



**CHALMERS**  
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# User willingness to accept vehicle-to-grid

Master's thesis in Sustainable Energy Systems

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DEPARTMENT OF SPACE, EARTH, AND ENVIRONMENT  
CHALMERS UNIVERSITY OF TECHNOLOGY

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MASTER'S THESIS 2025

# User willingness to accept vehicle-to-grid

Model based on survey data from residents of Gothenburg, Sweden

IVAN SANTIAGO ARANA TORREALBA



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## Abstract

As electric vehicles (EVs) become more prevalent and the energy mix increasingly includes variable renewable energy (VRE), there is a growing need for strategies that balance electricity supply and demand. Vehicle-to-grid (V2G) technology allows EVs to act as distributed storage units, feeding energy back to the grid during peak hours. However, the effectiveness of this approach depends on user participation. This thesis explores the willingness of EV users in Gothenburg, Sweden, to engage in V2G programs and accept different charging conditions and remuneration. A stated choice experiment was designed and distributed to EV users and vehicle owners, collecting 153 valid responses. The survey included demographic questions, behavioral preferences, concerns, and discrete choice tasks involving four key attributes: minimum guaranteed range, minimum plug-in hours, days of required connection per week, and monthly remuneration. The resulting data were analyzed using a multinomial logit model implemented in Biogeme. The findings reveal that plug-in time and financial compensation are the most influential factors affecting involvement. Longer plug-in requirements reduce utility, while higher recompense increases it. Users also showed moderate sensitivity to guaranteed driving range and a slight positive inclination toward routine schedules. Willingness to accept calculations and scenario simulations show that participation likelihood increases significantly when plug-in requirements are lower or when monthly payment reaches realistic upper thresholds. This research provides quantitative insights into user preferences and offers recommendations for designing user-centric V2G programs that align technical feasibility with behavioral acceptance, ultimately supporting grid flexibility and decarbonization goals.

**Keywords:** Vehicle-to-grid (V2G); Electric vehicles (EVs); Stated choice experiment; Discrete choice modeling; Willingness to accept (WTA); Energy policy; Peak load management; Mobility behavior.

“We can no longer afford to assume that addressing climate change is the sole responsibility of national or local governments, or corporations or individuals. This is an everyone-everywhere mission in which we all must individually and collectively assume responsibility.”

— Christiana Figueres

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Gothenburg, Sweden. May 27, 2025.

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## List of Abbreviations

ASC - Alternative Specific Constant

GHG - Greenhouse Gas

ENTSO-E - European Network of Transmission System Operators for Electricity

EV - Electric vehicle

ICE - Internal Combustion Engine

MGR - Minimum Guaranteed Range

SEK - Swedish Krona

SE3 - Swedish electricity bidding zone 3

SK - Svenska Kraftnät

VRE - Variable renewable energy

V2G - Vehicle to grid

WTA - Willingness to accept

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# 1 Introduction

## 1.1 Background

As the energy transition progresses, the energy mix increases its share of variable renewable energy (VRE) such as wind and solar energy. This poses a challenge for the existing grid infrastructure and the liberal energy market currently operating, as production does not necessarily match consumption, and behavioral patterns create peak load hours. This results in higher volatility of electricity prices and higher strain on the grid [1]. One of the strategies to reduce these impacts is to utilize batteries to store energy in times of high production and low consumption, and discharge at peak hours. With the decrease in electric vehicle (EV) prices and the governmental push of Sweden to stop selling engine vehicles (ICEs) by 2030 [2], massive adoption of EVs is expected. EV batteries could be used in a vehicle-to-grid (V2G) strategy to alleviate the grid. The success of implementing this strategy depends on the willingness of the user to participate in the V2G programs.

## 1.2 Aim

The project aims to design and conduct a survey targeted to EV owners with various scenarios of V2G, using a discrete choice model to extract a mathematical form and find the probability of EV users participating in V2G programs. The survey will collect information on their demographics such as age, income, gender, and others such as schedule and environmental consciousness. The discrete choice model will contain scenarios with variables such as charging/discharging times and participation conditions, while considering their concerns to consequences to their vehicle's use caused by range loss or unavailability. The data will be analyzed to conclude the willingness of EV users to participate in V2G programs that could help offer recommendations for V2G providers and power grid operators.

## 1.3 Limitations

The survey will be done with the researcher's own resources; therefore, there will be a limit on the number of respondents. The survey cannot be very long or complicated

to avoid overwhelming participants in terms of the time taken or information they are supposed to process to answer. The answers that participants give and what they would do in real life could be different; this error will not be considered. Therefore, the scenarios will be designed to be as realistic as possible. This survey will be made available only online and published to people residing in Gothenburg, Sweden.

The calculations for battery charge and discharge times will be assumed to be linear for simplicity; this will allow every available hour of V2G to be treated the same, even if real-life batteries do not behave this way.

## **1.4 Literature review**

Previous studies have had different approaches while defining the parameters in their experiments. Three different experiments were analyzed, one in 2014 done in the United States [3], one in Germany in 2018 [4], and the latest in 2021 done in the Netherlands [5]. This analysis will consist of comparing the parameters in the three studies, as well as their respective options, considering which ones appear more frequently.

### **1.4.1 Demographics**

All authors collected data for demographic parameters such as age, gender, and education level. The user's previous knowledge of the V2G concept was surveyed [4] and [5], but not [3], given that part of their survey design consisted of explaining to the respondents the concept of V2G. Only [5] did not collect data on income or environmental consciousness. [3] and [5] considered the car type the user owned.

[4] was the only one to consider household size, and [3] was the only one to consider different car features such as acceleration, driving range at full capacity, charging time, and pollution emitted.

Refs. [3] and [4] also deepened in behavioral patterns of drivers; both obtained data on distance driven. [3] also asked about people's tendency to buy new things, whereas [4] tackled the psychological perception of the car as more of an instrument to use rather than attributing a more symbolic value to it.

### 1.4.2 Minimum guaranteed range

The first of the parameters that appear in the three studies is minimum guaranteed range. Parsons and his team in [3] divided it into three options: 25, 75, and 125 miles out of 200 mi available (or 321 km) when fully charged. They found out that there is a non-linear perception in the value of every unavailable mile: taking a mile away from the consumer is the same as increasing the original cost of the vehicle at \$10/mile in the range from 175 to 125 miles, \$70/mile from 125 to 75 miles, and \$88/mile from 75 to 25 miles. The most sensitive change is in the second range, or where the battery availability is at the halfway mark. In the report, the difference between fast and slow charging as a relevant factor is mentioned but later determined as not within the limits of the study as they fixed the charging time at 1 hour in all cases.

Authors of [4] used the values of 10, 20, 30, 40, and 50 km based on the average driving range of 38 km per passenger car in Germany. In their results, they report that increasing the minimum range to 60 km significantly raises the participation rates, even without remuneration, meaning that people care more about being guaranteed enough driving range than about getting paid.

Authors of [5] instead defines the minimum range as a percentage of the maximum battery capacity based on another report by [6] and sets the values at 10%, 30%, and 50%. Setting the average capacity to be 280 km, translating those values equals to 28, 84, and 140 km. In contrast to Parson's report, [5] decided to give more importance to the subject of fast charging by setting up two different contexts, one where current charging speed remains, and a counterpart where fast charging is implemented. The team ended up determining that Dutch EV owners consider the minimum guaranteed range to be important; however, this importance drops significantly if fast charging is present: they value it at €5.91 per month for every 1% increase in guaranteed minimum battery level with current charging options and €2.73 per month if fast charging is available.

### 1.4.3 Cashback payment

The second parameter that appeared every time was the payment to the user. [3] established an annual cashback payment of 500, 1000, 2000, 3000, 4000, and 5000 USD. These ranges were defined to “cover the relevant range” of what could be expected so that both the conservative (low) and generous (high) end scenarios could be represented.

Ref. [4] determined fixed monthly payments of 15, 30, 45, and 60 EUR and applied a formula for NPV to calculate an annual payment equivalent to the monthly income stream with an interest rate of 1.5% over 10 years, resulting in single payments of 1000, 3000, 5000, and 7000 EUR.

The study in [5] divides the payments into fixed monthly remuneration, and extra remuneration rewarded for every extra hour outside of the plugin time obligation. The former with ranges of 20, 60, and 100 EUR per month and the latter at 0, 0.15, and 0.30 EUR per hour. These values were explained to be based on previous studies and on the situation of the Netherlands at the time of writing.

### 1.4.4 Minimum hours plugged in

Continuing with the subject of minimum plug-in hours, this attribute also appears in all three reports as the obligatory number of hours in a day the user needs to be plugged in. [3] set the base at 5 hours, increasing in ranges of 5 hours: 10, 15, and 20 hours maximum. The results showed per-hour incremental costs of \$282/h from 5 to 10 h, \$608/h from 10 to 15 h, and \$810/h from 15 to 20 h.

