EVS30 Symposium
Stuttgart, Germany, October 9 - 11, 2017

A customer's view on policy measures to promote electric vehicles

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Abstract

Electric vehicles represent a promising approach to reduce local vehicle emissions, and thus to improve air quality in urban regions. Their market uptake, however, is still staying below expectations in most countries across Europe, due to monetary and non-monetary barriers. Besides monetary incentives, different non-monetary policy measures to promote electric mobility are either discussed or already in place. Since the different monetary incentives across Europe have proven to be not equally effective in the support of the electric vehicle market uptake, it is expected that non-monetary policy measures will not express the same impact level in different countries, too. Therefore, the project "Incentives for Cleaner Vehicles in Urban Europe" (I-CVUE) aims to understand the efficacy of policy measures that promote electric vehicles in Europe. In order to gain a deeper understanding a stated preference survey was executed that focusses on studying the value of policy measures and further non-monetary aspects of electric vehicle ownership. The online survey was directed at vehicle drivers and fleet managers in Austria, Germany, the Netherlands, the United Kingdom, and Spain. Based on the obtained data, country-specific willingness-to-pay values are deducted, which can be used to assess the utility of electric vehicles. The results are used to derive recommendations to city-level policy makers on efficient measures to promote electric vehicles.

Keywords: BEV, policy, utility, user behavior

1 Introduction

In recent years, the purchase and ownership of electric vehicles (EVs) has been incentivised through various monetary and non-monetary benefits in many European countries. These incentives differ strongly among the countries with respect to their total fiscal benefit, type of subsidies, and their impact on the registration of EVs [1]. With the exception of Norway, which has experienced a thunderous market uptake of EVs since 2011 [2], the impact of these incentives on EV sales are rather small. Nevertheless, cities are more and more confronted with urban air quality and noise issues. Therefore, city regulators discuss or have implemented a variety of additional local non-monetary policy measures [3], e.g. the access of EVs to bus lanes, parking slots reserved for EVs, or the setup of zones with entry restrictions for conventional vehicles, in order to further support the EV market uptake [4]. Since each of these measures discriminate the use of conventional vehicles (CVs) to a greater or lesser extent, it is all the more important to understand the efficacy of these effects on the EV market uptake [5], [6]. Consequently, the implementation of ineffective measures with low public acceptance can be prevented. As a prerequisite, regional differences in infrastructure, e.g. bus lane abundance, parking space availability, and possible areas of entry-restricted zones need to be analysed [7]. Additionally, the customers' perception of vehicle parameters differing between electric and conventional vehicles, i.e. acceleration or greenhouse gas, and air pollutant emissions need to be considered. The willingness to purchase an EV also depends on consumer preferences, which might differ for private and corporate car owners [8]. Therefore, a stated preference survey was conducted focusing on the value of policy measures and further non-monetary aspects of EV ownership. The combination of the survey data with a thorough analysis of monetary aspects of EV market penetration in those countries (cf. e.g. [5]), will grant a comprehensive understanding of the efficacy of various incentive measures on the uptake of electric mobility across Europe.

2 Methodology

The survey was targeted at private vehicle owners, and fleet managers in Austria, Germany, the Netherlands, the United Kingdom, and Spain. It was made available in English, Spanish, German, and Dutch. The survey was published online, and distributed via different social media channels, i.e. Twitter, and Facebook, as well as websites to reach private vehicle owners. Fleet managers were primarily sourced via email contacts of project partners. Due to these distribution channels, the survey population is assumingly not representative for the target group of new vehicle customers, or fleet managers. Still, the results may aid the understanding of incentive measures and support the development of future surveys in this direction.

2.1 Questionnaire design

In order to gather as many complete fill-ins as possible the survey was restricted to 15 questions in total. The first 2 questions were designed to classify the respondents with respect to car ownership type (private or corporate vehicle ownership), and the geographic area of operation of the respondents on a regional level. Respondents that filled in the survey on behalf of their organization were additionally asked about their type of corporation (private or public sector), the organisation's predominant type of vehicle fleet (e.g. car rental, taxi, or company cars), the number of employees and vehicles in their organisation, as well as if the respondent is responsible for the procurement of fleet vehicles.

