-0.05	-0.15	**0.71**
"I would be afraid that battery life would be shorter than without bidirectional charging"	-0.04	-0.07	**0.60**
"I would expect an increase of charging failures on public spaces"	-0.16	-0.09	**0.62**
"I fear that V2G will add complexity to planning the charging of my vehicle"	-0.05	-0.06	**0.84**
"I will lose some control of charging my electric vehicle"	-0.07	-0.01	**0.83**
Cumulative Variance explained	0.27	0.20	0.14

- *Linear regression models*

To determine the effect of socio-demographic variables on the three dimensions of expected outcomes from V2G, meaning the three dimensions extracted from the PCA "Sustainability", "Efficiency" and "Uncertainties", three multiple linear regression were modelled with the dimensions as dependent variables and the socio-demographic variables as independent variables. The prediction of each dimension was based on car type (ICE, PHEV, BEV), gender, age, electricity plan (Variable rate hourly, variable rate monthly or fixed rate), housing (house, rented apartment or owned apartment) (see Table 3).

For the regression model for Sustainability, the coefficients for gender, housing and electricity contracts presented values under the significance level. Women ($ß = -0.33$, $p = .024$) and people living in apartments that they own (ß = -0.34, *p* = .037) had a negative association with the sustainability aspects of V2G, while users that have hourly based electricity contracts had a positive association (ß = 0.35, *p* = .008).

For the regression model for Efficiency, the coefficients for gender, housing and car type presented values under the significance level. Women (ß = 0.31, *p* = .026), people living in apartments that they own (ß = 0.38, *p* = .014) and drivers of ICE cars (ß = 0.56, *p* = .014) had positive associations with aspects related to the efficiency of V2G.

For the regression model for Uncertainties, any of the tested socio-demographic variables presented values under the significance level.

Table 3. Multiple linear regression analyses with the variables Sustainability, Efficiency and Uncertainties as outcomes and sociodemographic variables as predictor variables.

	Sustainability			Efficiency			Uncertainties		
	ß (SE)	*t*	*p*	ß (SE)	*t*	*p*	ß (SE)	*t*	*p*
Car type ICE	-0.45(0.24)	-1.86	0.063	0.56(0.23)	2.46	0.014	-0.27(0.23)	-1.15	0.248
Car type PHEV	-0.28(0.23)	-1.17	0.241	0.42(0.22)	1.86	0.062	-0.17(0.23)	-0.72	0.468
Gender (woman)	-0.33(0.14)	-2.25	0.024	0.31(0.13)	2.23	0.026	-0.25(0.14)	-1.78	0.075
Age (26-35 years)	-0.13(0.56)	-0.23	0.817	-0.12(0.53)	-0.23	0.813	-0.44(0.55)	-0.80	0.420
Age (36-45 years)	-0.33(0.56)	-0.59	0.554	0.13(0.53)	0.24	0.803	-0.58(0.55)	-1.06	0.289
Age (46-55 years)	-0.33(0.56)	-0.59	0.552	0.37(0.53)	0.69	0.487	-0.50(0.55)	-0.91	0.359
Age (56-65 years)	-0.53(0.56)	-0.93	0.348	0.39(0.54)	0.72	0.468	-0.65(0.56)	-1.16	0.244
Age (66+ years)	0.35(1.09)	0.32	0.745	-0.78(1.04)	-0.75	0.450	-1.23(1.07)	-1.14	0.253
El_plan Others	-0.25(0.29)	-0.86	0.389	-0.13(0.27)	-0.49	0.617	-0.08(0.28)	-0.30	0.764
EL_plan Variable rate (hourly)	0.35(0.13)	2.62	0.008	-0.21(0.12)	-1.67	0.094	0.13(0.13)	0.99	0.322
EL_plan Variable rate (monthly)	-0.11(0.13)	-0.84	0.400	-0.03(0.12)	-0.28	0.776	-0.19(0.13)	-1.49	0.136
Housing_Rented apartment	-0.05(0.17)	-0.28	0.776	0.25(0.16)	1.53	0.125	-0.14(0.17)	-0.81	0.418
Housing_Owned apartment	-0.34(0.16)	-2.08	0.037	0.38(0.15)	2.45	0.014	-0.00(0.16)	-0.02	0.977
Housing_Other	1.06(0.98)	1.08	0.279	-0.75(0.93)	-0.81	0.417	0.06(0.96)	0.06	0.948
Model	R^2_{adju} = 08, F(14, 369) = 3.5, *p* <.001			R^2_{adju} = .07, F(14, 369) = 3.07, *p* <.001			R^2_{adju} = .01, F(14, 369) = 1.48, *p* = .112		