Ref. [4] came up with a subcategory of hours per day (0, 5, 7, 10, and 14) and days per week (3, 4, and 5). The impact of minimum hours was significant in two of their three groups, and minimum days were insignificant in all of them.

Values in [5] were 5, 10, and 15 hours per day. They found another non-linear pattern in how people value having their electric vehicle (EV) plugged in for an extra hour. If the base plug-in time is 5 hours per day, participants required an additional €12 per month as compensation. However, if the base plug-in time increases to 15 hours per day, the required compensation jumps to €35 per month. This also

meant that the value of extra remuneration was insignificant for the users, as the maximum monthly compensation offered was €9. Lower than the earnings from an extra hour beyond a 5-hour base.

#### 1.4.5 Other attributes

In addition to the three previous attributes, [3] adds a price difference in comparison to the preferred gasoline vehicle. Given that this survey is designed solely for EV owners, this one will be disregarded.

Ref. [4] add instead the possibility of the user indicating the beginning and duration of the next trip; this feature increases the likelihood of users participating in V2G.

Ref. [5] added to the attributes the duration of the contract between the user and the aggregator, who is the intermediary between the EV owner and the electricity grid: 6, 12, or 24 months. Their results showed that there is a negative sign for the coefficient, meaning that people prefer shorter contracts; there is, nonetheless, no clear evidence that shows the duration is important. Another attribute in [5] was the number of discharge cycles per session, designed at 1, 4, and 7. The results showed that users expect €6.81 for every additional cycle per session, which is significantly higher than the degradation cost.

#### 1.4.6 Data collection and processing

The study in [3] obtained the data from 3029 people randomly selected from a U.S. household sample. They processed the responses with a latent class random utility model; this was chosen over the mixed and standard logit due to the model being good at capturing preference heterogeneity by estimating separate models for different classes of consumers.

The study in [4] got their responses from 611 participants, each making 8 decisions to obtain a total of 4888 responses. The participants were selected to be a representative sample according to the German data from “Consumer Analysis 2012”. They also processed the data with a latent class model, which was preferred over the mixed logit model according to previous literature. Specific logit models

were used nonetheless to calculate the impact of characteristics on decisions.

The study in [5] had a sample size of 148: 42 on paper and 106 online; they were approached at random at EV charging points with an invitation to fill out the survey either physically or online. They processed their data through the multinomial logit model in which three alternatives were shown: two V2G options and the option to opt out.

## 2 Methods

The survey was designed to last no longer than 15 minutes to ensure the attention and engagement of interviewees [7]. The vocabulary was simple to be understood by anyone, regardless of their level of technological knowledge.

### 2.1 Survey design

The survey consisted of four sections, which will be explained in detail below.

#### 2.1.1 Demographics

The following basic questions for obtaining general information about the participants have been present in previous studies and were asked here as well: age, gender, education level, and income; additional questions related to V2G knowledge, employment status, and work modality were also asked as they are external factors that affect the user's participation.

#### 2.1.2 Behavior related questions

The following questions are aimed to collect data on the respondent's current situation regarding owning a vehicle.

- Do you own a vehicle? (Answer options: No, yes - fuel based, yes - hybrid or electric)
- If you have an electric vehicle (EV), is it your main or secondary car?

Based on their answer to the first question, they were led to different sections; non-owners had to answer the following questions:

- On average, what's the approximate distance you travel on a weekday?
- Is your daily trip schedule consistent throughout the week?
- If you had an electric vehicle, what is the minimum distance your car should be able to cover to make you feel safe, especially in an emergency? Please enter a number between 0 and 150 kilometers.

For those who answer that they do own a vehicle, whether electric or fuel-based, the questions were slightly rephrased, and some additional questions were added:

- How often do you use your vehicle? (Answer options: Daily or almost daily, several times a week, a few times a month, less than once a month)
- On average, what's the approximate distance you drive on a weekday? (Answer options: 0–5 km, 5–15 km, 15–30 km, 30–60 km, 60+ km)
- What types of trips does the car accommodate? (Multiple answer enabled. Answer options: Daily commute, holiday and weekend trips, short trips, long trips)
- Is your driving schedule the same every weekday?
- What is the minimum distance your car should be able to cover to make you feel safe, especially in an emergency? Please enter a number between 0 and 150 kilometers.

The last question for all respondents was used to identify the main driver for them to participate in V2G if any: “The main advantage of participating in this V2G contract is:” and the possible answers were:

- Benefiting monetarily from my EV
- Acquiring a charger at my home
- My increased participation in environmental causes
- I don't think there is a relevant advantage for me

### **2.1.3 Matrix of concerns**

This section contains some of the most common concerns related to V2G and has two purposes: the first one is to get the overall sentiment towards each question, and the second one is to identify patterns. The respondent was asked to select on a scale from one to seven, where one means totally disagree and seven means totally agree, each of the following questions:

- I fear that the suggested monetary compensation of V2G would not sufficiently compensate for the battery degradation of my vehicle.
- Having to comply with a V2G contract constrains my freedom.
- I would feel uncomfortable sharing the data on my routine and driving behavior with the V2G company.
- I am concerned that I could get stranded because I started my trip without sufficient battery.
- I think it is very unlikely that there could be V2G infrastructure set up in my workplace.
- The suggested monetary benefit from participating in V2G is insignificant to me in comparison to other income sources I have.

All questions are presented so that seven means the highest concern and therefore a higher number could be linked with lower participation.

## 2.2 Stated choice experiment

The scenario was set to be the same for all responders:

- They are signing a contract with a V2G aggregator who will cover the costs of installing a V2G charging point at the user’s home.
- The contract is flexible, meaning that it can be modified if the users’ routines change.
- The user can program times and dates when V2G is not enabled even if the vehicle is plugged in.
- The user has the control to override the “discharge command” sent by the aggregator.
- The user can visualize (i.e., through a mobile app) the hours completed, and hours missing to reach the goal and can see their battery level when plugged in.

- There is V2G availability at their workplace.\*

\*Involving the employer raises the complexity of the setup; however, [8] surveyed employers and found out that they could consider installing V2G stations in exchange for subsidies or tax exemptions [8].

Just as in the previous studies, this survey will be composed of four attributes: Minimum guaranteed range, monthly remuneration, plug-in hours, and active days, each of them with four possible options to choose from. These will be explained below.

### **2.2.1 Minimum guaranteed range**

The minimum guaranteed range (MGR) has been a common attribute to survey in previous studies; for that reason, it will be added as well in this project. According to the International Energy Agency, the weighted average range of a new electric vehicle is 350 km, with a capacity of 55 kWh [9]. The 60 km baseline suggested by Geske and Schumann will be set as the starting point for option one; this happens to be about double the average driving range per person in Sweden at 28.2 km [10].

At an average of 6.36 km per kWh, the MGR requires around 9.43 kWh, or 17% of the battery, leaving 45.57 kWh at disposal for V2G. Given that people react sensibly to changes below this base, the minimum range options will only be numbers above 60 km, in increments of 30 km, at 90, 120 km, and 150 km, or 25%, 34%, and 43% of the battery respectively, which is within the range suggested by Huang. For the second option, however, the MGR will be set slightly lower at 50 km. This will be coupled with a higher remuneration which will be explained in the payment calculation section.

### **2.2.2 Days of participation per year**

In Sweden, the reported statistics say that the average person works 30 hours per week [11], and 1440 hours per year [12], meaning 48 weeks per year. If an EV owner uses their vehicle for V2G every weekday, this equals 240 days per year, which will be the baseline for calculations. For simplicity in the experiment, the options will be based on days per week participation: 3 days as a minimum, passing through 4

and 5, and 6 days per week as a maximum.

### 2.2.3 Minimum plug-in hours

The main purpose of V2G is to alleviate the grid and behave as a power source during peak consumption hours, which can in turn increase the participation of solar and wind energy and cut GHG emissions [13]. This, however, makes the V2G schemes time-dependent, meaning that plugging in at different times will yield varying results. Previous studies have not addressed this issue and instead have used the attribute of mandatory plug-in minimum time. In reality, a contract of a minimum time of 8 hours could be fulfilled by being plugged in from 22:00 to 6:00 with minimum benefit to the grid, the user, or the aggregator. Instead, in this project, there will be a characterization of hours depending on whether it is a peak (p) or non-peak (np) hour.

Therefore, there needs to be a definition of what constitutes a peak and a non-peak period. For that, the data on electricity prices were taken from the ENTSO-E platform for bidding zone SE3 [14], which is where Gothenburg lies. The data was categorized for every hour of the day, and then the average was plotted vs. price in EUR/MWh; this is shown in Fig. 1, and the data is displayed in Table 1.