Then, in further 8 questions, the survey covered the importance of several non-monetary aspects of vehicle ownership, and the importance of possible policy measures to the vehicle owners. The design of these questions was threefold. First, the reader was introduced to the topic, using one to two concise sentences. Second, the conjecture of the question was presented to the participants. Third, the respondents were asked to state their maximum willingness-to-pay for the item in question from a predefined list of 15 to 23 possible responses, covering ranges from 0 EUR to up to 5,000 EUR on logarithmic scales. This approach minimizes the risk of missing the important range of possible answers for the yet unknown distribution of responses at the sacrifice of response precision. The UK survey version featured GBP instead of EUR on the same response scale. Those responses were then converted to EUR based on daily currency conversion rates. All survey questions were posed in a neutral manner to minimise the impact on the results. Furthermore, direct references to vehicle technologies (e.g. "Diesel car" or "Battery Electric Vehicle") were avoided where possible to circumvent negative or positive associations of the respondents. Two questions were posed to the respondents with regard to CO_2. The first of these covered CO_2 reductions by technical means, whereas the second one covered carbon offset. This measure was taken in case the respondents were biased with respect to any of the two approaches to handle CO_2 emission reduction. Furthermore, the question description stated convenient payment modalities via an App or website, and specified which party would receive potential revenues from user payments, where applicable.

The following textual questions were posed to the participants:

- Question 1 (corporate respondents only): What is the maximum amount you would be happy to pay in order to reduce the costs paid for by the user(s) of one vehicle by 1,000€ in total during the ownership period of this vehicle?
- Question 2: What is your maximum willingness to pay to be allowed to use all bus or taxi lanes in your urban region for one day?

- Question 3: Please tick the maximum amount you would be happy to pay per month to get one reserved parking lot at a destination of your choice for one vehicle, on top of any parking fees that apply.
- Question 4: How much would you be willing to pay on top of all your other expenses, including taxes, duties, and parking per day to be allowed to enter and/or circulate within the urban region most relevant to you?
- Question 5 & 6: Please tick the maximum amount you would be willing to pay per year to avoid in the same period 2 tons of CO_2 emissions, either by technical means (Question 5) or a certified carbon offset project (Question 6).
- Question 7: What is your maximum willingness to pay once, on top of the purchase price of a vehicle, to prevent all air polluting exhaust emissions from that vehicle?
- Question 8: Which of the listed amounts best describes your willingness to pay once, on top of the purchase price of a vehicle, for an available extra feature that would improve the time to accelerate to 100 km/h by 1 second?

2.2 Evaluation

In total, 619 responses were collected of which 191 responses were disregarded due to inappropriately short questionnaire completion time or due to many omitted answers or missing association to the spatial scope. In total 57 hypotheses were tested against the survey sample.

Table 1 contains the count of responses by country and ownership type. Since there are not enough responses to investigate country specific differences by ownership type only the following three hypothesis types were tested: Do survey results differ by private and corporate ownership? Are results of two individual countries different? Do results of one country differ from results found for the other countries? Note that no country-specific analysis was performed for Spain due to the low number of responses from this country. However, the Spanish responses were taken into account when combined with answers from other countries.

