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But can it drive to Lapland? A comparison of electric vehicle owners with the general population for identification of attitudes, concerns and barriers related to electric vehicle adoption in Finland

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Abstract

Transportation is a major source of greenhouse gas emissions with private car use accounting for a large proportion of those emissions. Battery powered electric vehicles (EV) are a currently available technology that has the potential to significantly reduce emissions from car use. Therefore, promoting a shift from internal combustion engine vehicles to EVs should be supported by policy makers aiming to curtail emissions from car use. To design policies and interventions to promote EV adoption, information is needed on how people perceive electric vehicles and what are the real and perceived barriers preventing their adoption. With this objective in mind, it was investigated what the current EV owners in Finland are like and how they compare with the general population. We also endeavored to identify real as well as potentially misperceived barriers to EV adoption and factors affecting EV purchasing intentions. The study utilizes a sample of 3857 participants, including 141 electric car owners, who answered a questionnaire investigating lifestyle, car use, environmental and political attitudes as well as household carbon footprint and attitudes towards EVs. EV owners in Finland have more financial security, own more cars, drive more, and have a larger average household carbon footprint than the general population. There are two distinct subgroups among electric car owners, one group being interested in environmental impact of their car use and the other focused on the performance of their cars. People without experience of EVs generally have negative attitudes towards electric cars and also maintain some misconceptions about EVs. Personal experience with electric vehicles is associated with a positive outlook on these types of vehicles and is the strongest predictor of EV purchasing intentions.

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1 Introduction

Transportation is a major source of greenhouse gas emission (GHG) representing a 16–22% of all global emissions [1, 2]. In Finland, the transport sector produces 20% of the nation's GHGs, with cars contributing 53% (5 million tons of CO_{2e}) of those emission [3]. Thus, there is both a large potential as well as an urgent need to reduce emissions from car use.

Moving from fossil fuel based internal combustion engine vehicles (ICEV) to alternative fuel vehicles can reduce road traffic emissions. Although various alternative fuels such as natural gas, biofuels and hydrogen exists, currently the most mature and scalable technology is the battery powered electric vehicle (BEV or just EV). For reference to all abbreviations used in the study see Table 1.

EVs boast several advantages over ICEVs. They produce no tailpipe emissions, fewer unhealthy particle emissions [4] and are more energy efficient than ICEVs. Furthermore, and most importantly, energy charged into EVs can be produced with renewables or nuclear power instead of fossil fuels making EVs a step towards energy infrastructure that is not dependent on fossil fuels [5, 6]. For the user EVs generally provide higher acceleration, less noise, a smoother drive and lower running cost than comparable ICEVs.

The disadvantages of EVs include the high environmental impact of manufacturing the batteries and concerns related to the sufficient supply of raw materials used in the batteries [7, 8]. The materials for batteries are also occasionally sourced from regions with a potential risk for the unethical treatment of workers. From a user perspective, charging an EV takes longer than refueling an ICEV, and the charging infrastructure is less developed than the fuel distribution infrastructure. Therefore, long trips can be more challenging with an EV than an ICEV and owners must acquire new skills related to charging and range management. Finally, EVs typically have a higher purchase price than comparable ICEVs.

Estimating the real-world reduction in GHG emissions of EVs compared to ICEVs is complex: Factors affecting EV emissions include: the source of the electricity used to charge the EV, the battery and vehicle lifetime, the physical characteristics of the vehicle and how the vehicle is used. Most studies suggest that lifecycle GHG emissions of EVs are significantly lower than similarly sized ICEVs by 20 to 72% [4, 9, 10].

In the most ideal scenarios, such as only charging the EV with home generated solar power, the GHG emission savings compared to ICEV could be as high as 97% during the vehicles lifecycle [9]. However, if EVs are mostly charged with electricity produced with fossil fuels their GHG emissions are similar or greater than ICEVs [10–12]. Thus, the carbon intensity of a region´s electric grid plays a significant role in the emissions of EVs. Nonetheless, future decarbonization of electric grids as well as advances in battery recycling and manufacturing have the potential to significantly reduce the lifecycle emissions of EVs amplifying their advantage over ICEVs even in regions with a currently carbon intensive grid.

Table 1. Definitions and abbreviations used in the study.

TERM USED IN THE STUDY	DEFINITON GIVEN TO THE STUDY PARTICIPANTS
Electric vehicle, EV	Vehicle running only with electric power.
Internal combustion engine vehicle, ICEV	Vehicle using only petrol or diesel as a fuel.
Hybrid electric vehicle, HEV	Vehicle with both combustion engine and electric motor that cannot be charged from a power outlet.
Plug-in hybrid electric vehicle, PHEV	Vehicle with both combustion engine and electric motor that can be charged from a power outlet.
Natural gas vehicle, NGV	Vehicle that can utilize natural gas as a fuel source in addition to petrol or diesel.

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An EV´s lifecycle emissions are initially higher in comparison with comparable sized ICEVs due to the larger emissions in the construction phase; however, due to lower usage emissions overtime the lifecycle emissions will be lower. In Finland, which sharing an electric grid which is mostly powered by hydro and nuclear power with Sweden and Norway, a compact family EV is estimated to achieve emission parity with an similar ICEV during the third year of use and after a decade of use, the EV´s lifecycle emissions are less than half of those of an ICEV [4, 9, 10].

1.1 Literature review

The first obstacle in EV adaptation is setting up a sufficient charging infrastructure in order to make them a viable alternative to ICEVs. In regions where the charging network makes EVs a practically and feasible alternative to ICEVs, such as Finland, economic, social, and psychological factors play a major role in the EV adoption rate. Recent reviews [13–16] of studies investigating what factors affect EV purchase intentions have identified several factors that are repeated across a wide range of studies but also discovered significant variation in the results between the studies and the regions.

The reviews identified positive attitudes and norms towards EVs, personal experience with electric vehicles, economic benefits including low running cost and financial incentives, and openness and interest towards new technology as common factors that had positive association with EV purchase intentions. High purchase price, concerns related to vehicle range and adequacy of the charging network were often found to constitute barriers to EV adoption [13–16].

Mixed results were found regarding the association of gender, age, education, income and environmental attitudes with EV purchase intentions: Some of the reviewed studies found these factors to have a significant effect, others found non-significant effects and some studies found conflicting effects, such as women being more interested in purchasing EVs than men or men being more interest than women [16]. The region where the study was conducted affected the results suggesting significant differences between countries and cultures as determinants of purchase intentions. The majority of the recent studies were conducted in China or the US and the heterogeneity of the results as well as the rapidly advancing EV technology, together with the charging infrastructure and market situation suggest that more regional studies on EV adaptation are warranted [14, 16].

Current EV users, who can still be regarded as early adapters of the technology, are often middle-aged men who are interested in technology, not concerned about ease of use, often own multiple cars, are financially affluent and value the symbolic attributes of car ownership and social status that an EV provides [17–25]. A review of user experiences of early EV owners [26] found that the majority did not experience the range of their EV to be a major issue and they had learned to be effective with range management with their vehicle. Features that set EVs apart from ICEs such as reduced noise were regarded positively and some studies found EV drivers to highly value the symbolic aspects of their vehicles such as perceived environmental friendliness or superior performance [26].

However, the widespread electrification of road traffic requires EVs to be adopted by many kinds of people, not just typical early adopters of new technology, and therefore information on attitudes and barriers to adoption among the general population is required.

1.2 Aim of the study

To identify factors that increase or decrease interest towards EVs in Finland, the current study sets out to investigate the current characteristics of EV owners in Finland and compare them with the remainder of the population. The aim being to identify barriers to EV adaption and factors affecting EV purchasing intentions.

Finland is situated in northern part of Europe and has a large surface area but a low population density, a high level of education and relatively high incomes. In the rural regions a private car is often the only viable mode of transportation. Also, in cities where there is public transportation and other viable modes of travel private car use is nevertheless common. Due to owning a car being a norm, adults who do not own a car are often students, pensioners or people with a low income [27].

The EV charging network in Finland was already well developed in 2022 during the data collection period and enabled long distance trips to most areas of the country even with modest ranged EVs (including major attractions of Lapland). The only exception being some sparsely populated areas in the north and east parts of the country [28]. Since then the charging network has continued to grow at a steady pace. The popularity of electric vehicles is growing in Finland, evidenced by the increasing share of EVs in new car purchases: from 4.4% in 2020, to 10.3% in 2021, and reaching 17.8% in 2022. Notably, in 2023, EVs represented 33.8% of all new vehicles, with most new vehicles in Finland being either EVs or plug-in hybrid electric vehicles (PHEVs), indicating a significant shift towards electric mobility. Despite this growth, EVs accounted for just 2.6% of the total vehicle fleet in 2023, denoting them as a relatively new introduction [29].

Specifically, the study has three aims:

The first, is to understand the sociodemographic characteristics, car usage patterns, environmental attitudes, and carbon footprints of early EV adopters in Finland by analyzing and categorizing them into distinct user profiles. The analysis includes comparing these profiles with the ICEV users as well as people without a car to highlight differences and potential barriers to EV adoption that exist among the wider population.