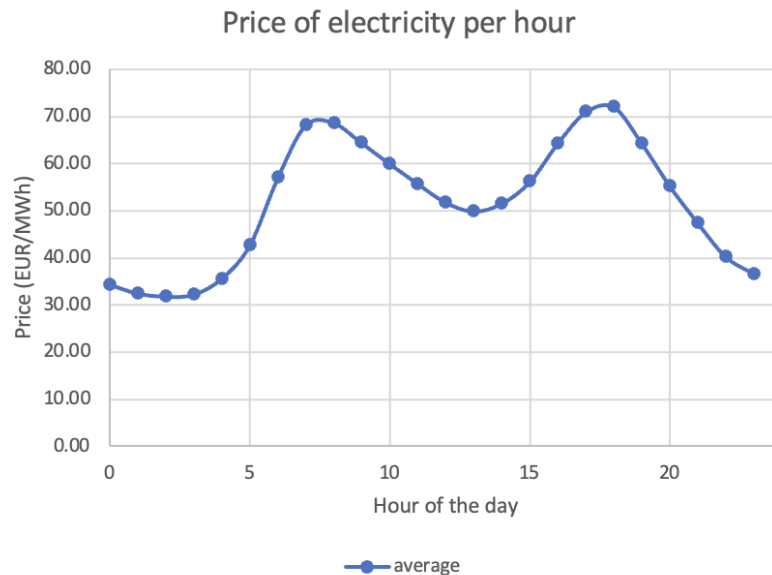


Figure 1: Price of electricity per hour in 2023.

Table 1: Electricity prices in €/MWh arranged in ascending order.

Hour	Price	Hour	Price	Hour	Price	Hour	Price
02	31.68	22	40.12	10	59.90	16	64.28
03	32.10	05	42.56	19	64.24	09	64.35
01	32.34	21	47.30	16	64.28	07	68.17
00	34.22	13	49.81	09	64.35	08	68.59
04	35.51	14	51.48	07	68.17	17	70.93
23	36.48	12	51.70	06	56.90	18	71.99

It is visible that there are two peak periods of consumption, alternated by two periods of lower demand. The next step is to build blocks based on these periods.

For reference, the Ford Charger Station Pro is an existing bidirectional charger with a power input and output of 11.5 kW, available for \$1310 [15]. This means that the 45.57 kWh of available energy (obtained from Section 2.2.1) from a participating EV could be fully charged and discharged in just under 4 hours. Higher power chargers are in development phases, such as a 25-kW power converter proposal by [16], which would more than halve the charging and discharging times.

With this in mind and based on Table 1, an ideal battery would be connected for 4 hours from 00 to 04 to charge, then discharged from 07 to 11 hours, charged again from 12 to 16 hours and discharged again from 16 to 20 hours in a two-cycle day that suits the price behavior. Any additional number of cycles is not convenient given that there are only two local minimums and maximums across the day. Given that this is an unrealistic schedule to be followed, there will be blocks of a minimum of 5 hours to give the user some more leeway. The block schedule is then as shown in Table 2.

Table 2: Time Blocks and Peak/Non-Peak Hours

Block	Peak / Non-Peak	Time
A	Non-peak	21:00 - 06:00 (9 hours)
B	Peak	06:00 - 11:00 (5 hours)
C	Non-peak	11:00 - 16:00 (5 hours)
D	Peak	16:00 - 21:00 (5 hours)

In reality, it is most likely that an EV that is plugged in from 00:00 to 04:00 will continue to be plugged in in adjacent hours, for example from 22:00 to 06:00 as the

owner sleeps. This small advantage of choosing from a bigger pool can be ignored and considered instead as part of the profit of the aggregator.

Parting from here the attribute of minimum hours can be transformed into pairs of peak and non-peak hours. Even if it is possible to have the car plugged for 16 hours per day in what would be the  $8p + 8np$  maximum, it is more likely that this setting will be preferred by the minority. For this reason the pair of  $4p + 4np$  will be considered as it is the starting point, with the options of  $1p + 1np$  for those who want to participate but not commit strongly, as well as  $2p + 2np$  and  $6p + 6np$ .

#### 2.2.4 Monthly retribution calculation

The following section is dedicated to obtaining realistic ranges to offer the participants and the decisions made to set the ranges.

The classification in Table 2. leads to the average price for peak hours at €64.45/MWh and €42.65/MWh for non-peak hours. Assuming that the users will be evenly distributed within their block, we can set those two prices as a reference for the calculations.

The monetary yearly estimation per pair of hours is obtained by equation 1:

$$\text{Earnings} = \left( \frac{\text{Price}_p - \text{Price}_{np}}{1000} \right) \cdot N_{\text{hours}} \cdot P \cdot d \quad (1)$$

where:

- *Earnings* are yearly and in €/MWh,
- *Price* is in €/MWh,
- $N_{\text{hours}}$  is the amount of hours  $p + np$  that the user must be plugged in, counted in pairs,
- $P$  the power in kW of charge and discharge (set in this case by Ford's charger),
- $d$  is the minimum days per year that the user must be connected.

Changes in technology are continuous and oftentimes unpredictable; the current

state of V2G as the example set by Ford could change in terms of power output and price diminution caused by the increased efforts in development. For power, the limits will be 11.25 kW at minimum as the existing technology and 25 kW at maximum, with the expectation that Wang’s converter could be commercialized soon. The maximum capacity will be extended so that the guaranteed minimum level increases to 50 kWh, so it is convenient to charge or discharge in 2 hours with Wang’s power converter.

Volatility in the electricity prices is the main factor that defines the potential earnings, if the data of 2018, 2019, and 2020 (until September) are treated in the same manner: 4 blocks of 5 hours minimum, the difference between peak and non-peak prices has become larger with time. The behavior of electricity prices vs. the hour of the day can be seen in Fig. 2.

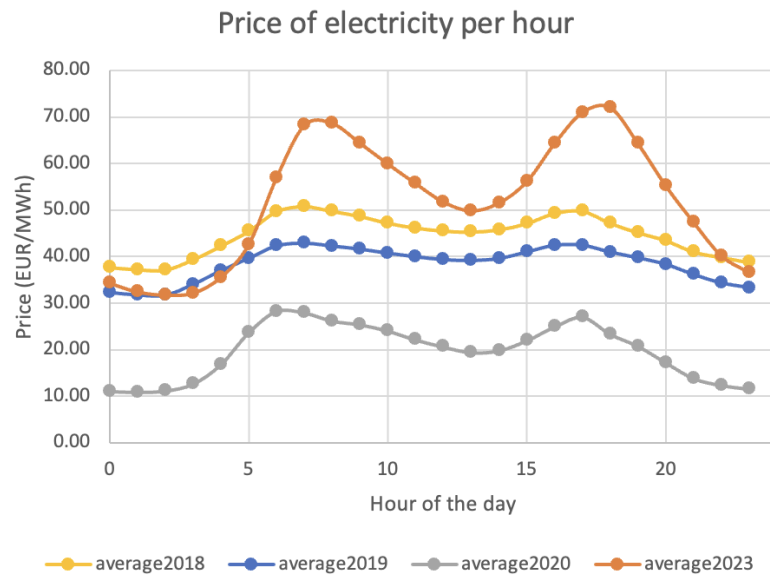


Figure 2: Price of electricity per hour in 2018 to 2023.

Table 3 shows that peak prices have gone from 14% higher than non-peak in 2018 and 2019 to 51% in 2023. This can be attributed to the merit order effect [17], as the stage of penetration of VRE in the electricity mix determines the electricity prices and Sweden has incorporated more and more VRE in their mix [18].

Let’s assume then, that with this trend, the difference between peak and non-peak prices will reach 100% by 2030. That would be the equivalent of having the

Table 3: Peak and Non-Peak Prices in €/MWh with Price difference

<b>Year</b>	<b>Peak Price</b>	<b>Non-Peak Price</b>	<b>Price difference (%)</b>
2018	48.05	42.01	14.37%
2019	41.45	36.19	14.52%
2020	24.42	15.71	55.40%
2023	64.45	42.65	51.13%

current earnings divided by 1.5 and then multiplied by 2. The volatility baseline will be the current state, and the maximum is set by this factor of 1.5/2.

According to the policies from Naturvårdsverket [19], the environmental protection authority in Sweden, valid from July 1st, 2022, the maximum power input to avoid paying a fee for feeding electricity to the grid is 43.5 kW. The value is the same to avoid paying a one-off charge to the network operator when connecting. There is then taxation for V2G as it is currently.

Svenska Kraftnät, the company in charge of electricity distribution in Sweden, set that “As of January 1st, 2020, the price for energy losses is based on the actual hourly market price per bidding zone with an additional supplement charge to cover risks” [20]. The Environmental Investigation Agency in the United States estimates that losses in transmission and distribution average about 5% [21]. Without any further details from SK of what is the “additional charge to cover risks” the total cost is set at 6% as this insurance should not be that expensive. This cost is subtracted from the earnings to obtain the values of Table 4. Additionally, there is a row for the theoretical maximum earnings for the price data of 2023, this scenario being charging fully in minimum-price hours to sell all the energy in maximum-price hours. The rate of change used for the calculations was that of mid-February 2025 at 11.25 SEK/€. The conditions that were set to obtain these estimates are displayed in Table 5.