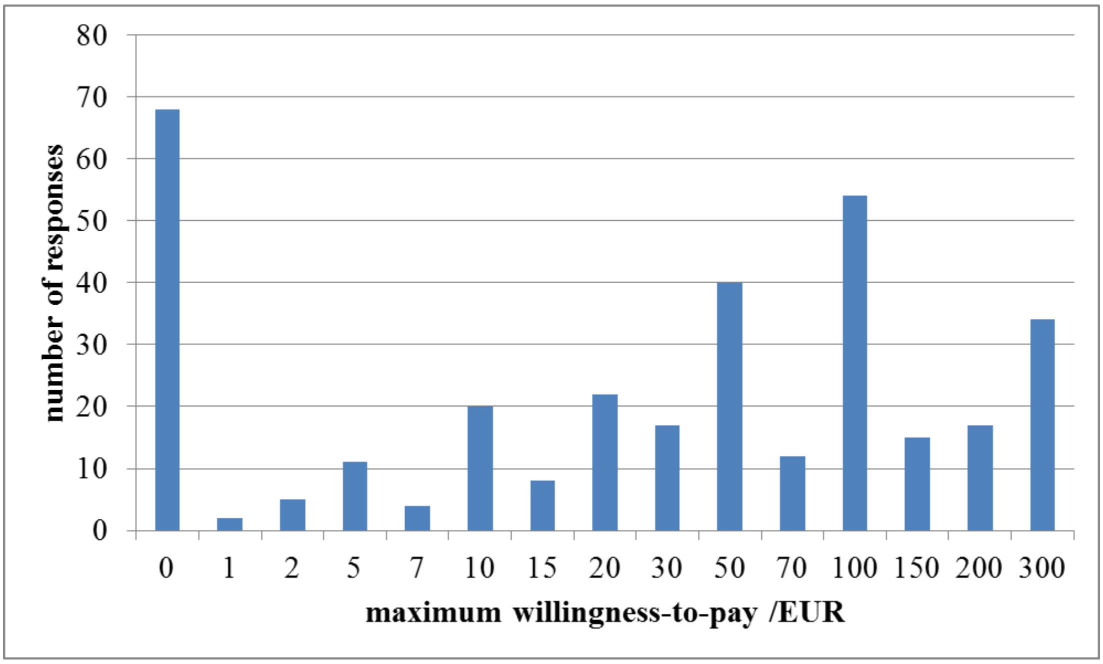

Figure 1: Maximum annual willingness-to-pay to avoid 2 tons of CO_2 emissions per year by carbon offset (Question 6) in Austria, Germany, the Netherlands and Spain – UK data are not included due to the different monetary scale

Figure 1 shows an example result from Austria, Germany, the Netherlands, and Spain for the maximum willingness-to-pay in order to avoid two tons of annual CO_2 emissions (Question 6). It can be clearly seen that the results have a wide spread and do not resemble a normal distribution on a linear or logarithmic scale. The *Shapiro-Wilk test* rejects the hypothesis of an underlying normal distribution with over 99.99%. Similar non-normally distributed responses were found for the results of the other posed questions. Therefore, a regular *t-test* cannot be used. Instead, the non-parametric *Mann-Whitney U test* was employed to check against the null hypothesis for the hypotheses proposed above. Since multiple hypothesis tests are performed on the same survey population the *Benjamini-Hochberg* procedure was employed to estimate false-discovery rates. In total 57 hypotheses were tested against the survey sample.

Table 1: Number of responses by country and ownership type

	AT	DE	ES	NL	UK	Total
Corporate	14	25	6	36	55	92
Private	86	133	23	44	6	286

3 Statistical analysis

3.1 Response distributions

An analysis of the response set's modality implies a multimodal distribution for many result sets, where at least one mode is located at very low willingness-to-pay values (see Figure 1). Similar findings can be made for the response sets of the other questions: The "0" – response is always among the most often chosen answers. Therefore, the response behaviour of the participants was evaluated.

The number of responses for each of the questions is shown in Figure 2. The first question was only addressed to corporate respondents, whereas the second question was not posed to participants from the UK due to political issues. Thus the total number of responses is less for the first two questions. It can be seen, that the number of valid responses declines slightly with the progression of the questionnaire. Nevertheless, the participants' perseverance was large enough to obtain more than 360 responses for all questions but the first one.