The second aim is to evaluate how personal experiences with EVs influence perceptions of their environmental impact, practicality, and ease of use. This is done by presenting participants with specific statements about EVs and analyzing the differences in responses between those who have personal experiences with EVs and those who do not. Identifying disagreements will help pinpoint misconceptions or unfounded concerns, that might be targets for future interventions to enhance EV acceptability.

The third aim is to explore the factors that influence future EV purchase intentions. By examining a variety of influences, the goal is to identify which factors are most closely associated with a strong interest in either adopting EVs for the first time or continuing their use in the future. The intention is to shed light on the main motivators and barriers affecting EV adoption decisions.

The nature of the study is explorative and hypothesis generating, however, we do expect to find results that are in line with previous studies. Personal experience with EVs, appreciation of their economic benefits and interest towards new technology is expected to increase interest in EVs. While in contrast lack of personal experience is expected to be associated with negative attitudes towards EVs; especially regarding concerns related to range and charging. The results of this study will clarify the current situation of EV related attitudes in Finland, as well as the real and perceived barriers. It could also inform policy decisions and intervention designs aimed at increasing EV acceptability and adoption, not just in Finland, but in any country where EVs are a viable alternative to ICEVs but are met with public skepticism.

2 Materials and methods

2.1 The CLIMATE NUDGE survey

Data from the CLIMATE NUDGE survey is utilized. The survey investigated various aspects related to climate change, lifestyle and attitudes and was collected online by the marketing research company Kantar TNS from 22 April 2022 until 16 May 2022. Participants could answer the questionnaire in Finnish, Swedish or English with 97.2% of participants choosing to answer in Finnish.

Three different samples were collected in the CLIMATE NUDGE survey. The first was a sample of 3600 participants from a panel maintained by Kantar. The panel is representative of the general Finnish adult population regarding age, gender and place of residence. However, the sample drawn from the panel for this study had a higher mean age (54 years) than the population average (44 years). Regardless, it was chosen to not weight the data to maintain more accurate measurements. Additionally, two non-representative samples were also collected: a sample of clients of organization selling carbon compensation services, Compensate, and a sample of members of the association of EV owners in Finland (Sähköautoilijat RY). These additional samples were collected to recruit more participants who own an EV to the study. Additional samples included a further 267 participants bringing the total sample size to 3867. The panel sample recruited by Kantar received minor monetary compensation for participation. Additional samples were recruited via email with no compensation was offered. Additional information on the dataset can be found at: https://osf.io/3s8uc.

2.2 Ethics statement

Participants who were invited to take part in the CLIMATE NUDGE survey provided written informed consent to participate in the study via the online system before they were able to access the survey. They were also informed of the right to discontinue answering the survey at any point and in such cases their previous answers would be deleted and not used in the study. The CLIMATE NUDGE survey study received ethical approval from ethical board of Humanities and Social Sciences at the University of Turku and the study was conducted in according to principles of Declaration of Helsinki.

2.3 Participants

During the initial review of answers given by EV owners, 10 cases with an impossible combination of answers (such as owning an EV but not owning a car) were identified and these cases were omitted from all the analyses.

After the exclusions, the sample included 3857 participants of which 54.3% were women, 45.2% men and 0.2% non-binary. The mean age was 53.18 (range 19–90, SD 16.73) and 77.9% of the participants reported that there was at least one car in their household and 3.7% (141 participants) reported that there was an EV in their household.

Among the EV owners, 67 were part of the additional samples and 74 were part of the panel sample. Therefore 2.1% of the panel sample report owning an EV.

2.4 Measures

Participants answered various questions regarding their sociodemographic background, place of residence, lifestyle as well as car ownership and use. Additionally, they answered questions regarding political opinions and attitudes towards climate change. These variables were used to identify differences between EV owners, ICEV owners and participants without a car.

Experience with EVs was identified in previous research to be a major factor affecting EV attitudes and purchase intentions [14]. In the current study this was investigated with two questions: Participants were asked to indicate how many cars they had in their household and the type of powertrain utilized by each car to identify EVs in the household. Additionally, participants were asked what sort of experience they personally had with an EV; the answer options being "I own an EV", "I have driven and EV", "I have been a passenger in an EV" and "I have no personal experience with EVs".

Attitudes towards EVs were investigated with 14 statements regarding EVs to which participants indicated their agreement or disagreement on a one to five scale. These statements were generated for the study based on technical knowledge of EVs and by following public discourse surrounding concerns related to EVs in Finland. They include statements such as "Electric cars produce fewer emissions than internal combustion engine cars" and "Buying an electric car is expensive". The full list of these statements can be found in Table 7 in Chapter 3.5. For the EV owners further questions on why they had acquired an EV were presented. These participants were asked to indicate the 1–3 most important reasons why they had acquired their EV and this data were used for the EV user group segmentation. A full list of these questions can be found in Table 5 in Section 3.3.

The shortened version Environmental Attitudes Inventory (EAI-12) [29] was used to investigate environmental attitudes of the participants and to investigate whether pro-environmental attitudes were associated with owning an EV. The 12-item EAI in these data consisted of the following items from the original 72-item version: Scale 1: item 10, Scale 2: item 3, Scale 3: item 4, Scale 4: item 8, Scale 5: item 10, Scale 6: item 5, Scale 7: item 7, Scale 8: item 8, Scale 9: item 1, Scale 10: item 2, Scale 11: item 1 and Scale 12: item 1. These items were mostly those that the original authors recommended for shortened version of EAI; some exceptions were made and items were chosen that were considered to best suit the Finnish culture. The EAI can be used as a unidimensional construct in which a high total score represents a favorable attitude towards nature or it can be divided into two factors, preservation which represents participants belief that nature should be protected, and utilization which represents the belief that humans have the right to use and alter nature for their own gain. In the current sample the preservation factor had a Cronbach Alpha of .72 and the utilization factor an Alpha of .70 signaling reasonable reliability.

For a measure of actual pro-environmental behavior, a carbon footprint of participants was estimated. The carbon footprint is a rough measure of how much greenhouse gas emissions the lifestyle of the participant produces measured in Carbon Dioxide equivalent (CO_{2e}) tons. The footprint was estimated based on the answers to 51 questions in the survey related to housing, transportation, diet and consumption. Details of how this measurement was constructed can be found at https://osf.io/myhnr. In the analyses involving carbon footprint participants with incomplete information to calculate the measurement or a carbon footprint that deviated three or more standard deviations from the mean were excluded reducing the sample size available in these analyses to 3782.

The order of different question blocks in the survey were partly randomized: sociodemographic questions were always first and wellbeing related questions last, but the order of questions related to lifestyle, car use and environmental attitudes and so forth were randomized to prevent item order effects.

2.5 Statistical methods

A Pearson Chi Square (X^2) was used for significance testing of the associations between categorical variables with a Cramer V (φ_c) test providing the measure for the strength of the association. Associations between categorical and continuous variables were tested with an Analysis of Variance (ANOVA) with an Omega Squared (ω^2) effect size measure. For analyzing factors affecting the interest in purchasing an EV a logistic regression model was constructed with an odds ratio (OR) serving as an effect size measure and to classify EV owners into user groups based on their motivations to purchase an EV. A latent class analysis (LCA) with a number of segments based on the Bayesian Information Criterion (BIC) was utilized.

To lower the risk of false positive inferences due to multiple comparisons within the dataset, an Alpha level of $< .001$ was considered statistically significant. Statistical analyses were conducted with SPSS 28, Python 3.9 and Displayr.

3 Results and discussion

3.1 Comparison of EV owners and general population: Sociodemographic

The first aim of the study is to understand the sociodemographic characteristics, car usage patterns, environmental attitudes, and carbon footprints of early EV adopters in Finland and how they differ from the rest of the population. Starting with the sociodemographic characteristics (Table 2), EV owners have a higher education level and are more often in full time employment than ICEV owners or participants without a car. Differences with the largest φ_c among these group can be observed in their relationship status; EV owners tend to be in a relationship with a shared household more often than other groups (X2 $p < .001$, $\varphi_c = 0.30$). In addition, EV owners more frequently own their home (X2 $p < .001$, $\varphi c = 0.29$) and their home is more often a single-family house than among other groups (X2 $p < .001$, $\varphi c = 0.31$).

The Largest effect size difference between EV owners, non-EV car owners and households without a car can be observed in income levels, as can be seen in Fig 1. EV owner households have a significantly higher mean income than households with other types of car and especially households without a car (X2 $p < .001$, $\varphi_c = 0.34$ N = 3857).

Overall these results demonstrate that the current EV households are generally in a financially secure position with a stable high income while the situation among other car owners and carless households is more varied. EV owners are also willing to pay more for their next car than other participants. When asked how much participants who were considering purchasing a new car within the next three years would be willing to pay for the vehicle, 39.8% of the participants from EV households said they would consider a car costing over 40 000€ while only 9.9% of participants with a non-EV car and 4.5% of participants without a car would consider this amount (Table 3). The participants were not asked to indicate whether their next car would be a new or used vehicle.