There needs to be also a discount for the installation cost of the V2G point, let’s assume that this cost is initially paid by the aggregator, and is discounted from the earnings of every month, given a contract of 10 years, with a 3% annual interest rate, and the initial payment of \$1310, the monthly discount is given by equation 2 to obtain a monthly payment of \$12.65 or around €12.

Table 4: Gross Yearly and Monthly Earnings

Nmin	Yearly Earnings		Monthly Earnings	
	€	SEK	€	SEK
1p/1np	56.57	636.40	4.71	53.03
2p/2np	113.14	1272.81	9.43	106.07
4p/4np	226.28	2545.61	18.86	212.13
6p/6np	339.42	3818.42	28.28	318.20
2-cycle max	607.61	6835.56	50.63	569.63

$$PMT = \frac{P \cdot r}{1 - (1 + r)^{-n}} \quad (2)$$

where:

- $PMT$  is the monthly payment,
- $P$  is the initial principal (1300),
- $r$  is the monthly interest rate, calculated as  $r = \frac{i}{12}$  where  $i$  is the annual interest rate,
- $n$  is the total number of months (loan or investment duration in years multiplied by 12).

Lastly, the aggregator will take a 5% commission on the earnings to operate; the results for best-case and baseline scenarios are displayed in table 5. There is no need for a worst-case scenario because, with some combinations, after the aggregator's cut, the earnings become negative; therefore, the worst-case scenario will be set as zero earnings. Appendix B shows more extensively how the remuneration was calculated in Excel.

Table 5: Comparison of Different Conditions

Conditions	Best	Base
Plug in time (h)	4p/4np	4p/4np
Max. available cap. (kWh)	50	45.57
Power (kW)	25	11.5
Days (d)	288	240
Price volatility multiplier	1.333	1
Earnings (SEK)	737.86	212.13
After cut installation + aggregator (SEK)	565.63	66.19

The fact that the maximum remuneration value is close to the 2-cycle maximum reinforces the idea that this value sets the upper bound under current market conditions. Treating the values from table 5 as maximum, the four options of monthly retribution can be established as the 1st, 2nd, 3rd, and 4th quartiles of the scale, rounded to the nearest ten-SEK.

Offering more money than this in zone SE3 is not realistic at the moment, but could be a possibility in the foreseeable years as volatility grows, combined with the commercialization of more capable chargers in terms of power charge and discharge capacity. Imagining a near future where the profits increase significantly, the values for the economic offer will be doubled for option 1 and tripled for option 2, just as [3] did to cover for conservative and generous scenarios. The set of attributes is displayed in table 6.

Table 6: Attribute Levels Table

<b>Attributes</b>	<b>Attribute levels</b>
Plug-in time	1p + 1np
	2p + 2np
	4p + 4np
	6p + 6np
Participation days	3 days per week
	4 days per week
	5 days per week
	6 days per week
Minimum guaranteed range	60 km (approximately 17%)
	90 km (approximately 25%)
	120 km (approximately 34%)
	150 km (approximately 43%)
Monthly remuneration (SEK)	300
	580
	860
	1160
Monthly remuneration (SEK)-Option B	450
	870
	1290
	1740

## 2.3 Scenario design

Using Orme’s rule, equation (3) can be used to estimate how many scenarios a person can respond to [22].

$$n \geq \frac{500 \times c}{t \times a} \quad (3)$$

Where:

- $n$  = minimum sample size
- $c$  = maximum number of levels for any one attribute
- $t$  = number of tasks per respondent
- $a$  = number of alternatives per task

Considering the time of the survey, it was decided that every participant should choose between 6 scenarios. This gives us a sample size of 112. With a target of 200 respondents, assuming only 75% is achieved, that would still be enough. In total, 12 different scenarios were designed so that each scenario would appear around 75 times in total, which is within the 50 to 100 range suggested by Orme. The scenarios are shown in Table 7.

## 2.4 Survey distribution

The survey was designed with the software SurveyEngine; the layout of some example questions can be seen in Appendix C. It was shared both in person and online. Participants were invited through the researcher’s and supervisor’s personal and professional contacts, including a post on LinkedIn, most of whom reside in Gothenburg. Additionally, the platform Prolific was used to obtain answers. On it, the requisites for participation were to be fluent in English and currently living in Sweden, as it was not possible to additionally filter by city. A total of 251 people began the survey; 70 of them were through Prolific.

Table 7: Comparison of Option 1 and Option 2

**Sc.:** Scenario, **P:** Plug-in pairs, **D:** Days per week, **R:** Range (km), **I:** Income (SEK/month)

Sc.	Option 1				Option 2				Option 3
	P	D	R	I	P	D	R	I	No Participation
1	2	4	150	860	4	4	50	1290	–
2	2	4	150	1160	6	5	50	1740	–
3	1	6	60	580	1	5	50	450	–
4	4	5	120	860	4	4	50	870	–
5	1	3	90	300	1	5	50	450	–
6	6	6	90	1160	1	3	50	1290	–
7	2	4	150	1160	4	4	50	1740	–
8	4	5	120	860	2	4	50	1290	–
9	1	6	90	580	6	3	50	1740	–
10	6	3	60	1160	2	3	50	870	–
11	4	5	120	580	2	3	50	450	–
12	6	3	60	300	6	5	50	450	–

## 2.5 Data cleansing

The two main problems regarding incomplete and untrustworthy data were the incompleteness of the survey and the completion in a very short time. As mentioned earlier, answers from 251 respondents who began the survey were collected; out of that group, only 175 completed it up to the experiment. The responses from the remaining 76 were discarded as they did not give any insight into their preferences, which was the main goal of this study.

The second filter to clean the data was to eliminate those responses from the users who finished the survey too quickly. The survey was designed to last from 5 to 8 minutes; there were 22 people who took less than 3 minutes to input all their answers. Given that the subject is somewhat niche, and the experiment requires that the respondent takes some time to analyze the options based on their schedules and possibilities, it is likely that these people did not put much effort into this analysis or even probably clicked at their responses randomly. This possibility comes from the fact that the platform Prolific pays all the users just on the condition of survey completion, so some of them may only be motivated by the money they receive

and do not take the surveys seriously. For this reason, the responses from those 22 people were discarded, leaving 153 trustful participants. Out of these, 144 answered all the questions: the questions regarding demographics were all set as optional so the responses from those 9 people will be accounted for, except for when the analysis requires classifying the sample based on their demographics.

## 2.6 Evaluation

When individuals face a choice among alternatives, they evaluate each option based on the utility it gives them. This utility represents the perceived benefit that comes from an alternative, and is influenced by various attributes such as price, quality, convenience, or personal preferences. Users assign higher value to options that maximize their personal utility, analyzing trade-offs between attributes. For example, if an option is cheaper but requires a higher commitment, a user may assess whether the cost savings outweigh the inconvenience. This balance between attributes ultimately determines which alternative is chosen, making utility a key driver of consumer decision-making [23].

### 2.6.1 Standard logit model

The standard logit model is a discrete choice model that assumes individuals select the option that provides them with the highest utility. In this model, the utility of each alternative is composed of a systematic component and a random error term. According to Train, they are given by equation (4), and their utility function is given by equation (5) [23].

$$P_i = \frac{e^{V_i}}{\sum_j e^{V_j}} \quad (4)$$

where:

- $P_i$  is the probability of choosing alternative  $i$  choosing option  $j$ ,
- $V_i$  is the deterministic utility perceived,

$$V_i = ASC_i + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_n X_{ni} \quad (5)$$

where:

- $ASC_i$  is the alternative specific constant,
- $\beta_i$  are the coefficients to be estimated,
- $X_{ki}$  are the attributes,

### 2.6.2 Multinomial logit model

With the same base as the standard logit model, the multinomial logit (MNL) model allows for more than two possible choices. The objective of the model is to obtain the beta coefficients that represent the strength and direction of the individual attributes in the overall perception of utility. This model, however, is based on the irrelevant alternatives assumption (IIA); it states that adding an additional option will not change the relative odds of the previous options being chosen.

Given the time constraints in terms of sample size and computational limits, this study employs the MNL model. While it does not account for unobserved preference heterogeneity, it offers interpretable coefficients that are able to understand general trends and provides reliable estimates of marginal utilities and willingness to pay.

### 2.6.3 Willingness to accept

Once the coefficients for the individual attributes are calculated, Train described a way to calculate willingness to accept (WTA) that is shown in Eq. (6). It gives a numerical measure of how much an individual is prepared to spend to obtain a benefit or to avoid something undesirable. It is helpful to visualize preferences by assigning monetary terms to otherwise more abstract benefits [23].

$$WTA_k = -\frac{\beta_k}{\beta_{cost}} \quad (6)$$

### 2.6.4 Spearman Rank Correlation

To assess the association between ordinal concern responses and demographic variables, Spearman's rank correlation coefficients can be calculated.