4 Discussion

In line with previous research in the Swedish context [11], our study indicates a clear preference for home charging and V2H (vehicle-to-home) over public charging and V2G (vehicle-to-grid). Participants associated V2G in public spaces primarily with economic incentives, such as discounts for making the vehicle available for V2G and free parking. In contrast, within the domestic context, participants highlighted not only economic incentives but also the resilience and efficiency benefits of V2H.

This preference for home charging is significant for various stakeholders in the V2G ecosystem, including electricity retailers, charge point manufacturers, and operators. The interest in creating resilient homes among certain consumers and EV drivers suggests a demand for services that integrate technologies for home energy efficiency and V2G. While this trend is more pronounced among homeowners, housing associations are also striving to provide tenants with apartments that feature more efficient electricity consumption and increased charging availability, albeit still limited.

Our linear regression models revealed that women and apartment owners had a negative association with the sustainability aspects of V2G, despite having positive associations with its efficiency aspects. Similarly, drivers of ICE (internal combustion engine) cars showed positive associations with V2G's efficiency aspects, while individuals with ToU (time-of-use) electricity contracts had positive associations with V2G's sustainability aspects.

These varied evaluations of V2G highlight the multifaceted nature of the technology's appeal to different user profiles. Women and apartment owners view V2G as a resource to be optimized rather than a sustainable transport mode. Conversely, individuals with ToU contracts, who are likely more aware of electricity consumption, may be more sensitive to V2G's sustainability benefits. ICE car drivers, on the other hand, see V2G as a means to enhance vehicle efficiency, particularly when the car is parked.

Integrating findings from both qualitative and quantitative studies, we observe a strong interest in using cars for optimizing household electricity, contributing to the concept of a resilient home. This value of a smart, energy-efficient home is more tangible for homeowners but less so for apartment dwellers, as in Sweden, apartment owners typically do not own their garages, which are managed by housing associations. This limits their ability to optimize electricity consumption between their living spaces and vehicles.

Consistent with existing literature on V2G barriers, participants expressed concerns about battery degradation. Various actors in the V2G ecosystem are addressing this issue from technical (protocols and standards) and regulatory perspectives, though the future trajectory remains uncertain due to the topic's complexity.

Further research on the social and behavioral aspects of V2G is essential. This study contributes to understanding household routines around electricity consumption and EV use. However, the limited and non-representative sample size restricts the generalizability of our findings. Additionally, the lack of validated scales specifically for V2G attitudes and evaluations is a limitation. While our study developed a preliminary scale for this purpose, it did not explain a high level of variance. Other studies have attempted to apply validated scales from other contexts to the V2G context [10], but their conclusions tend to be abstract and theoretical, limiting insights into specific behaviors related to V2G's future use and needs.

Understanding household decision-making regarding electricity contracts, energy system preferences, and travel mode choices will be valuable for designing services that promote sustainable solutions in both transport and energy sectors.

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Presenter Biography

Érika has a Ph.D. in Psychology from the University of Gothenburg. Her research is focused on transport behavior, mobility and sustainable innovation. Érika is employed as a senior researcher at RISE Research Institutes of Sweden and her current work is focused on charging behavior, use of electric micromobility, and carsharing use.