At the time of the data collection, the majority of new EVs in Finland cost over 40 000€, with cheaper options limited to a few specific models or heavily used vehicles. Therefore, the price of EVs was a major barrier for many people in 2022 and the current EV owners generally had higher income than Finnish average. However, between the data collection and writing the article the used-car market conditions have already changed significantly with more lightly used EVs becoming available. This increased supply together with the market entry of new lower priced EV models and the price cuts for new EVs initiated by Tesla have made EVs more accessible to the average consumer with several options in the 20 000–30 000€ price range. Among the current non-EV car owners who were considering buying a new car, 65.2% would consider a car in this price range. While the reduction in the cost of EVs has made them a viable option to more households, their higher cost compared to used ICEVs is still a real barrier to adoption for many people.

Responses to "how likely your next car will be an electric car?" were significantly influenced by experience with EVs (Fig 2) with 81.7% of EV household respondents saying it would be very or quite likely that their next car would be an EV, compared to 18.4% of non-EV car households and 27.6% of car-free households (X2 $p < .001$, $\varphi_c = 0.32$ (n = 2204)).

EV owners reported high satisfaction with their EV with 65.2% reporting that they were very satisfied and 27.0% reporting they were quite satisfied. These results suggest that once a person has acquired an EV they are unlikely to go back to an ICEV and therefore interventions and policies that aim to convert ICEV users to EV users for the first time could be beneficial;

Table 2. Sociodemographic information on EV owners compared to rest of the population.

	Household with an EV (n = 141)	Household with car that is not EV (n = 2873)	Household without a car (n = 843)	Statistical difference
Age	M 45.7 SD 13.48	M 54.7 SD 16.23	M 49.4 SD 17.94	F $p < .001$, $\omega^2 = 0.10$
Gender				
Female	41.1% (58)	52.1% (1497)	64.7% (545)	X^2 $p < .001$, $\varphi_c = 0.10$
Male	58.2% (82)	47.9% (1375)	34.6% (292)	
Other	0.7% (1)	0.1% (1)	0.7% (6)	
Education				
PhD	5.7% (8)	3.2% (93)	2.6% (22)	X^2 $p < .001$, $\varphi_c = 0.08$
Upper tertiary	32.6% (46)	22.3% (641)	19.6% (165)	
Lower tertiary	26.2% (37)	27.9% (803)	25.3% (213)	
High school	10.6% (15)	12.7% (366)	17.9% (151)	
Vocational	21.3% (30)	27.4% (786)	24.9% (210)	
Primary	3.5% (5)	6.4% (184)	9.7% (82)	
Employment				
Full time	72.3% (102)	44.8% (1286)	28.8% (243)	X^2 $p < .001$, $\varphi_c = 0.17$
Part time	6.4% (9)	6.3% (182)	10.1% (85)	
Student	5.0% (7)	4.2% (120)	13.5% (114)	
Retired	9.9% (14)	36.2% (1041)	32.4% (273)	
Other	9 (6.4%)	8.5% (244)	15.2% (128)	
Relationship status				X^2 $p < .001$, $\varphi_c = 0.30$
With shared household	81.6% (115)	70.9% (2036)	22.4% (189)	
No shared household	6.4% (9)	6.8% (195)	12.0% (101)	
Not in a relationship	12.1% (17)	21.4% (615)	64.2% (541)	
Other	0% (0)	0.9% (27)	1.4% (12)	
Urbanicity of place of residence				X^2 $p < .001$, $\varphi_c = 0.17$
City centre	70.1% (96)	64.4% (1841)	90.1% (757)	
Area surrounding city	16.1% (22)	9.7% (276)	2.5% (21)	
Rural area	7.3% (10)	13.9% (397)	4.2% (35)	
Sparsely populated rural	6.6% (9)	12.1% (346)	3.2% (27)	
Home ownership				X^2 $p < .001$, $\varphi_c = 0.29$
Owner	82.1% (115)	78.9% (2267)	34.8% (292)	
Rental	12.9% (18)	18.2% (522)	60.2% (506)	
Right-of occupancy	4.3% (6)	2.3% (67)	3.5% (29)	
Other	0.7% (1)	0.6% (16)	1.5% (13)	
Apartment type				X^2 $p < .001$, $\varphi_c = 0.31$
Detached house	58.9% (83)	45.1% (1297)	4.4% (37)	
Apartment building	17.7% (25)	33.4% (961)	83.3% (702)	
Terraced house	17.0% (24)	15.9% (457)	9.8% (83)	
Semi-detached house	5.0% (7)	4.4% (127)	1.3% (11)	
Other	0.7% (1)	1.0% (30)	0.8% (7)	
Apartment size (m^2)	M 142 SD 76.77	M 108 SD 54.56	M 57 SD 29.93	F $p < .001$, $\omega^2 = 0.16$

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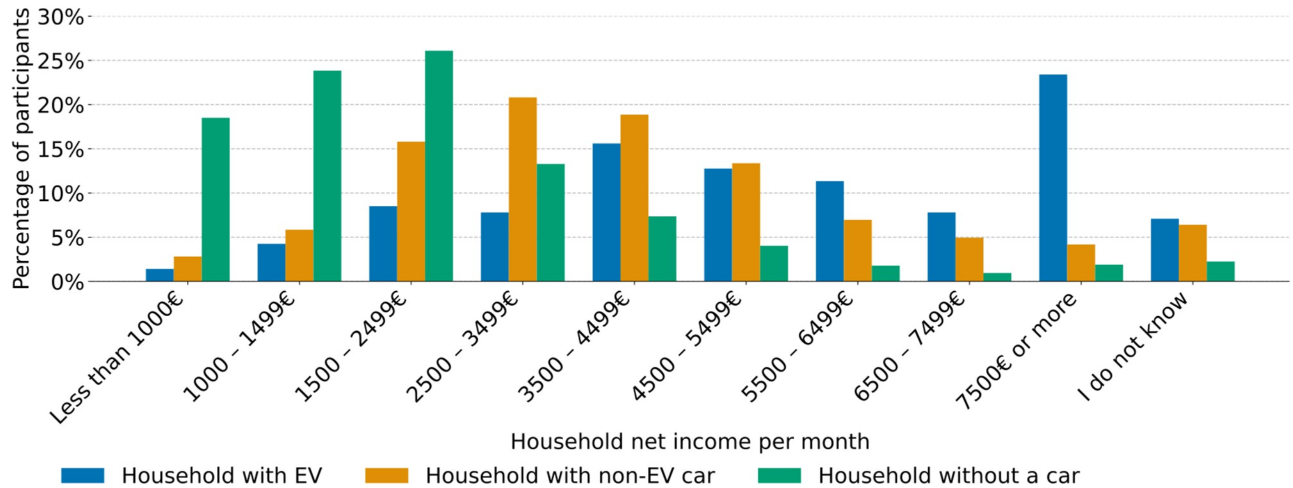

Fig 1. Income distribution (X^2 p < .001, φ_c = 0.34 N = 3857).

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however, there is less need to support existing EV users in staying EV users. There were twenty participants who reported to having previously owned an EV but then reverted to an ICEV. These participants were asked to provide reason why they relinquished their EV with an open question and the most common answer (4 answers) was too high cost of ownership, the second most common answer was dissatisfaction with charging (3 answers) and besides those reasons there were single answers with various reasons for giving up an EV from ceasing car use altogether to a spouse wanting an ICEV. The small number of participants who had given up owning an EV makes it hard to conclude anything from these results, but the most common theme was pointing towards high cost of EVs playing a role in giving this sort of vehicle up reinforcing the observation that price can be a barrier for EV ownership.

Table 3. Experience with EVs and car buying intentions.

	Household with an EV (n = 141)	Household with car that is not EV (n = 2873)	Household without a car (n = 843)	Statistical difference
Planning to buy a car in 3 years?				X^2 p < .001, φ_c = 0.28
Yes	31.9% (45)	26.4% (759)	3.9% (33)	
Maybe	37.6% (53)	40.7% (1169)	17.2% (145)	
No	30.5% (43)	32.9% (945)	78.9% (665)	
Next car price range will be*				X^2 p < .001, φ_c = 0.21
Less than 5000€	0.7% (1)	8.6% (166)	19.7% (35)	
5000–10 000€	4.1% (4)	12.7% (245)	16.9% (30)	
10 001–15 000€	8.2% (8)	11.5% (221)	11.8% (21)	
15 001–20 000€	8.2% (8)	13.1% (253)	6.7% (12)	
20 001–30 000€	10.2% (10)	19.3% (372)	6.7% (12)	
30 001–40 000€	8.2% (8)	11.1% (190)	6.7% (12)	
Over 40 000€	39.8% (39)	9.9% (190)	4.5% (8)	
Car provided by employer	8.2% (8)	1.3% (25)	2.2% (4)	
I don´t know	12.2% (12)	12.6% (242)	24.7% (44)	

*This question is only presented to participants who answered “yes” or “maybe” to question about considering buying a new car (n = 2204).