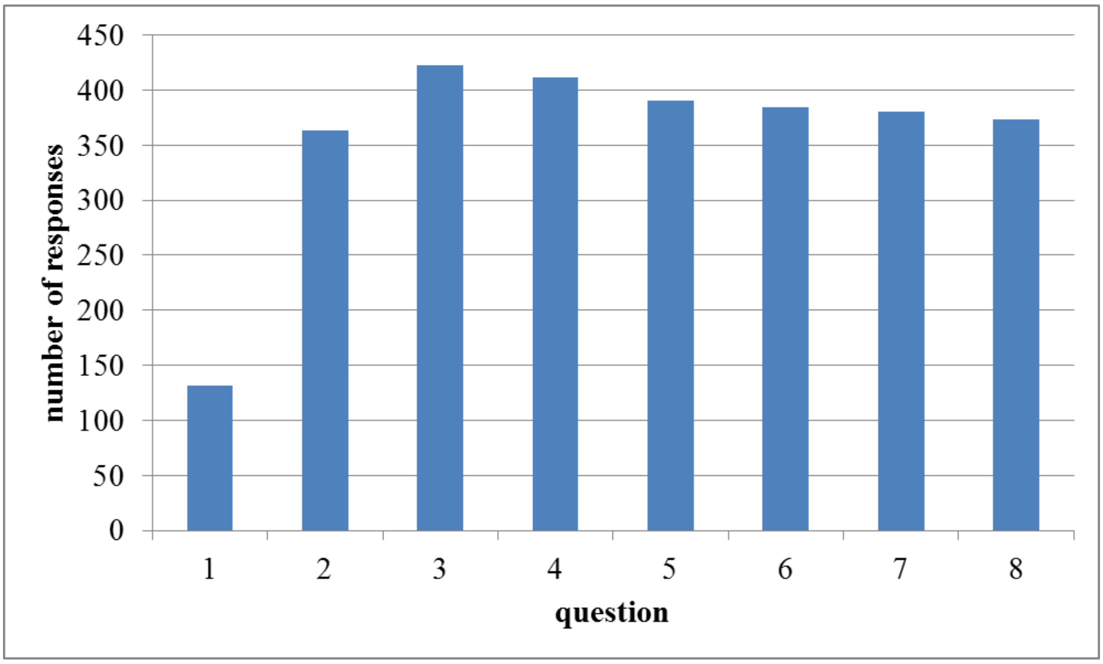

Figure 2: Number of responses for each question

Figure 3 shows, per respondent, the sum of unanswered questions, as well as the sum of non-Zero answers. It can be seen that the large majority of the respondents provided an answer for all questions. On average, each respondent missed only 1.0 answer. Of the given answers, 4.5 answers resemble a positive willingness to pay on average, i.e. non-Zero answers. The large majority of the respondents seem to have clear preferences what feature they would be willing to pay money for and for which they wouldn't. Only a minor subset of the respondents answered all questions with a vanishing willingness-to-pay. Therefore, the high incidence on the “Zero” willingness-to-pay response is not related to a single group of respondents, but seems to be caused by a strong diversity of the participants’ preferences and a clear idea of which non-monetary aspect they value and which not. As a consequence, a separate treatment of responses with Zero willingness-to-pay is not necessary and these responses were fully considered in the statistical analysis process.

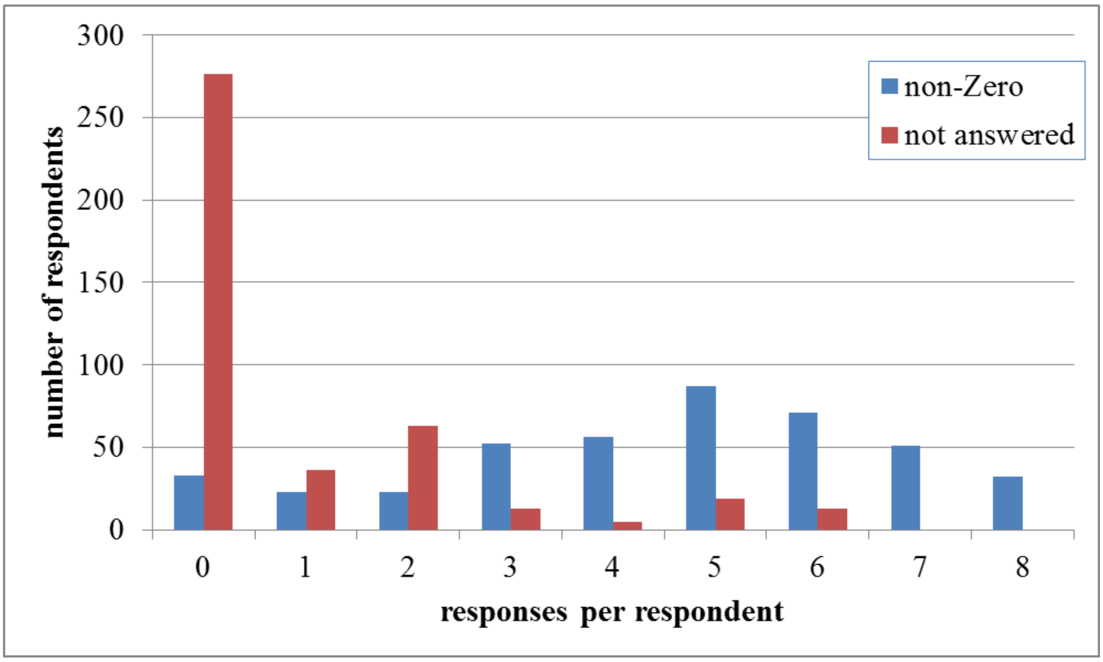

Figure 3: Sum of responses with positive willingness-to-pay per respondent as well as sum of not filled-in questions per respondent

3.2 Population differences

The result sets were tested for differences between corporate and private ownership types and for differences with respect to nationalities. Test results that showed a less than 5% false-positive discovery probability (fdp) according to the Benjamini-Hochberg procedure are shown in Table 2.