To test the statistical significance of Spearman's rank correlation coefficient for

large samples ( $n > 100$ ), Zar suggests using a normal approximation [24]. The test statistic is computed using Eq. (7).

$$z = \frac{r_s \sqrt{n-1}}{\sqrt{1-r_s^2}} \quad (7)$$

where  $r_s$  is the Spearman coefficient and  $n$  is the number of valid paired observations.

All coefficients were obtained by ranking each variable and then applying the built-in Spearman method in Python's pandas (`corr(method='spearman')`).

## 2.7 Coding

For the obtaining of results, this study used Biogeme, an open-source software package specifically designed for discrete choice modeling, including multinomial logit (MNL), nested logit, and latent class models. Biogeme is optimized for the estimation of random utility models and provides efficient estimation algorithms for stated preference data, which is particularly helpful when considering scenarios that need heterogeneous preferences to be accounted for, such as V2G. Unlike other software or packages, Biogeme is free, regularly updated, and supported by extensive documentation and academic tutorials available online, making it suitable for research and making it easy to have the results reproduced by another user [25].

The full code can be seen in Appendix A. What is worth mentioning from it are: `ASC_3` and `V3` are set to 0 or base alternative. This is done because the current situation is no participation, and the coefficients need to tell if the attribute will increase or decrease the likelihood of participation from the perspective of a non-participant.

For the values of attributes in option 3, the days, hours, and payment are set to zero. The MGR, however, is set as 350 or the maximum capacity as there is no MGR limit for a non-participant.

### 3 Results

Among the interviewees, the majority (70 individuals) reported not owning a vehicle, while 55 owned a fuel-based vehicle and 28 owned a hybrid or electric vehicle (83 vehicle owners and 153 in total). When asked about their familiarity with Vehicle-to-Grid (V2G) technology, 65 people indicated they had never heard of it, 31 had heard of it but were unsure what it was, and 53 stated they understood the theoretical concept. A small group (4 individuals) reported that either they or someone they know had participated in a V2G program; these starting values are shown in Fig. 3.

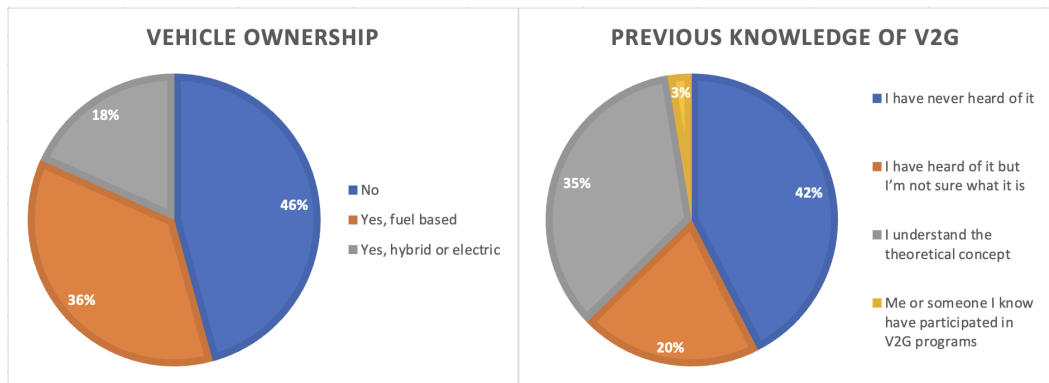


Figure 3: Vehicle ownership and previous knowledge of V2G.

#### 3.1 Demographics

Table 8 shows the remaining data for the responses and Figure 4 shows the distribution graphically. The group has slightly more male participation, but fairly balanced overall. Almost half of the participants are between 25 and 34 years old and two thirds are under 34. Around a third has completed up to bachelor’s degree and another third up to master’s degree. More than half perceive less than 40’000 SEK monthly and the number increases to 80% when including up to 60’000 SEK. More than half are employed and around 3 out of every 10 are currently students. Almost half are working in-person, a quarter work on a hybrid scheme and less than 10% are working fully remotely.

The overrepresentation of young adults studying or recently graduated comes from the fact that it is also the group the researcher belongs to; hence, the immediate

Table 8: Summary of demographic variables: age, education, income, gender, employment status, and work modality.

<b>Age Group</b>	<b>Education Level</b>	<b>Household Income</b>
Under 25 (30)	Primary or less (1)	<20 000 SEK (43)
25–34 (74)	Upper secondary (21)	20–40 k SEK (44)
35–44 (24)	Bachelor’s (58)	40–65 k SEK (37)
45–54 (10)	Master’s (52)	65–100 k SEK (14)
55–64 (4)	Postgraduate (12)	>100 k SEK (6)
65 or more (3)	Missing (9)	Missing (9)
Missing (8)		
<b>Gender</b>	<b>Employment Status</b>	<b>Work Modality</b>
Male (78)	Unemployed (9)	In person (74)
Female (64)	Self-employed (8)	Hybrid (39)
Other (3)	Full-time employed (69)	Remote (10)
Missing (9)	Part-time employed (13)	Not applicable (21)
	Student (45)	Missing (9)
	Missing (9)	

network of personal and professional contacts shares similar circumstances.

### 3.2 Behavior related questions

The results shown in Fig. 5 show there is a very even divide of car owners with constant and inconstant week schedules, with 41 and 42 participants respectively. This split differs significantly for the non-vehicle owners, with the majority, 53, being constant, while the remaining 19 have non-constant schedules.

Additionally, most of the car owners (57) are somewhere in the 5-30 km range, whereas the majority (47) of non-owners sit in a shorter range between 0 and 15 km.

Fig 6 shows the percentage of the respondents who said they use their car for certain trip types; this is out of the 83 car owners. This was a question with multiple answers enabled, as people can have more than a single purpose for their car. Three-quarters of them use their vehicle for daily commute, and 4 out of 5 use it for short trips within nearby places. Less than half use it for long distances.



Figure 4: Demographics data on pie charts.

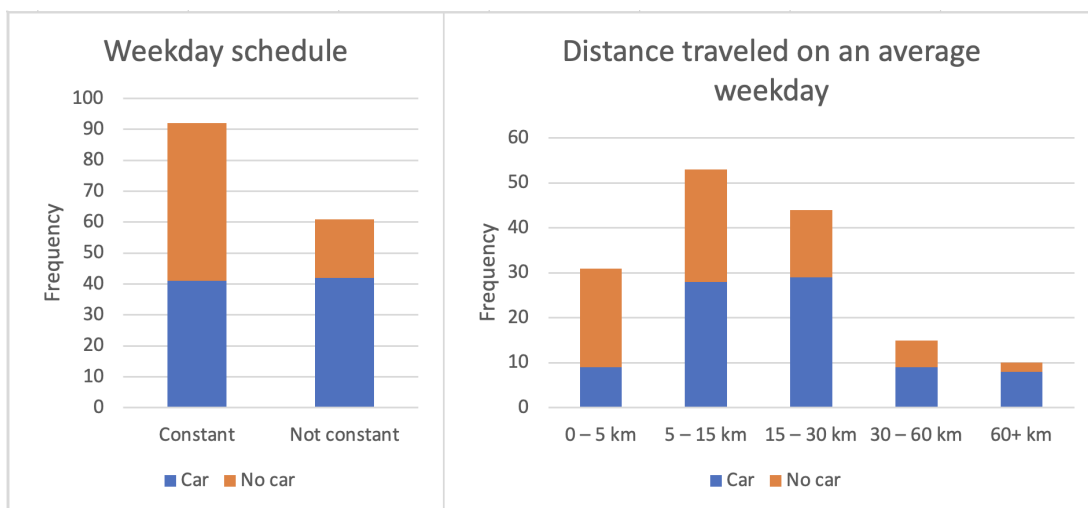


Figure 5: Driving behavior.

Fig 7 shows the answer to the question related to range anxiety. The range people feel comfortable with varies, starting with a group that grows steadily from less than 5 km up to 40 km. The second bar of the histogram is mainly composed of 20 people settling at 50 km. The next range group is not as popular but still chosen

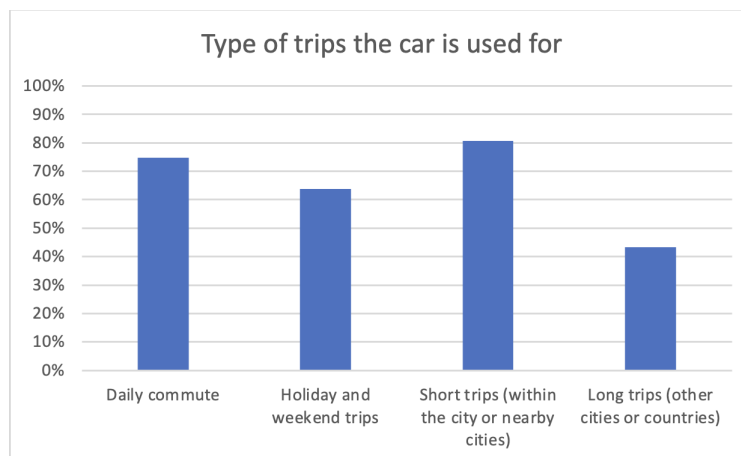


Figure 6: Frequency of trip types.

by some users; the peak range of 75-100 km is made up of 8 people choosing 80 km and the remaining 49 going for a rounded value of 100. A couple more responders go somewhere between 100 and 125, and for the top range, one person set it at 135 and the last 34 went for the maximum of 150 km. This question was asked before the experiment so that the respondents wouldn't be influenced by the options suggested by the options. However, setting the range from 0 to 150 might have created a subconscious grouping of 50, 100, and 150 km, which is why more than two-thirds went for one of these 3 numbers.