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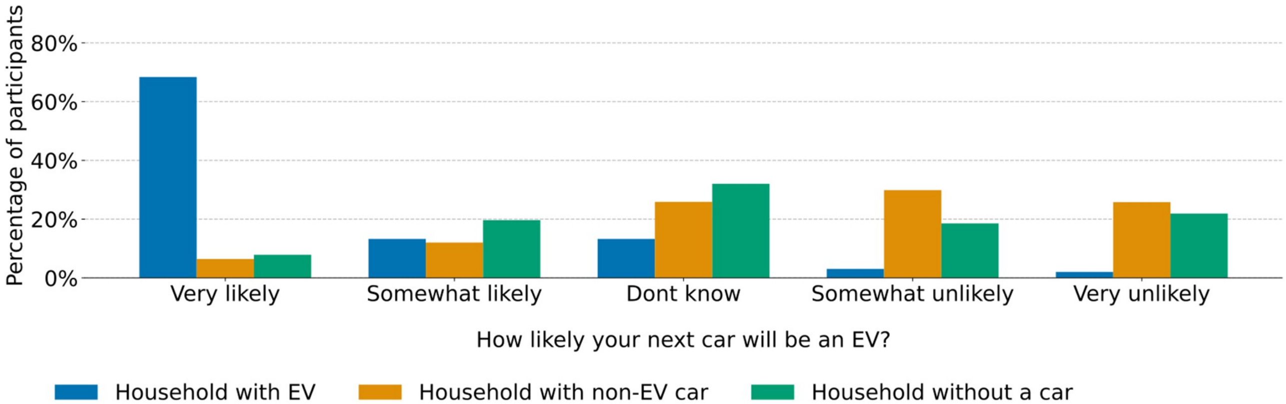

Fig 2. Interest in purchasing an EV X^2 p < .001, $\varphi_c = 0.32$ (n = 2204).

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3.2 Comparison of EV owners and ICEV owners: Car use

Comparison of car ownership and usage between households that currently own an EV and households that own other type of vehicle(s) is displayed in Table 4. The majority (70.9%) of current EV households own more than one car while only 37.4% of non-EV households have additional cars (X^2 p < .001, $\varphi_c = 0.58$). EV households also report driving significantly more on average (30 000km per year) compared to non-EV households (14 200km per year) (p < .001, *d* = 1.55). Since EV households also often own non-EV vehicles, not all of their driving is done with an EV. EV owners estimated that they drove 72% of all their yearly kilometers with an EV. Compared to non-EV households, EV owners also reported driving daily trips of 200-400km or over 400km more often than ICEV drivers (X2 p < .001, φc = 0.15). However, from the data available it is not clear whether they used their EV for these trips if they also owned ICEVs. Among non-EV owners, only 13.5% reported driving trips longer than 200km more often than a few times a year indicating that for their driving needs an EV with quite a modest range would actually be sufficient.

These results indicate that current EV owners are heavy users of their cars, and their driving habits are not similar to non-EV owners. This might suggest that among current EV users there are large numbers of participants who use their car for work or consider driving their hobby, but this cannot be verified from the available data. Since EVs have higher purchase costs but lower running costs than ICEVs, their total cost of ownership also compares more favorably to ICEVs with an increase in the amount of driving. Therefore, owing an EV may be bring financial benefits for people and businesses who drive long distances. However, with the available data the reason why the participants drive is not available for analyses.

EV use reduces emissions from traffic only if driving done with an EV replaces driving with and ICEV instead of being additional driving that is done on top of using an ICEV. If the current EV owners would still drive around 30 000km per year also if they only owned ICEVs, acquiring an EV and using it for 72% of their trips would have a significant environmental benefit. However, there is also an risk that the low running cost and enjoyable driving experience of EVs would entice some users to drive more after switching to EV, even if the driving is non-essential or it would have previously been accomplished with active forms of traffic or public transport. Such behavior would carry with it a negative environmental impact. Unfortunately, there is no data concerning the pre- and post-EV driving distances of these respondents in order to analyze whether the driving distances have increased after EV acquisition, but future research should address this question.

Table 4. Comparison of car ownership and driving habits between EV owners and other car owners.

	Household with an EV (n = 141)	Household with car that is not an EV (n = 2873)	Statistical association
Total Number of cars in the household			X^2 p < .001, $\varphi_c = 0.58$
1	29.1% (41)	62.6% (1792)	
2	45.4% (64)	28.0% (800)	
3 or more	25.5% (36)	9.4% (270)	
EV			N/A
0	0% (0)	100% (2857)	
1	82.6% (119)	0% (0)	
2	16.0% (23)	0% (0)	
3 or more	1.4% (2)	0% (0)	
ICEV			X^2 p < .001, $\varphi_c = 0.29$
0	45.1% (65)	7.4% (214)	
1	39.6% (57)	60.4% (1739)	
2	13.2% (19)	24.9% (718)	
3 or more	2.1% (3)	6.8% (197)	
HEV			X^2 p < .001, $\varphi_c = 0.13$
0	84.7% (122)	93.0% (2677)	
1	9.7% (14)	6.5% (186)	
2	4.9% (7)	0.5% (14)	
3 or more	0.7% (1)	0.1% (2)	
PHEV			X^2 p < .001, $\varphi_c = 0.19$
0	82.7% (119)	95.4% (2747)	
1	9.7% (14)	4.3% (125)	
2	5.6% (8)	0.2% (6)	
3 or more	2.1% (3)	0.03% (1)	
NGV			X^2 p < .001, $\varphi_c = 0.20$
0	88.9% (128)	98.7% (2839)	
1	5.6% (8)	1.3% (38)	
2	4.9% (7)	0.03% (1)	
3 or more	0.7% (1)	0.03% (1)	
Average distance driven per year (thousand kilometers)	M 30.0 SD 18.3	M 14.2 SD 9.6	T p < .001, d = 1.55
Drives 201–400 km during a single day			X^2 p < .001, $\varphi_c = 0.17$
Several times per week	2.2% (3)	1.0% (28)	
Once a week	4.4% (6)	1.4% (38)	
1–3 times a month	23.0% (31)	11.1% (295)	
Few times per year	45.2% (61)	41.4% (1104)	
Seldom	22.2% (30)	37.8% (1008)	
Never	2.8% (4)	7.2% (192)	
Drives over 400 km during a single day			X^2 p < .001, $\varphi_c = 0.15$
Several times per week	0.7% (1)	0.3% (7)	
Once a week	12.1% (17)	0.6% (17)	
1–3 times a month	36.2% (51)	3.0% (79)	
Few times per year	36.2% (51)	30.1% (803)	
Seldom	38.3% (54)	49.8% (1327)	
Never	8.5% (12)	16.2% (432)	
Experience with EVs			X^2 p < .001, $\varphi_c = 0.64$
Personally owns EV	80.9% (114)	0% (0)	

(*Continued*)

Table 4. (Continued)

	Household with an EV (n = 141)	Household with car that is not an EV (n = 2873)	Statistical association
Has previously owned	3.5% (5)	0.4% (11)	
Has driven EV	8.5% (12)	12.0% (346)	
Has been passenger	7.1% (10)	14.7% (421)	
No experience	0% (0)	72.9% (2095)	
EV network			
Friend has EV	76.6% (108)	36.2% (1040)	X^2 $p < .001$, $\varphi_c = 0.21$
Relative has EV	29.8% (42)	13.8% (397)	X^2 $p < .001$, $\varphi_c = 0.11$
Neighbor has EV	30.5% (43)	12.1% (349)	X^2 $p < .001$, $\varphi_c = 0.14$
Doesn't know any owner	7.8% (11)	46.5% (1337)	X^2 $p < .001$, $\varphi_c = 0.23$

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From the results it can also be observed that EV owners often know other EV owners: 92.2% of EV owners knew someone else owning an EV while only 53.5% of participants from non-EV households knew an EV-owner. These results may be somewhat biased by the fact that 48% of the EV owners in our sample are recruited from the members of Finnish EV association and it is expected that the association members often know each other. Regardless, this result can also be seen as reinforcing previous results [14, 15] that have identified the influence of friends and family as well as personal experience as factors that have potential to increase individuals interest in EVs. Knowing people who already drive an EV provides opportunities to learn about and test these vehicles before a purchase decision and also expose the person to more likely positive attitudes towards EVs or even social pressure to purchase one.

3.3 EV user segment identification

To understand heterogeneity among EV owners, latent class analysis (LCA) was utilized to find subgroups among EV owners (Table 5). This method uncovers concealed, 'latent' groups within a dataset through their response patterns to a set of variables [30].

Given the relatively small sample size (n = 141), this analysis should be viewed as a preliminary exploration rather than a definitive segmentation of the population but can still provide

Table 5. Latent class analysis to identifying user segments among EV owners.

1–3 most important reasons for purchasing EV	Economical & Eco-conscious (n = 77)	Performance & Brand-oriented (n = 64)	NET (n = 141)
Environmental friendliness	73%**	28%	52%
Low running costs	83%**	50%	68%
Performance of the car	0%	73%**	33%
Brand of the car	0%	25%**	11%
The appearance and design of the car	0%	25%**	11%
Ease of use of the car	31%*	9%	21%
Tax advantages	14%*	3%	9%
The car was recommended by a person I know	1%	6%	4%
Interest in new technology	27%	34%	30%
I want to be part of the renewal of motoring	35%**	8%	23%
Other reason	0%	6%*	3%

* confidence level > = 95%),

** confidence level > = 99.9%

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insight into differences among EV owners. The LCA was guided by responses to the survey question about primary reasons for purchasing an electric vehicle ('Why did you buy an electric vehicle? Please select the 1–3 most important reasons for you.') and revealed two distinctive segments.