Table 2: Sample averages and p-values for population difference tests by question with Benjamini-Hochberg false-discovery probabilities less than 5%

Question	**2**	**5**	**7**	**8**
Sample 1	NL	DE	UK	private
Sample 2	DE	UK	others	corporate
Average 1	1.8 €/d	94 €/2t CO_2	215 €	215 €/s
Average 2	1.2 €/d	65 €/2t CO_2	394 €	81 €/s
p-value [%]	0.7	0.6	0.1	0.01
fdp [%]	5	5	1	1

It shows that the difference in maximum willingness-to-pay for the privilege to use bus- or taxi lanes in the Netherlands (average of 1.8 EUR per day of usage) to that in Germany (average of 1.2 EUR per day of usage) is significant at a high confidence level. At about the same confidence, the willingness-to-pay for 2 tons of saved CO_2 per year differs in the UK and Germany. The response average from the UK (215 €) differs also significantly to that from the other countries (394 €) with respect to avoiding the emission of local pollutants. Private and corporate vehicle owners differ with respect to their willingness to pay for higher vehicle accelerations: Private owners value this higher (215 €/s) than corporate vehicle owners (81 €/s).

Although the test results in Table 3 have low p-values and thus high individual significances, their false-discovery probabilities are above 5% and thus should be handled with care. Some of these results specify the findings in the previous table and hint to individual statistical populations of Germany and the Netherlands with respect to the willingness to pay for bus- or taxi lanes usage. Regarding the willingness-to-pay for a private parking slot differences seem to exist between private and corporate vehicle owners as well as between those from the UK and the other countries. However, due to the large proportion of corporate responses from the UK, its national average is most likely defiled by this correlation. The willingness-to-pay for CO_2 emission reductions seems to be above average in Germany and below average in the UK.

Table 3: Sample averages and p-values for population difference tests by question with Benjamini-Hochberg false-discovery probabilities (fdp) over 5%

Question	**2**	**2**	**3**	**3**	**5**	**5**	**6**
Sample 1	DE	NL	private	UK	DE	UK	UK
Sample 2	Others	others	corporate	others	others	others	others
Average 1	1.2 €/d	1.8 €/d	18 €/month	22 €/month	94 €/2t CO_2	65 €/2t CO_2	56 €/2t CO_2
Average 2	1.7 €/d	1.4 €/d	26 €/month	20 €/month	84 €/2t CO_2	92 €/2t CO_2	77 €/2t CO_2
p-value [%]	1.7	1.5	4.5	1.2	2.2	3.3	4.4
fdp [%]	6	6	13	6	6	8	10

4 Policy option assessment

The assessment of policy options for the investigated countries requires but a full set of monetised items for policy options and vehicle parameters for each country. Therefore, the findings of the survey can be combined into monetarisation tables considering the national characteristics shown in Table 2 and Table 3.

Table 4: Monetarised values of vehicle aspects and policy options by country and vehicle ownership type; question indices relate to that in Section 2.1

Question: Topic	**1: user cost**	**2: priority lane usage**	**3: priority parking**	**4: entry restrictions**	**5+6: CO_2 emissions**	**7: local pollutants**	**8: vehicle acceleration**
Unit	**€/€**	**€/a**	**€/a**	**€/a**	**€/t CO2**	**€**	**€/s**
AT		510	240	2520	42	394	
DE		360	240	2520	42	394	
ES		510	240	2520	42	394	
NL		540	240	2520	42	394	
UK		n/a	260	2520	30	215	
private	n/a		215				215
corporate	0.23		310				81

Table 4 shows monetarised values of vehicle aspects and policy options by country and vehicle ownership type. Here, countries that showed significant differences to all other countries were assigned a country-specific average. For those countries which did not show significant differences to all other countries, a combined average is shown. The same applies to vehicle ownership types. It was assumed that, per year, vehicles are used on 300 days or 12 months. The values in Table 4 can be adjusted proportionally to match other vehicle usage patterns.

On average, corporate vehicle owners value cost of their customers or employees with 23% compared to their own cost. A car rental company, for example, would be willing to pay 0.23€ in order to avoid 1€ of customer costs. Specific values for different countries or corporation types could not be obtained. The potential usage of bus or taxi lanes was found to vary among the countries. Since the willingness to pay for priority lane usage is expected to correlate with the availability of these lanes, our expectation is that these values show regional variations – an analysis for regional differences was however not possible due to the low response count and missing regional restriction within the questionnaire. Nevertheless, the results indicate that priority lane usage is less valued in Germany and slightly higher valued in the Netherlands. The question was not posed to participants in the UK, thus no value is given.