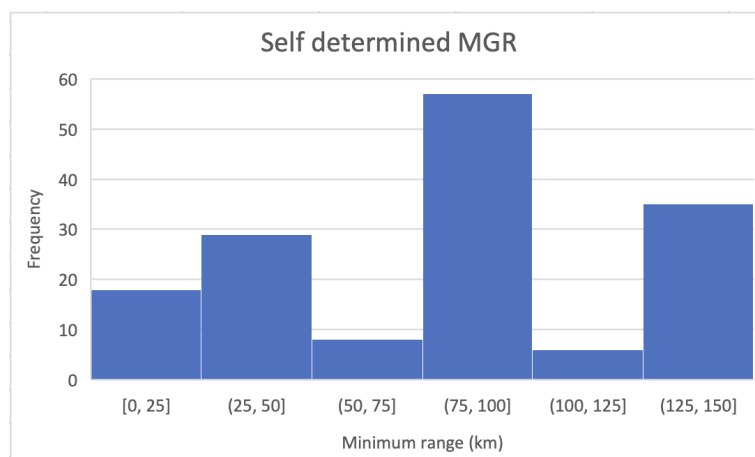


Figure 7: MGR that the user would feel safe with.

Fig 8 shows that the largest group, conformed of 62 people, considers that the main advantage of their theoretical participation in a V2G program would be their increased support for environmental causes. An equally large group would be motivated by more personal benefits: 42 for the direct monetary retribution, and 22

for acquiring a charger at home, which is a hidden benefit related to convenience. There is also a 20-person group that feels indifferent towards any of these benefits.

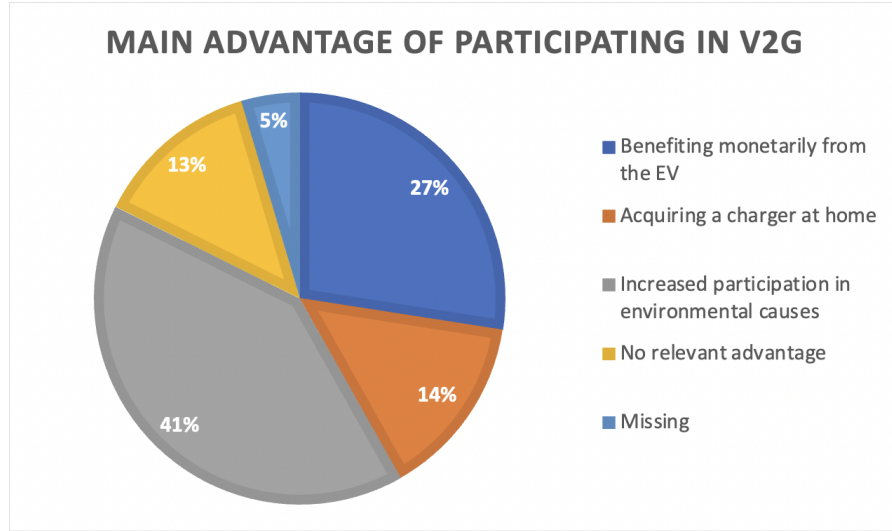


Figure 8: Main advantage of participating in V2G.

### 3.3 Utility coefficients

An adjustment was made so that the coefficient for hours was not displayed as pairs of hours per day, but instead as pairs of hours per week. This was done as a first iteration showed the coefficient for days as marginally significant.

The coefficients obtained from the biogeme model as well as their p-values are reported in Table 9. Their meaning and relevance are explained below.

Table 9: Estimated coefficients and robust p-values from the multinomial logit model.

Variable	Coefficient	p-value
ASC_1	-0.178530	0.538250
ASC_2	-0.499951	0.086160
$\beta_{\text{DAYS}}$	0.133335	0.011475
$\beta_{\text{HOURS\_WEEK}}$ (per pair of p + np hours)	-0.019910	0.006447
$\beta_{\text{RANGE}}$ (per 10 km)	0.028022	0.001008
$\beta_{\text{REMUNERATION}}$ (per 100 SEK)	0.052347	0.000098

ASC\_1 and ASC\_2 represent the alternative-specific constants for options 1 and 2, respectively. These values are not statistically significant ( $p = 0.538$  and  $0.086$ ), indicating that, after separating them from the observed attributes, there is no

inherent preference for either alternative over the opt-out option. This result aligns with expectations and indicates internal consistency: the only difference between options was the position in which they were displayed, and that should not be relevant.

$\beta_{\text{DAYS}}$  (0.133) represents the change in utility for each additional day of weekly participation in the V2G program. The result indicates a positive trend: participants favor longer engagement. This could be due to a preference for predictable routines or the ease of committing when their driving schedule is consistent throughout the week. For example, individuals with stable Monday-to-Friday routines might view full-week participation not as a burden, but as an opportunity to receive higher compensation.

$\beta_{\text{Hours\_week}}$  (-0.0199) is highly statistically significant ( $p = 0.006$ ) and negative, indicating that as plug-in hours increase in the week, the likelihood of choosing that alternative decreases. This aligns with expectations that convenience and the feeling of freedom are very important for participants.

$\beta_{\text{Range}}$  (0.0280) is also significant ( $p = 0.001$ ), implying that respondents prefer a greater minimum driving range. This is consistent with prior literature that states range anxiety is a critical factor in participants' decision to get involved.

$\beta_{\text{Remuneration}}$  (0.0523) is highly significant ( $p < 0.001$ ), meaning that, as expected, financial compensation strongly increases the likelihood of participation. It is the highest coefficient, albeit not a very strong one; this relates to fig 8 where it can be seen that economic benefit is not the strongest motivation.

### 3.4 Willingness to accept

Per equation (6) it is possible to calculate the WTA per attribute:

$$\text{WTA}_{\text{hours\_week}} = -\frac{-0.019910}{0.052347} \approx \mathbf{0.3803} \Rightarrow \mathbf{38.03 \text{ SEK}}$$

$$\text{WTA}_{\text{range}} = -\frac{0.028022}{0.052347} \approx \mathbf{0.5353} \Rightarrow \mathbf{53.53 \text{ SEK}}$$

Hours per week: Participants require approximately 38.03 SEK in compensation to accept one additional pair of plug-in hours per week.

Guaranteed range: Answerers are willing to give up 53.53 SEK for each additional 10 km of guaranteed driving range. This indicates a moderate valuation of range availability.

### 3.5 Concerns

From Fig. 9 the general sentiment towards external factors of V2G can be extracted. Below are each addressed individually. Although the total number of survey respondents was 153, only 144 participants provided valid responses for both variables in the tested pair, so  $n = 144$  was used for the calculation based on Eq. (7).

Under the standard normal distribution, the critical z-value for a two-tailed test at the  $\alpha = 0.05$  level is approximately  $\pm 1.96$ . Therefore, any correlation coefficient  $r_s$  that produces a z-score greater than 1.96 or less than -1.96 is considered statistically significant. For  $n = 144$ , this corresponds roughly to a threshold of  $|r_s| \geq 0.16$ . Thus, any observed rank correlation exceeding this threshold can be interpreted as statistically significant at the 5% level.

Battery degradation is a big concern among potential participants; they are aware that it is a hidden cost and accepting V2G will shorten their battery's lifespan, forcing them to replace it earlier. According to the Spearman's rank correlations, education is the demographic most strongly correlated with this concern, showing a positive value of 0.13. It is on the non-significant side of the calculation, but if considered, could suggest that more highly educated individuals tend to be more aware of the issue and, as a result, more skeptical about it.

The feel of having their freedom constrained is also high for people in general. The Spearman coefficient shows the highest correlation when paired with income at 0.19, pointing out that higher income individuals give more importance to their ability to move freely and independently.