The first segment, economy orientated, and eco-conscious EV owners (N = 77) is defined by emphasis on environmental friendliness and financial factors. An above-average proportion of this segment cited environmental friendliness (73% vs 52% sample average) and low running costs (83% vs 68%) as key reasons for their purchase. A slightly higher proportion in this segment also mentioned the ease of use of the car (31% vs 21%), tax advantages (14% vs 9%), and a desire to be part of the renewal of motoring (35% vs 23%). However, this segment showed a significant lack of interest in the performance of the car, the brand, and the appearance and design, as these factors were cited by 0% of this group, which is considerably lower than the sample average.

In contrast, buyers in the second segment, performance and brand orientated EV owners (n = 64), in appeared to be more influenced by the car's performance (73% vs 33%), the brand of the car (25% vs 11%), and its appearance and design (25% vs 11%). This suggests that they view their electric vehicle as a performance or luxury item, and they also value attributes often associated with non-EV cars. Although half of this segment also cited low running costs as a reason, its was significantly lower than the sample average (50% vs 68%). They also exhibited lesser interest in the environmental aspect of electric vehicles (28% vs 52%).

The "Economical & Eco-conscious" segment, comprised approximately equally of males and females (51% male), and had an average age of 49 years. In contrast, the "Performance & Brand-oriented" segment was notably more male-dominated, with males constituting 67% of this segment, and had a younger average age of 42 years. Among the performance oriented EV owners 39.1% owned 3 or more cars while only 14.3% of economy orientated EV owners did so (X2 $p = .003$, $\varphi c = 0.29$, $n = 141$) and the performance oriented EV owners had significantly less environmentally friendly attitudes (mean EAI score 52.7) as measured by EAI compared to economy oriented EV owners (mean score 63.1) (t $p < .001$, $d = 10.7$, $n = 141$). The differences between performance and economy-oriented EV owners were not limited to environmental attitudes but there was also a significant difference in the carbon footprint of these groups that will be discussed in the next section.

3.4 Comparison of EV owners and general population: Environmental attitudes and carbon footprint

Differences between households with EV, with other type of vehicle or no car at all in relation to environmental attitudes and lifestyle factors related to GHG emissions is presented in Table 6.

Overall there were no large differences in the environmental attitudes of the different car owners but the participants from car-free households showed more pro-environmental attitudes, less climate denialism, more climate concern, and lower meat consumption. More often the EV owners had green electricity contracts and consumed less meat than ICEV owners.

Answers to the question "If there would be an election in Finland now, what party would you vote?" revealed that among EV owners the most popular political parties were The National Coalition Party (31.9%), a center-right party focusing on economic issues, The Greens (22.7%), a center-left party focusing on environmental issues, and The Finns Party (9.9%) which is a national conservative right-wing populist party. While the National Coalition Party was the most popular party in Finland at the time of the data collection, the popularity of

Table 6. Environmental attitudes, lifestyle and political opinions.

	Household with an EV (n = 141)	Household with car that is not an EV (n = 2873)	Household without a car (n = 843)	Statistical association
Environmental attitudes inventory (EAI)				
Preservation	M 5.16 SD 0.99	M 5.18 SD 0.88	M 5.39 SD 0.95	F $p < .001$, ω^2 = 0.01
Utilization	M 3.54 SD 1.12	M 3.49 SD 1.00	M 3.19 SD 1.03	F $p < .001$, ω^2 = 0.02
Total Score	M 4.87 SD 0.99	M 4.89 SD 0.86	M 5.15 SD 0.91	F $p < .001$, ω^2 = 0.01
I suspect that there is no climate change				X^2 $p < .001$, φ_c = 0.08
Describes me perfectly	1.4% (2)	1.9% (54)	1.3% (11)	
Describes me pretty well	4.3% (6)	3.7% (105)	2.4% (20)	
Describes me somewhat	9.2% (13)	13.4% (386)	9.3% (78)	
Describes me poorly	17.0% (24)	22.7% (651)	15.5% (131)	
Does not describe me	68.1% (96)	58.4% (1677)	71.5% (603)	
Are you worried about climate change?				X^2 $p < .001$, φ_c = 0.01
Extremely worried	8.5% (12)	6.2% (178)	12.5% (105)	
Very worried	29.1% (41)	22.0% (632)	29.1% (245)	
Somewhat worried	39.0% (55)	47.3% (1359)	40.2% (339)	
Not very worried	12.8% (18)	17.5% (502)	13.8% (116)	
Not worried at all	10.6% (15)	7.0% (202)	4.5% (38)	
What sort of electricity contract do you have?				X^2 $p < .001$, φ_c = 0.12
100% renewables	35.0% (49)	19.5% (559)	28.5% (239)	
Renewables and nuclear	17.1% (24)	9.7% (278)	8.0% (67)	
Mixed source	37.1% (52)	58.6% (1682)	42.7% (359)	
I do not know	10.7% (15)	12.3% (353)	20.8% (175)	
Diet				X^2 $p < .001$, φ_c = 0.13
Vegan	2.9% (4)	0.6% (16)	2.3% (19)	
Lacto-ovo-vegetarian	7.1% (10)	3.8% (108)	9.8% (82)	
Seldom eats meat	8.6% (12)	13.3% (382)	21.7% (182)	
Regularly eats meat	81.4% (114)	82.4% (2366)	66.3% (557)	
Number of flights during the last 12 months				
Domestic	M 0.65 SD 1.83	M 0.17 SD 1.03	M 0.12 SD 0.65	F $p < .001$, ω^2 = 0.01
Within Europe	M 1.38 SD 3.14	M 0.45 SD 1.50	M 0.46 SD 1.33	F $p < .001$, ω^2 = 0.01
Transcontinental	M 0.36 SD 2.00	M 0.08 SD 0.47	M 0.04 SD 0.30	F $p < .001$, ω^2 = 0.09
What political party would you vote at the moment?				X^2 $p < .001$, φ_c = 0.18
The National Coalition Party	31.9% (45)	22.8% (655)	10.7% (90)	
The Finnish Social Democratic Party	4.3% (6)	16.0% (459)	20.2% (170)	
The Finns Party	9.9% (14)	13.2% (378)	8.9% (75)	
The Centre Party of Finland	7.8% (11)	9.2% (263)	4.7% (40)	
The Greens	22.7% (32)	9.9% (285)	18.7% (158)	
The Left Alliance	2.1% (3)	6.2% (178)	14.7% (124)	

(*Continued*)

Table 6. (Continued)

	Household with an EV (n = 141)	Household with car that is not an EV (n = 2873)	Household without a car (n = 843)	Statistical association
Swedish People's Party of Finland	6.4% (9)	3.0% (86)	2.0% (17)	
Christian Democrats in Finland	1.4% (2)	2.2% (62)	1.2% (10)	
Movement Now	4.3% (6)	3.1% (89)	1.1% (9)	
Other	1.4% (2)	3.9% (113)	3.4% (29)	
Would not vote	7.8% (11)	10.6% (305)	14.4% (121)	

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the Greens was higher, and the popularity of the Finns was lower among EV owners than among the general population.

In Fig 3 the estimation of carbon footprint of participants in CO_2 equivalent tons (tkg CO_{2e}) is displayed. Participants from EV households had an average carbon footprint of 8.66 tkg CO_{2e} (SD = 3.62), participants from households with cars that were not EVs had a slightly lower average of 8.05 tkg CO_{2e} (SD = 3.01) and participants from households without a car had significantly lower average carbon footprint of 5.75 tkg CO_{2e} (SD = 2.34) (Overall difference F $p < .001$, ω2 = 0.09). Post hoc analyses demonstrated that the difference between participants from EV and ICEV households was not statistically significant (F p = .03, ω2 = 0.001, Tamhane's T2: 0.13) while the difference between participants from a carless household and from a household with any type of car was significant (Car that is not an EV vs. no car F $p < .001$, ω2 = 0.10, Tamhane's T2: < .001, EV vs. no car F $p < .001$, ω2 = 0.13, Tamhane's T2: < .001).

However, among the EV owners there is a significant difference in carbon footprint between economy and performance oriented car owners (T $p < .001$, d 0.773): Economy oriented car owners had a significantly lower carbon footprint (M = 7.59 tkg CO2e SD = 3.17) compared to performance oriented car owners (M = 10.25 tkg CO2e SD = 3.69).

Prior research [31–35] has established that income is the strongest predictor of carbon footprint as higher income is associated with larger homes as well as more travel and consumption and since EV households tend to have a high income, their total carbon footprint is also above average. Despite this, these results suggest that the more environmentally conscious outlook of economy-oriented EV owners significantly reduces their carbon footprint compared to performance-oriented EV owners even though there are no significant difference in income between these groups (X2 p = .98, φc = 0.14, n = 141).