The willingness to pay for a reserved parking slot is marginally higher in the UK than in the other countries. Additionally, corporate vehicle owners value this aspect higher than private vehicle owners. The access to urban areas was valued higher in comparison to the previous two discussed goods. However, no country- or fleet-specific differences for these values were identified. Since the findings from questions 5 and 6, which were both targeting the willingness to pay for reduced CO_2 emissions, were similar, the average of both values was used for further processing. On average, the participants claimed to be willing to pay about 40 € per ton of avoided CO_2 emissions. This value is significantly higher than the current price of European CO_2 emission allowances (about 5 €/ton CO_2 [9]), but are lower than experts estimates for the carbon price in order to achieve world-wide climate goals (about 70 €/ton CO_2 [10]). A lower willingness to pay for the reduction of CO_2 emissions was found for the UK. This also applies to the avoidance of local pollutant emissions - countries other than the UK have a higher willingness to pay to avoid these emissions. Private vehicle owners seem to attribute higher values to vehicle acceleration than corporate vehicle owners. Despite the higher amount of responses in comparison to the first questions, no country-specific differences could be identified with respect to vehicle acceleration.

The comparison of the willingness to pay values for the three assessed policy options reveals that, as expected, the application of restricted access zones with exemptions for a certain group of vehicles, e.g. electric vehicles, would have an about ten times as large impact on the vehicle user's utility than a widespread supply of parking slots restricted to that same group of vehicle users. The impact onto vehicle utility of granting vehicles access to priority lanes can be higher than that of the latter policy measure provided a certain availability of these priority lanes is given in the considered region.

Under the assumption of an average ownership period of four years for first vehicle owners, and equivalence of electric and conventional vehicles with respect to all other parameters but emissions, an average new vehicle customer would be willing to pay about 700 € more for an electric vehicle than for a conventional one. This result, and the fact that EV suffer from practical and monetary disadvantages (e.g. long charging durations, restricted charging infrastructure, restricted range, high invest cost) explains, why new electric vehicle registrations shares are still below 1% in many European countries [11]. At the same time, this number sets the benchmark for combined monetary incentives and policy options for electric vehicles. These need to compensate for the restricted utility and higher cost of electric vehicles. An applied model for the uptake of electric vehicle markets in Europe [12] indicates that only the combination of strong monetary and non-monetary measures is likely to have significant impact on the uptake of electric vehicle market shares in the near future. Policy makers should also draw their attention to company car users and owners: When electric vehicles offer financial saving opportunities for the company car user, the owning company may show additional intentions to offer these cars to their employees.

5 Conclusions

The market uptake of electric vehicles across Europe is falling short of expectations, despite significant monetary incentives. The project I-CVUE strives to enhance the understanding of the impact of monetary and non-monetary policies to enhance EV market penetration. In order to gain a deeper understanding, a stated preference survey was conducted in five European countries (Austria, Germany, the Netherlands, Spain and the United Kingdom), focusing on non-monetary aspects of electric vehicle ownership and consumers perception of possible policy measures.

The survey results indicate that the investigated customer perception of possible incentive measures for electric mobility differs between European countries and vehicle ownership types. This holds also true for the willingness to pay for non-monetary aspects of electric vehicle ownership. Of the three investigated policy options, the application of restricted access zones yields by far the highest potential to influence vehicle ownership utility. The permission to use priority lanes and the availability of (sufficiently many) parking slots restricted to electric vehicles, on the other hand, are also valued by the European vehicle owners, although the benefits to vehicle utility are less emphasised than for the policy option mentioned before.

The reduction of vehicle emissions, regarding both CO_2 and local pollutants, has even less influence on the vehicle utility than any of the discussed policy measures. In case a strong market uptake of electric vehicles is desired, policy makers should not rely on the environmental awareness of the vehicle customers, but instead consider strong monetary incentives and additional policy options to compensate for disadvantages of electric vehicles with respect to invest cost and usability restrictions.

Acknowledgments

The I-CVUE project is co-funded by the Intelligent Energy Europe Programme of the European Union. Special thanks go to all partners of the I-CVUE project who provided crucial data input to the design and dissemination of the survey, especially Huw Davies, Georgina Santos, Marc Figuls Rovira, Rob Kroon, Ian Faye, Tim Anderson, and Simon Talbot.

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