Data privacy seems to be evenly divided between those who are more mistrustful of the incorrect handling of their data and those who feel indifferent towards the

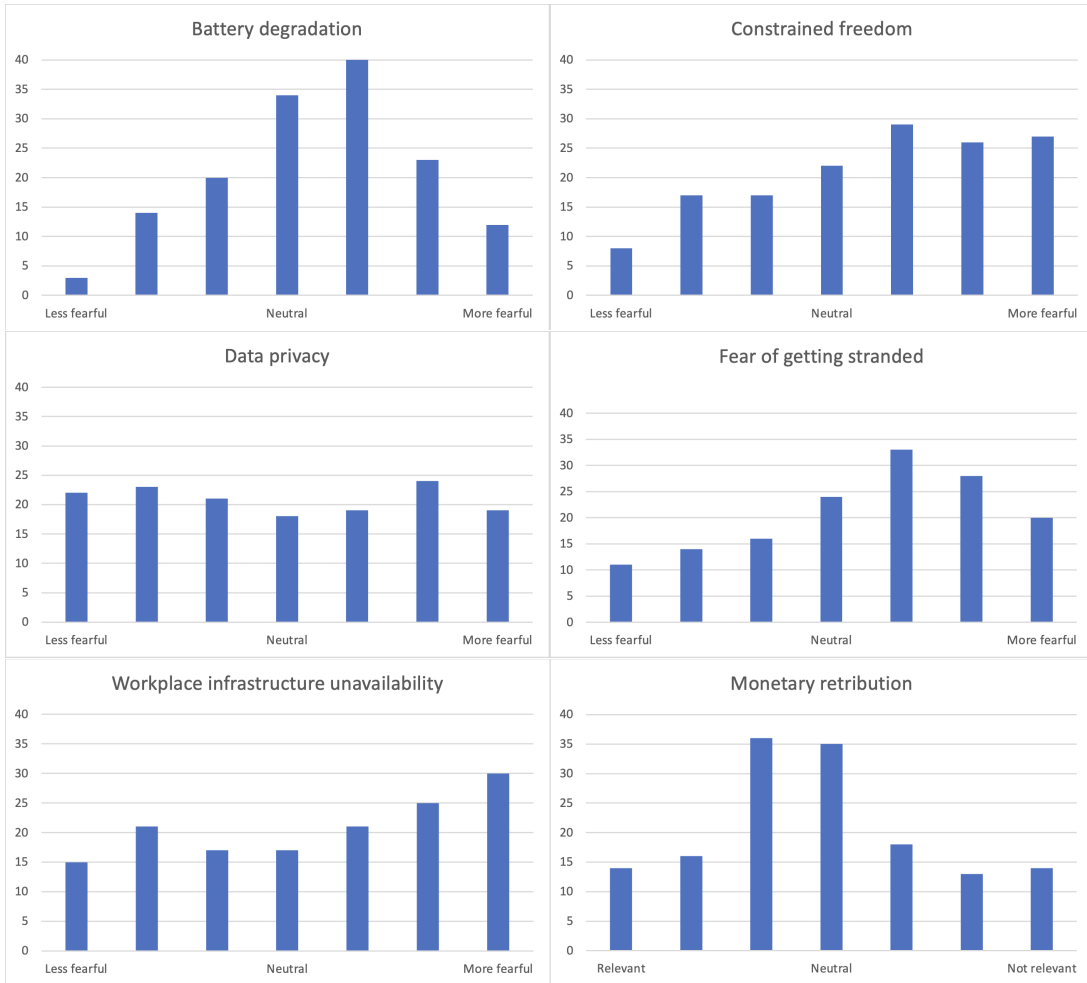


Figure 9: Matrix of concerns questions results. Responses out of 146 total sample.

subject. When accounting for age, the Spearman coefficient reached 0.21, suggesting that older people are more reluctant to share their data.

The fear of getting stranded is also generally strong. It has nevertheless an inverse correlation ( $-0.15$ ) with education; this value is near-significant, implying that there is a weak trend that higher-educated individuals feel more confident with the vehicle’s mechanisms to avoid getting stranded.

Out of all the concern-related questions, the only one where a majority of interviewees selected the highest level of fear was the unavailability of installing V2G infrastructure at their workplace. This reflects skepticism and shows a lack of belief that their employer has the interest or possibility to implement V2G.

The suggested monetary compensation seems to be significant to the respondents, not life-changing amounts but certainly high enough to pique their interest. It is

important, nonetheless, to mention that some of the suggested sums of money are not realistic with the current accommodation of factors.

## 4 Discussion

Using the coefficients from Table 9 it is possible to estimate the probability of participation based on different scenarios to design the optimal attributes for a pilot test. We now consider a scenario in which the aggregator offers compensation for a total of 48 plug-in hours: 24 peak and 24 non-peak. There are three possible ways of achieving this number of hours in a week: 8 pairs of hours, 3 days per week; 6 pairs of hours, 4 days per week; and 4 pairs of hours, 3 days per week. Using Eq. (1) the earnings for a participant that complies with the required hours (assuming a volatility of 1.333) reach only 187.11 SEK per month with the electricity prices of 2023. Setting 60 km as the base MGR, all attributes are assigned to estimate the enrollment rate of these 3 plans. Table 10 shows the estimated participation, calculated through Eqs. (4) and (5).

Table 10: Estimated probabilities of participation under different combinations of days and plug-in time, with fixed values of 60 km range and 187.11 SEK of monthly payment.

<b>Scenario</b>	<b>Probability of participation (%)</b>
3 days, 8 hours	54.69
4 days, 6 hours	57.97
6 days, 4 hours	64.30

Given that all scenarios achieve 48 hours, they are equal in the eyes of the aggregator, but not the same for the participants. As it is much more likely that they will participate in the scheme with more days and fewer hours.

Going further with this set scenario, it is also possible to change other attributes to make it more attractive. For example, the decision of setting MGR at 60 km as a base was in part to make the battery charge and discharge times to be around 4 hours. A more relaxed plan could set the MGR at 100 km as it was the most popular response as seen in Fig. 7. This lowers the battery availability to around 3.4 hours per session, lowering the compensation to around 140.04 SEK. The estimated participation rates are in Table 11.

Once again there is a different perception of the same attribute by the aggregator and the EV-owner: While the owner perceives every remaining kilometer more

Table 11: Estimated probabilities of participation for two scenarios with varying range and compensation, with fixed values of 6 days and 4 hours.

<b>Scenario</b>	<b>Probability of participation (%)</b>
60 km, 187.11 SEK	64.30
100 km, 140.04 SEK	66.28

valuable than the last one, the aggregator values every km equally. The perceived gain of more available kilometers compensates for the perceived loss of a couple of crowns of monthly income.

As mentioned in Section 2.2.4, the two factors that can increase the payment offer from the aggregator to the participant are price volatility and technological improvement of power rates. We now consider a couple of future scenarios where volatility increases and the power capacity reaches 25 kW for a commercial charger.

Estimating the monthly remuneration for a plan that guarantees 100 km of availability was done by averaging the worst- and best-case scenarios for earnings with a 4 peak + 4 non-peak setup. For example, adding the 40 km from the starting 60 km reduces the battery availability from 4 to 3.5 hours per session; the worst-case scenario then assumes that no energy is being delivered or taken by the battery in that half an hour and thus profitability is reduced. The best-case scenario assumes that the user complies with their 8 hours in different sessions, and for that, there is no idle time, so all the hours are being profited on.

For the technology improvement scenario where a 25 kW charger is in place, it is also assumed that battery capacity is increased as well; this is done to give some more leeway for the charger as it can charge and discharge the full availability in around 1.5 hours, and realistically, battery developers will continue increasing their capacity. In addition, this scenario assumes a 50% drop in technology costs. The now 70 kWh with 450 km range vehicle can have its available energy disposed of and replenished in 2 hours and 10 minutes. The worst-case scenario then will be calculated with the remaining hour and 50 minutes as idle time and the best-case as if the whole 8 hours are operational. Table 12 shows the remuneration estimation for the next example.

Table 12: Charging performance scenarios under different volatility multipliers and charger capacities, all values are in SEK.

Vol.	11.25 kW charger			25 kW charger		
	Worst case	Best case	Average	Worst case	Best case	Average
1	82	119	101	164	486	325
1.333	155	204	179	264	670	467
1.5	191	247	219	314	762	538
2	300	374	337	464	1039	752
3	518	628	573	764	1593	1178

Table 13: Estimated probability of participation (in percent) by compensation level, categorized by volatility and technological improvement assumptions. All scenarios assume 100 km range, 6 days, and 4 plug-in hours.

Scenario	Remuneration (SEK)	Participation prob. (%)
Low vol., low tech	101	65.82
	179	66.73
	219	67.20
	337	68.54
High vol., low tech	573	71.14
Low vol., high tech	325	68.41
	467	69.99
	538	70.77
	752	73.03
High vol., high tech	1178	77.19

Table 13 shows the estimates of participation according to the results in a near future with varying external factors.

The aim of this exercise was to describe numerically how setting up a plan for a particular participant can increase their probability of involvement and how changes in the future can help make V2G programs more attractive.