Assuming EV owners maintained their reported driving distances even if they would only drive ICEV, then EV ownership reduces their carbon footprint by an average of 19% compared to exclusively using an ICEV. However, this result is based on average emissions of ICEVs and EVs and there are significant differences in the emissions produced by different types of ICEVs and though among EVs the differences in emissions among different sort of cars are not as large as among ICEVs, there still exists more and less efficient EV models. However, the relationship between EV performance and energy use is not as straightforward as in ICEVs, for example, some car models by Tesla provide both high performance and high efficiency. If we would assume that all performance-orientated EV owners changed from high emissions ICEVs to high performance EVs, then their reduction in emissions would be higher than 19%; while a change from a small and efficient ICEV to an larger EV would realize less relative emissions savings. This line of thought leads to a hypothesis that EVs might be an effective and acceptable method for performance orientated car users to cut their emissions even if they are not interested in doing so as many EVs are attractive for these customers based on their

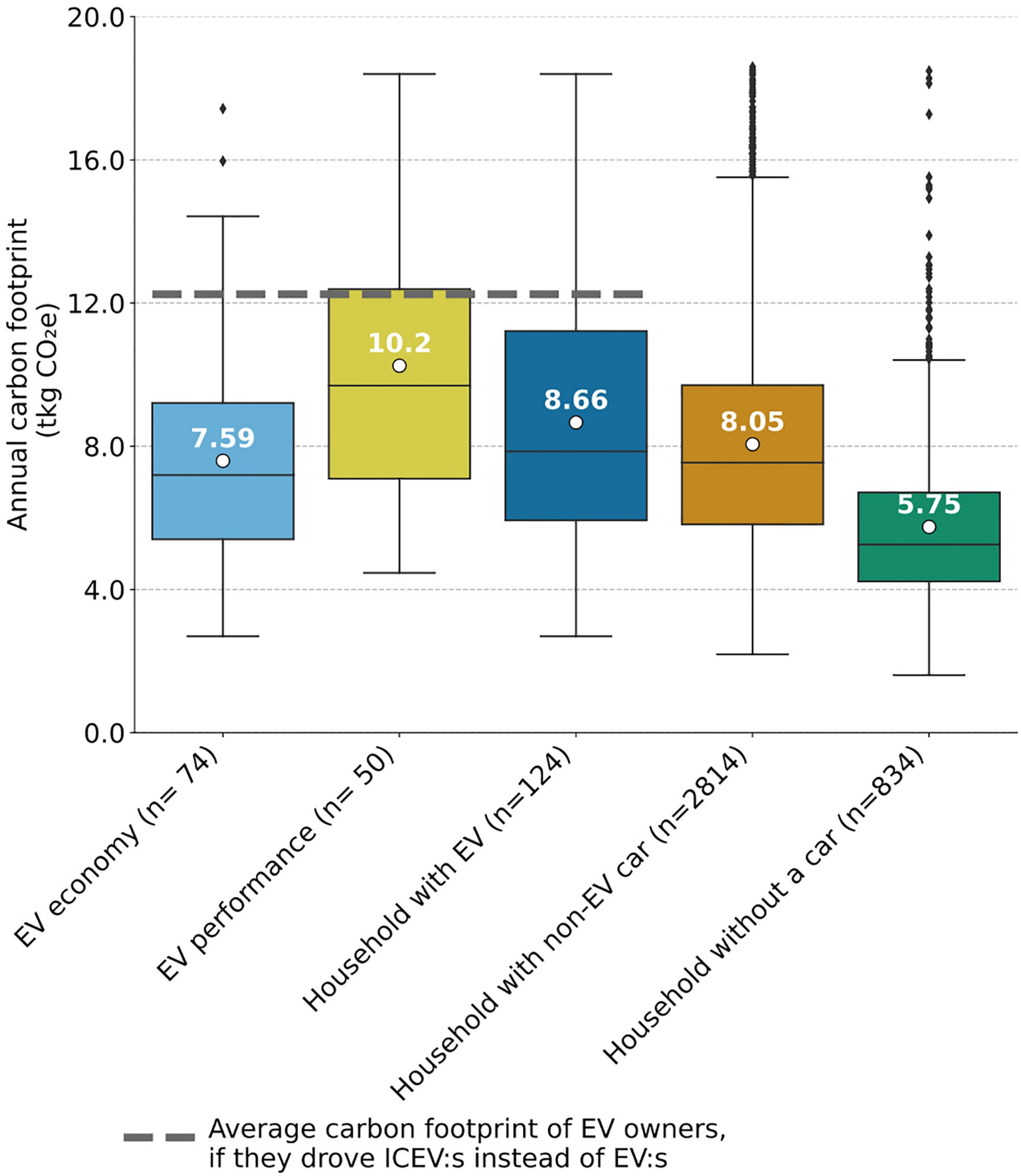

Fig 3. Carbon footprint comparison between participants from different groups.

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features other than emission savings. Therefore EVs could be attractive to people who might not want to or even actively avoid making decisions that are considered pro-environmental actions. Future research on this topic is warranted.

Overall, these results demonstrate that participants with the most pro-environmental attitudes as well as the lowest carbon footprint are those who do not own any car. This is something that should be noted when designing policies to promote EVs–converting people who currently do not own a car to EV owners will probably not lead to reduced emissions if these people convert from an active form of travel and public transport to driving an EV. Therefore, EV promotion could be most efficient when targeting current car owners with high income who are unlikely to reduce their driving.

3.5 Attitudes towards electric vehicles

To measure attitudes towards EVs, participants were asked to agree or disagree with 14 statements. Responses were compared between EV owners, those who had driven or had been a passenger in an EV, and those without any EV experience. Full categorical information can be found in the supporting material, S1 Table, with a summary presented in Table 7.

Some of the statements had an objective quality while others were more subjective. The more objective ones included "EVs produce less emissions than ICE vehicles" which is true if the vehicle is used in Finland, as well as statements such as, "Buying an EV is expensive" and "EVs have low running cost". The purchase cost of EVs in Finland are objectively higher and

Table 7. Summary of attitudes towards electric cars among participants with different degrees of experience with electric vehicles.

Completely agree (5) to Completely disagree (1) with a statement	Personally owns EV (n = 114)	Some experience with EVS (n = 992)	No experience with EVs (n = 2751)	Statistical association
It is easy to drive short daily journeys with an electric car	4.9	4.3	3.9	X2 $p < .001$, $\varphi c = 0.21$
Driving an electric car is fun	4.8	3.5	3.0	X2 $p < .001$, $\varphi c = 0.36$
The running costs of an electric car are low	4.6	3.6	3.2	X2 $p < .001$, $\varphi c = 0.25$
It would be easy for me to charge my electric car at home	4.6	2.9	2.5	X2 $p < .001$, $\varphi c = 0.27$
Electric cars produce fewer emissions than internal combustion engine cars	4.5	3.7	3.6	X^2 $p < .001$, $\varphi_c = 0.13$
When buying a car, the environmental impact is important to me	3.9	3.5	3.2	X2 $p < .001$, $\varphi c = 0.14$
The people I care about appreciate electric cars	3.9	3.2	2.8	X2 $p < .001$, $\varphi c = 0.20$
Buying an electric car is expensive	3.7	4.3	4.4	X^2 $p < .001$, $\varphi_c = 0.15$
Political support for electric cars in Finland is uncertain	3.5	3.4	3.4	X2 $p < .001$, $\varphi c = 0.10$
With an electric car one can easily travel a distance of 500 kilometers	3.5	2.6	2.5	X2 $p < .001$, $\varphi c = 0.21$
Using an electric car requires careful planning	3.1	3.7	3.8	X2 $p < .001$, $\varphi c = 0.16$
There are not enough charging stations in my neighborhood	3.0	3.7	3.8	X2 $p < .001$, $\varphi c = 0.16$
Electric cars perform poorly in winter	1.8	3.3	3.5	X^2 $p < .001$, $\varphi_c = 0.35$
Charging electric cars is difficult	1.9	3.2	3.4	X2 $p < .001$, $\varphi c = 0.27$

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the running cost lower compared to a similar class of ICEV, although the terms expensive and cheap are subjective.

Responses to these statements differed between EV owners and participants with less experience with EVs: Among the EV owners 85% agreed that EVs produce less emissions than ICEV while 60.5% of those with some experience and 54.7% of those with no experience agreed with the statement (X^2 $p < .001$, $\varphi_c = 0.13$). For a statement that EVs have low running cost 95.6% of the EV owners agreed while only 56.3% of those with some experience and 34.0% with no experience agreed (X^2 $p < .001$, $\varphi_c = 0.25$). The majority of all participants agreed with the statement that the purchase cost of an EV is expensive; although EV owners endorsed the statement less than other groups: with 15.8% of EV owners disagreeing while only 4.7% of participants with some experience and 1.8% of participants with no experience disagreed with the statement (X^2 $p < .001$, $\varphi_c = 0.15$).

The result that a large proportion of participants without EV experience disagreed with statements about EVs producing less emissions than ICEVs and having low running cost is significant as the accuracy of these statements can be supported with empirical data and disagreements with the statements can be seen as misconceptions about EVs.

In the more subjective statements the largest differences between EV owners and participants with less experience with EVs were found in regard to the difficulty of charging EVs (X^2 $p < .001$, $\varphi_c = 0.27$) as well as using EVs in winter (X^2 $p < .001$, $\varphi_c = 0.35$). The majority of EV owners did not find charging their EV difficult or felt that their EV performed poorly in winter while participants without EV experience either could not answer or estimated these situations to be difficult. Another major difference was the statement "Driving an EV is fun" of which 93.0% of EV owners agreed with and 43.5% of those with some experience and 16.3% of those with no experience also agreed (X^2 $p < .001$, $\varphi_c = 0.36$).

These results show that there is a linear association between personal experience with EVs and more positive attitudes towards these vehicles. In addition to providing accurate information about EVs, providing personal experience with these types of vehicles will be important for interventions aiming to promote EV adoption.

3.6 Factors affecting EV purchasing intention

To explore what factors are associated with high interest in purchasing EV in the future, a multinominal logistic regression model was constructed. The sample for the model were those participants who reported that they were considering buying a new car within the next three years (n = 2204).

The model was constructed in an explorative manner based on the prior results of this study and previous research. The following were used as the starting point for the variables: gender, household income, urbanicity of place of residence, EAI and climate worry, EV network and EV experience as well as kilometers driven per year. As the model included several variables with a small number of respondents in some categories, several categories needed to be combined to be able to achieve a stable model.

Gender, urbanicity of place of residence and EAI proved not to be significant predictors in the model and they were omitted from the final model. The final model (Table 8) included the main effects of five explanatory variables. The model had a mediocre fit to the data (X^2 (210) = 258, p = .013), a Nagelkerke pseudo R-Square statistic of 0.23 and an ability to correctly classify 57.3% of cases indicating that there are still significant variation affecting the interest in EVs which the current model is unable to capture.

Currently owning an EV has a very large effect (OR 92.90) on the likelihood that the participant belongs to the group who consider that their next car will be an EV instead of the group

Table 8. Multinominal logistic regression model (n = 2089). Risk is presented as Exp(B) odd ratios. Reference category for the interest in buying EV is "unlikely or very unlikely".

How likely your next car will be EV?		Very likely or likely			I do not know		
		p	OR	OR 95% CI	p	OR	OR 95% CI
Experience with EVs	Owns EV	<0.001	92.90	27.81–310.31	.005	7.17	1.81–28.39
	Has driven or been passenger	<0.001	2.66	2.03–3.49	.028	1.33	1.03–1.72
	No experience		1			1	
EV network	Knows someone who owns EV	<0.001	1.93	1.45–2.58	.509	1.08	0.86–1.37
	Does not know anyone with EV		1			1	
Worry about climate change	Worried or very worried	<0.001	4.74	3.31–6.79	<0.001	2.90	2.13–3.96
	Somewhat worried	<0.001	2.39	1.70–3.36	<0.001	2.31	1.74–3.06
	Not worried		1			1	
Household net income	Over 3500€	<0.001	2.66	1.59–4.45	.068	1.44	0.97–2.14
	1500–3500€	.533	1.18	0.70–2.02	.160	1.32	0.90–1.95
	Less than 1500€		1			1	
Yearly driving distance	Over 20 thousand km	<0.001	0.45	0.30–0.68	<0.001	0.48	0.34–0.69
	5–20 thousand km	<0.001	0.54	0.38–0.76	<0.001	0.58	0.44–0.78
	Less than 5 thousand km		1			1	

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of participants who think that is unlikely. In addition, having driven or having been a passenger in an EV (OR 2.66) or knowing someone who owns an EV (1.93) significantly increases the likelihood that the participant will consider an EV for their next car. These results point towards the conclusion that personal experience with EVs is the most important factor in EV purchasing intentions.

Worry about climate change (OR 4.74) as well as having a household income of over 3500€ per month (2.66) also increases the probability of a participant belonging to the group who believe their next car will probably be an EV.

However, yearly driving distance has a negative association with interest in EVs–those who reported driving over 20 000km per year (OR 0.45) and those who drive between 5000–20 000km (OR 0.54) are less likely to consider an EV as their next car than those who consider purchasing a car withing the next 3 years and currently drive less than 5000 km per year. This result might reflect concern that frequent drivers of long distances have about the feasibility of EVs for long distance driving as well as being uninformed about the potential financial benefit to be gained from using a low running cost vehicle for frequent driving. Disseminating information about the capabilities of different EVs in making long trips and their potential financial benefits for people who are driving more than the average for the population might be a potential intervention target.

4 Conclusions

The comparison between current EV owners and the general population highlights that in 2022 EV owners had a higher income than other car owners and that the high purchasing cost was perceived as one of the major drawbacks of electric vehicles. These results point towards the conclusion that high purchasing cost is a major barrier to EV adoption in Finland and reducing this financial barrier could expediently increase EV adoption, as shown by Norway's successful use of significant financial incentives to accelerate EV adoption.

However, recent car registration data suggest that among new car buyers high purchasing cost is a lesser barrier to EV adoption in 2024 than 2022 due to significant alterations in the market. Since the data was collected, prices of EVs have decreased substantially, especially those in the high price class, due to price competition among EV manufacturers. This has led to a rapid diffusion of EVs in the country, with almost 34 percent of the new cars registered in Finland in 2023 being EVs.

Despite the initial challenge of high entry costs, these developments have made EVs more accessible to a broader range of consumers. Based on the existing data EV owners are highly satisfied with their vehicles, with the majority intending to purchase EVs again in the future. Thus, the initial entry into EV ownership, which was once a significant hurdle, is becoming increasingly surmountable for consumers who are able to purchase a new or almost new vehicle. To increase the attractiveness of EVs for these people, the following would be of benefit: state support for the expansion and accessibility of charging infrastructure and encouragement for the development of EV technology to further reduce costs and improve vehicle efficacy and performance.

Regarding the financial incentives aimed at consumers, based on the results they should be aimed at lowering the cost of the entry barriers at the lower end of the market rather than supporting existing EV drivers or subsidizing high-priced EV purchases. In this sample, 45.9% of the existing ICEV owners who were considering buying a new car reported the price range for their next car to be less than 20 000€. These customers will be limited to the used car market, EV or ICEV and therefore, policies that would strengthen the used market for electric vehicles and incentives to owners of old ICEVs to change their cars to EVs would be useful to increase EV adoption. Comparing attitudes towards EVs between owners and those with indirect or no experience, substantial differences were found. Non-EV users held misconceptions about EV emissions and running costs and they had much more negative views on charging and winter use challenges than the actual EV owners. Additionally, EV owners strongly agreed that driving an EV is fun, a statement that few non-EV users endorsed.

Interventions targeting these differences could include providing easily digestible information on lower emissions and lower running costs of EVs compared to ICEVs. For this information, it would be important to consider the whole lifetime of the vehicle instead of single point in time. To alleviate concerns regarding charging, range and winter performance interventions providing information and demonstrations on how EV charging works and how to effectively manage range could be used. Interventions illustrating different EVs capabilities in relation to the actual driving needs of the person, such as the one described by [36] could be utilized. Additionally, increasing the visibility of the existing EV charging infrastructure might help to alleviate worries regarding the availability of charging. High visibility signs at fuel stations, shopping centers and other public spaces that have charging stations and are visited by ICEs owners would make the existence of charging infrastructure more salient for potential EV owners. Information campaigns including maps of the nationwide charging network would also serve the same purpose. Additionally, disseminating information on how to set up a home charging station for people living in detached houses would help alleviate concerns people have about the availability of charging stations in their local area.

Personal experience was the most important predictor of interest in purchasing an EV in the future. Therefore, providing personal experience with EVs to potential EV buyers could be intervention that would increase the likelihood of EV adoption in the future. These sort of experiences could be provided at events, by peers or by car sellers and could be part of interventions aiming to increase interest in EVs. Policymakers could increase such personal experiences by promoting or even mandating driving schools to provide lessons with EVs both for new students but also possibly during renewal of driving licenses.

The direct operating costs of EVs are lower than those of internal combustion engine vehicles under optimal conditions. However, in public discussions considerable attention is given to rare battery issues and high service and insurance costs possibly lowering the purchase intentions of potential customers due to the overestimation of the risk related to these problems due to high media visibility. While significant price reductions and increase of availability of used EVs are partially addressing the availability of affordable EVs, the uncertainty and worries related to the quality of EVs could decrease uptake or even lead to a perceived 'market for lemons' problem. Available data does not provide insights into these contemporary challenges, indicating a need for further research both on the actual running costs and prevalence of expensive repairs costs vis-à-vis ICEs, as well as the impact of price and market uncertainty on buying intentions.

The current study had some limitations that should be considered when interpreting the results. First, the number of EV owners in the sample was relatively small, and they were not a representative sample randomly picked from all EV owners in Finland. The modest number of EV owners limited the study's capabilities in LCA and Logistic regression. Second, the data are based on surveys instead of more objective data sources and therefore the limitations of subjective reporting apply: participants may not have answered truthfully or accurately at all items. Due to nature of the survey research, the estimation of the carbon footprint should also not be interpreted as a precise measurement of household emissions and instead be seen as a rough estimation to rank participants in relation to each other. Finally, the largest sample that is drawn from the Kantar panel and which aims to be representative of the general population may have a bias stemming from the fact it only includes people willing to take part in such panel and the mean age of the sample is higher than the population mean in Finland.