## 5 Conclusion

This thesis set out to understand the willingness of EV users in Gothenburg, Sweden, to participate in vehicle-to-grid (V2G) programs under different technical and financial conditions. By conducting a stated choice experiment with 153 valid participants, we captured user preferences across four key dimensions: guaranteed driving range, plug-in time, days of participation, and monetary compensation. The experiment design was grounded in both theoretical literature and real-world electricity market data.

The results from the multinomial logit model show that plug-in time significantly affects the intent of contributing. Users are reluctant to commit to long plug-in durations, likely due to concerns over loss of flexibility and perceived inconvenience. On the contrary, financial reward plays a key role in encouraging enrollment. Respondents are moderately sensitive to guaranteed range, reflecting latent range anxiety, and seem to be satisfied with 100 km of offered range; they also display a slight positive response to increased participation days, possibly due to the value placed on routine and predictability. In addition, the willingness-to-accept estimates further illustrate trade-offs users can make. On average, participants demand approximately 165 SEK to accept an additional pair of plug-in hours, and are willing to give up around 38 SEK for every 10 km of additional guaranteed range. Scenario simulations demonstrate that even small changes in remuneration or conditions can have a notable effect on participation likelihood, offering valuable insight for V2G providers and policymakers.

Future scenarios with higher electricity price volatility and improved charger technology show promise in increasing user profitability, thereby raising participation rates. However, this hinges on transparent communication, reliable infrastructure, and user trust in V2G schemes in terms of technological reliability and good-intentioned data handling. Ultimately, this thesis contributes empirical evidence supporting the design of user-oriented V2G policies. It highlights the need for economically viable participation schemes that respect user autonomy and convenience while aligning with grid optimization strategies. In relation to the general

concerns shown by the population, the conclusions here obtained can be used to design information campaigns from V2G providers to alleviate their potential customers' apprehensions with the goal of improving engagement. Future work could expand this research by exploring more diverse samples, applying latent class models to uncover deeper preference heterogeneity, or integrating qualitative interviews to complement the quantitative findings.

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## A Python Code Used for Estimation

```
1 import pandas as pd
2 import biogeme.database as db
3 import biogeme.biogeme as bio
4 from biogeme.expressions import Beta, Variable
5 import biogeme.models as models
6
7 file_path = "experiment_biogeme_3minmod.csv"
8 df = pd.read_csv(file_path)
9 database = db.Database('survey_db', df)
10 chosen_alternatives = df[df["choice"] == 1].groupby(["RID", "
    DESIGN_ROW"])["alternative"].first()
11 df["choice_biogeme"] = df.groupby(["RID", "DESIGN_ROW"])["
    alternative"].transform(
12     lambda x: chosen_alternatives.get((x.name[0], x.name[1])))
13 df.to_csv("biogeme_ready_3minmod.csv", index=False)
14 print(df)
15
16 CHOICE = Variable('choice_biogeme')
17 HOURS_WEEK = Variable('hours_week')
18 DAYS_PARTICIPATION = Variable('days_participation')
19 MIN_RANGE_KM = Variable('min_range_km')/10
20 REMUNERATION_SEK = Variable('remuneration_sek')/100
21 BETA_HOURS_WEEK = Beta('BETA_HOURS_WEEK', 0, None, None, 0)
22 BETA_DAYS = Beta('BETA_DAYS', 0, None, None, 0)
23 BETA_RANGE = Beta('BETA_RANGE', 0, None, None, 0)
24 BETA_REMUNERATION = Beta('BETA_REMUNERATION', 0, None, None,
    0)
25
26 ASC_1 = Beta('ASC_1', 0, None, None, 0) # Alternative 1
    constant
27 ASC_2 = Beta('ASC_2', 0, None, None, 0) # Alternative 2
    constant
28 ASC_3 = Beta('ASC_3', 0, None, None, 1) #(normalized for opt-
    out)
29
30 V1 = ASC_1 + BETA_HOURS_WEEK * HOURS_WEEK + \
31     BETA_DAYS * DAYS_PARTICIPATION + \
32     BETA_RANGE * MIN_RANGE_KM + \
33     BETA_REMUNERATION * REMUNERATION_SEK
34
35 V2 = ASC_2 + BETA_HOURS_WEEK * HOURS_WEEK + \
36     BETA_DAYS * DAYS_PARTICIPATION + \
37     BETA_REMUNERATION * REMUNERATION_SEK + \
38     BETA_RANGE * MIN_RANGE_KM
39
40 V3 = 0 # Base alternative (opt-out)
41 V = {1: V1, 2: V2, 3: V3}
42 av = {1: 1, 2: 1, 3: 1}
43 logprob = models.loglogit(V, av, CHOICE)
44 biogeme = bio.BIOGEME(database, logprob)
```



## C Survey layout example questions

### What types of trips does the car accommodate? (Multiple answer enabled)

Select all that apply

<input type="checkbox"/> Daily commute
<input type="checkbox"/> Holiday and weekend trips
<input type="checkbox"/> Short trips (within the city or nearby cities)
<input type="checkbox"/> Long trips (other cities or countries)

### Is your driving schedule the same every weekday?

Select only one answer

<input type="radio"/> Yes
<input type="radio"/> No

### What is the minimum distance your car should be able to cover to make you feel safe, especially in an emergency? Please enter a number between 0 and 150 kilometers.

Enter text below

### Please answer these questions on a scale from 1 to 7, where 1 is totally disagree and 7 is totally agree.

Select one response from each row

	1	2	3	4	5	6	7
I fear that the suggested monetary compensation of V2G would not sufficiently compensate for the battery degradation of my vehicle.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Having to comply with a V2G contract constrains my freedom.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I would feel uncomfortable sharing the data on my routine and driving behavior with the V2G company.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am concerned that I could get stranded because I started my trip without sufficient battery.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I think it is very unlikely that there could be V2G infrastructure set up in my workplace.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The suggested monetary benefit from participating in V2G is insignificant to me in comparison to other income sources I have.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Here is a short video if you need information on what Vehicle-to-grid (V2G) is:

<https://www.youtube.com/watch?v=Jh6B3eYQG90>

Imagine you have an electric vehicle and are offered to participate in a V2G program with the following conditions:

- The company will cover the costs of installing and will set up a V2G charging point at your home.
- There is V2G infrastructure available at your workplace.
- You can program times and dates when V2G is not enabled even if the vehicle is plugged in.
- You can visualize (i.e., through a mobile app) the hours completed, and hours missing to reach the goal and can see the battery level when plugged in.
- The contract is flexible, meaning that it can be modified if your routine changes.

**Attributes:**

**Plug in time** is the minimum number of hours your EV must be plugged in and operated as V2G, divided in peak and non-peak hours based on the table below.

Example: for a 2 peak + 2non peak you could participate from 19:00 to 23:00, that is 2 hours from block D and 2 hours from block A, any combination works!

**Days of participation** is the minimum number of days per week your EV must participate in the V2G program.

**Minimum guaranteed range** is the lowest battery level your EV will never drop below during V2G participation, no matter what. This is considering a car with a 350 km range when fully charged.

Block	Peak / Non-Peak	Time
A	Non-peak	21:00 - 06:00 (9 hours)
B	Peak	06:00 - 11:00 (5 hours)
C	Non-peak	11:00 - 16:00 (5 hours)
D	Peak	16:00 - 21:00 (5 hours)

Below are six different scenarios, you have two different options to choose from plus the option not to participate.

Each scenario is independent from each other and you should only ponder between the three shown options, without comparing them to those in different scenarios.

	Option 1	Option 2	Not willing
Plug-in hours per day	1 peak + 1 non peak	1 peak + 1 non peak	-
Days of participation	6 days per week	5 days per week	-
Minimum guaranteed range	60 km (approximately 17%)	50 km (approximately 15%)	-
Monthly remuneration (SEK)	580	450	-
	<input type="radio"/> Option 1	<input type="radio"/> Option 2	<input type="radio"/> Not willing

DESIGN FOR EVALUATION ONLY

	Option 1	Option 2	Not willing
Plug-in hours per day	1 peak + 1 non peak	1 peak + 1 non peak	-
Days of participation	3 days per week	5 days per week	-
Minimum guaranteed range	90 km (approximately 25%)	50 km (approximately 15%)	-
Monthly remuneration (SEK)	300	450	-
	<input type="radio"/> Option 1	<input type="radio"/> Option 2	<input type="radio"/> Not willing

DESIGN FOR EVALUATION ONLY

	Option 1	Option 2	Not willing
Plug-in hours per day	4 peak + 4 non peak	4 peak + 4 non peak	-
Days of participation	5 days per week	4 days per week	-
Minimum guaranteed range	120 km (approximately 34%)	50 km (approximately 15%)	-
Monthly remuneration (SEK)	860	870	-
	<input type="radio"/> Option 1	<input type="radio"/> Option 2	<input type="radio"/> Not willing