In summary, based on these findings, the factors that could increase interest in these vehicles include: financial incentives to lower the barrier for entry into EV ownership, providing people with personal experiences of EVs and disseminating information on EV charging and range management, low running cost and reduced emissions compared to ICEVs. However, it is important to keep in mind that while EVs do produce less GHG emissions than ICEVs, they still produce emissions and have a positive net effect on overall emissions only if they replace driving done with ICEVs. It would be counterproductive if interventions aiming to reduce emissions from transportation resulted in making EVs more attractive and steering people who do not own a car to purchase an EV. It would also not be beneficial if resources used to promote EVs would decrease resources used to support public transport and active commuting. The results clearly show that the lifestyle with the least emissions is one without any type of car, however, in situations where a car is the only viable option of transportation, such as in sparsely populated areas with poor public transport, EVs are useful tool to reduce emissions.

Supporting information

S1 Table. Attitudes towards electric cars among participants with different degree of experience with electric vehicles.
(DOCX)

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References

1. IEA, Global Energy Review: CO2 Emissions in 2021, IEA, Paris. 2022. https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2
2. Ritchie H, Roser M, Rosado P. CO_2 and Greenhouse Gas Emissions. Our World Data. 2020. [cited 2023 Aug 17]. https://ourworldindata.org/co2-emissions
3. Traficom. Tieto Traficom. 2022. Domestic CO2 emissions from transport by mode of transport. [cited 2023 Aug 17]. https://tieto.traficom.fi/en/statistics/domestic-co2-emissions-transport-mode-transport
4. Requia WJ, Mohamed M, Higgins CD, Arain A, Ferguson M. How clean are electric vehicles? Evidence-based review of the effects of electric mobility on air pollutants, greenhouse gas emissions and human health. Atmos Environ. 2018 Jul 1; 185:64–77.
5. Albatayneh A, Assaf MN, Alterman D, Jaradat M. Comparison of the Overall Energy Efficiency for Internal Combustion Engine Vehicles and Electric Vehicles. Environ Clim Technol. 2020 Jan 1; 24(1):669–80.
6. Kumar MS, Revankar ST. Development scheme and key technology of an electric vehicle: An overview. Renew Sustain Energy Rev. 2017 Apr 1; 70:1266–85.
7. Bicer Y, Dincer I. Life cycle environmental impact assessments and comparisons of alternative fuels for clean vehicles. Resour Conserv Recycl. 2018 May 1; 132:141–57.
8. Martins LS, Guimarães LF, Botelho Junior AB, Tenório JAS, Espinosa DCR. Electric car battery: An overview on global demand, recycling and future approaches towards sustainability. J Environ Manage. 2021 Oct 1; 295:113091. https://doi.org/10.1016/j.jenvman.2021.113091 PMID: 34171777
9. Buberger J, Kersten A, Kuder M, Eckerle R, Weyh T, Thiringer T. Total CO2-equivalent life-cycle emissions from commercially available passenger cars. Renew Sustain Energy Rev. 2022 May 1; 159:112158.
10. Knobloch F, Hanssen SV, Lam A, Pollitt H, Salas P, Chewpreecha U, et al. Net emission reductions from electric cars and heat pumps in 59 world regions over time. Nat Sustain. 2020 Jun; 3(6):437–47. https://doi.org/10.1038/s41893-020-0488-7 PMID: 32572385
11. Kawamoto R, Mochizuki H, Moriguchi Y, Nakano T, Motohashi M, Sakai Y, et al. Estimation of CO2 Emissions of Internal Combustion Engine Vehicle and Battery Electric Vehicle Using LCA. Sustainability. 2019; 11(9).
12. Yu A, Wei Y, Chen W, Peng N, Peng L. Life cycle environmental impacts and carbon emissions: A case study of electric and gasoline vehicles in China. Transp Res Part Transp Environ. 2018 Dec 1; 65:409–20.
13. Kumar RR, Alok K. Adoption of electric vehicle: A literature review and prospects for sustainability. J Clean Prod. 2020 Apr 20; 253:119911.
14. Pamidimukkala A, Kermanshachi S, Rosenberger JM, Hladik G. Barriers and motivators to the adoption of electric vehicles: A global review. Green Energy Intell Transp. 2024 Apr 1; 3(2):100153.
15. Singh V, Singh V, Vaibhav S. A review and simple meta-analysis of factors influencing adoption of electric vehicles. Transp Res Part Transp Environ. 2020 Sep 1; 86:102436.
16. Ivanova G, Moreira AC. Antecedents of Electric Vehicle Purchase Intention from the Consumer's Perspective: A Systematic Literature Review. Sustainability. 2023 Jan; 15(4):2878.
17. Berkeley N, Jarvis D, Jones A. Analysing the take up of battery electric vehicles: An investigation of barriers amongst drivers in the UK. Transp Res Part Transp Environ. 2018 Aug; 63:466–81.
18. Chu W, Im M, Song MR, Park J. Psychological and behavioral factors affecting electric vehicle adoption and satisfaction: A comparative study of early adopters in China and Korea. Transp Res Part Transp Environ. 2019 Nov 1; 76:1–18.
19. Higueras-Castillo E, Molinillo S, Coca-Stefaniak JA, Liébana-Cabanillas F. Potential Early Adopters of Hybrid and Electric Vehicles in Spain—Towards a Customer Profile. Sustainability. 2020 Jan; 12(11):4345.
20. Nayum A, Klöckner CA, Mehmetoglu M. Comparison of socio-psychological characteristics of conventional and battery electric car buyers. Travel Behav Soc. 2016 Jan; 3:8–20.

21. Noppers EH, Keizer K, Bockarjova M, Steg L. The adoption of sustainable innovations: The role of instrumental, environmental, and symbolic attributes for earlier and later adopters. J Environ Psychol. 2015 Dec 1; 44:74–84.

22. Okada T, Tamaki T, Managi S. Effect of environmental awareness on purchase intention and satisfaction pertaining to electric vehicles in Japan. Transp Res Part Transp Environ. 2019 Feb; 67:503–13.

23. Peters A, Dütschke E. How do Consumers Perceive Electric Vehicles? A Comparison of German Consumer Groups. J Environ Policy Plan. 2014 Jul 3; 16(3):359–77.

24. Plötz P, Schneider U, Globisch J, Dütschke E. Who will buy electric vehicles? Identifying early adopters in Germany. Transp Res Part Policy Pract. 2014 Sep 1; 67:96–109.

25. Vassileva I, Campillo J. Adoption barriers for electric vehicles: Experiences from early adopters in Sweden. Energy. 2017 Feb; 120:632–41.

26. Daramy-Williams E, Anable J, Grant-Muller S. A systematic review of the evidence on plug-in electric vehicle user experience. Transp Res Part Transp Environ. 2019 Jun 1; 71:22–36.

27. Karjalainen LE, Tiitu M, Lyytimäki J, Helminen V, Tapio P, Tuominen A, et al. Going carless in different urban fabrics: socio-demographics of household car ownership. Transportation. 2023 Feb 1; 50(1):107–42.

28. Latauskartta.fi—Map of Charging Stations in Finland. Latauskartta. 2023. [cited 2023 Aug 17]. https://latauskartta.fi/

29. Milfont TL, Duckitt J. The environmental attitudes inventory: A valid and reliable measure to assess the structure of environmental attitudes. J Environ Psychol. 2010 Mar 1; 30(1):80–94.

30. Collins L. M., & Lanza S. T. Latent class and latent transition analysis: With applications in the social, behavioral, and health sciences. Vol. 718. John Wiley & Sons; 2009.

31. Bruderer Enzler H, Diekmann A. All talk and no action? An analysis of environmental concern, income and greenhouse gas emissions in Switzerland. Energy Res Soc Sci. 2019 May 1; 51:12–9.

32. Christis M, Breemersch K, Vercalsteren A, Dils E. A detailed household carbon footprint analysis using expenditure accounts–Case of Flanders (Belgium). J Clean Prod. 2019 Aug 10; 228:1167–75.

33. Huddart Kennedy E, Krahn H, Krogman NT. Are we counting what counts? A closer look at environmental concern, pro-environmental behaviour, and carbon footprint. Local Environ. 2015 Feb 1; 20(2):220–36.

34. Salo M, Savolainen H, Karhinen S, Nissinen A. Drivers of household consumption expenditure and carbon footprints in Finland. J Clean Prod. 2021 Mar 20; 289:125607.

35. Theine H, Humer S, Moser M, Schnetzer M. Emissions inequality: Disparities in income, expenditure, and the carbon footprint in Austria. Ecol Econ. 2022 Jul 1; 197:107435.

36. Herberz M, Hahnel UJJ, Brosch T. Counteracting electric vehicle range concern with a scalable behavioural intervention. Nat Energy. 2022 May 19; 7(6):503–10.