

Characteristics of Dutch EV drivers

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Abstract

There has been little research towards the characteristics of Dutch electric vehicle (EV) drivers. This paper describes the result of focus groups and a survey with 286 respondents. Results indicate the current EV driver is predominantly a well-educated middle aged male with a high paying job. We link this to the price of the vehicles and the structure of tax incentives. He is moderately environmentally friendly and likes innovation. He loves the driving experience and promotes EVs towards friends. Most EV drivers are unsatisfied with their all electric range and on average a range of 375 km is desired. Bigger batteries will lead to better use of charging infrastructure. Fast charging is considered important for longer trips but not as a replacement for chargers at parking locations. Smart charging is well received – as long as the user stays in control – which bodes well for the synergy between EVs and the renewable electricity grid.

Key words: Electric vehicles, user behaviour, user expectations, electric mobility, charging behaviour

1 Introduction

Because fossil fuels cause global warming [1] of which 23% is caused by transportation [2], we urgently need transportation that does not rely on fossil fuels. Biofuels might sustainably replace 0.5-5% [3] but there is global competition between biofuels, nature and food [4]. Biofuels therefore exacerbate aquifer depletion [5], deforestation [6], [7] and soil erosion [8], [9]. Biofuels are also linked to food crises [10]–[12] while indications are that indirect land use change negates their carbon emission savings [13]–[16].

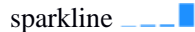
These problems surrounding fossil fuels and biofuels unfortunately mean that electric vehicles are currently the only scalable sustainable option for road transportation. EVs can run on renewable electricity from solar and wind that is potentially abundant [17] and is expected to become cheaper than fossil fuel and biofuel [18], [19]. Indications are that falling battery prices [20], [21] will make electric vehicles cost competitive without government stimuli within a few years [22], [23].

Governments are therefore stimulating the adoption of EVs. The Dutch parliament has indicated that it aims to ban the sale of non-electric personal vehicles between 2025 and 2035 and provides tax incentives. Adoption rates in the Netherlands are high [24], second only to Norway.

But who are these early adopters that might make the switch from fossil cars to EVs? If we know their priorities and mind-set we might know what to expect and how to convince them. Very little is known about them (at least in the public domain) and the lack of information was especially jarring in the Netherlands. We therefore conducted what is to our knowledge the most extensive research on Dutch EV drivers to date. This paper presents the results.

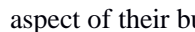
2 Survey setup

Norway and California are leading the way in terms of EV drivers research [25], [26]. Apart from more funding, the reason is that they have collected the (e)mail addresses of EV drivers and can thus send them a questionnaire. Unfortunately this is not possible in the Netherlands (see discussion). Therefore we conducted focus groups as part of the ElaadNL foundation *FlexPower* project [27] and we conducted an extensive online survey using 1300 addresses of people who requested a public charge point from the ElaadNL foundation.

A total of 286 EV drivers with an average EV experience of 3 years completed the survey. To our knowledge this is the most extensive research that has been conducted on the Dutch EV drivers to date. To be precise but concise we sometimes present the answers to Likert scales questions (e.g. strongly disagree, disagree, neutral, agree, strongly agree) using *sparklines* [28] that we have implemented as histograms [29]. Bars on the left show disagreement and bars on the right show agreement. For example, the following sparkline  implies that respondents strongly agree.

3 Results

3.1 EVs are currently bought by wealthy males that get tax deductions but this will change

We find that currently the typical Dutch EV driver is male (92%) and has a job (98%). His age is 50 on average with 77% older than 41 and younger than 61. He is well educated with a relatively high income (see Figure 1 and Figure 2). He has his own parking space: 63% while the national average is 25%. Sales of Plug-in Hybrid Electric Vehicles (PHEVs) spiked at the end of 2013, 2015 and 2016 which coincides with the end of favourable tax incentives and most drivers indicated that the low fixed cost were an important aspect of their buying decision . Since EVs were relatively expensive and Dutch incentives give tax breaks that favour people paying high income tax the effect on buying decisions of a combination of tax incentives and income was as expected. This confirms the caricature of the current EV drivers in the Dutch media [30].

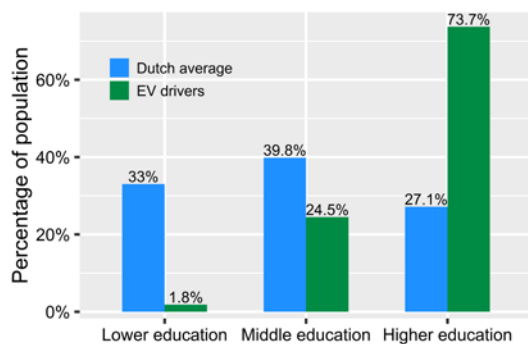


Figure 1 Education of EV drivers versus Dutch average

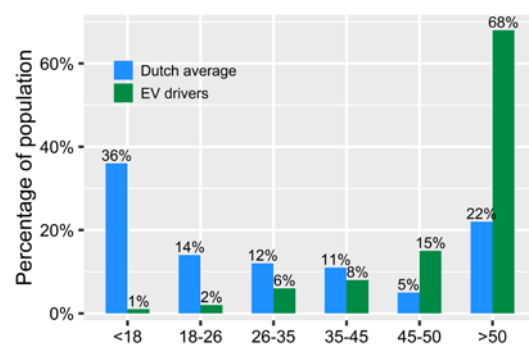


Figure 2 Yearly income of EV drivers (x1000 Euro)

However, recent studies regarding the Dutch situation indicate that second hand EVs already have a much lower total cost of ownership (TCO) than gasoline cars because of lower energy and maintenance costs per kilometer (both around 1/3) and lower road taxes [23]. Also, when regular A-class and C-class cars become available for business drivers (from 2018 onwards) they too will have a lower total cost of ownership (TCO). Finally, studies show that from 2020 onwards EVs will be cheaper for almost all customer categories both in terms of TCO and purchase price. [23] So, in the future the typical Dutch EV driver will probably lose his elitist characteristics.

3.2 Buying decision based on an interest in innovation and lower costs

When asked about their reason to buy an electric vehicle they indicate that low costs and being innovative are the main reasons, with FEV drivers focusing a bit more on innovation and PHEV drivers a bit more on costs (Figure 3).

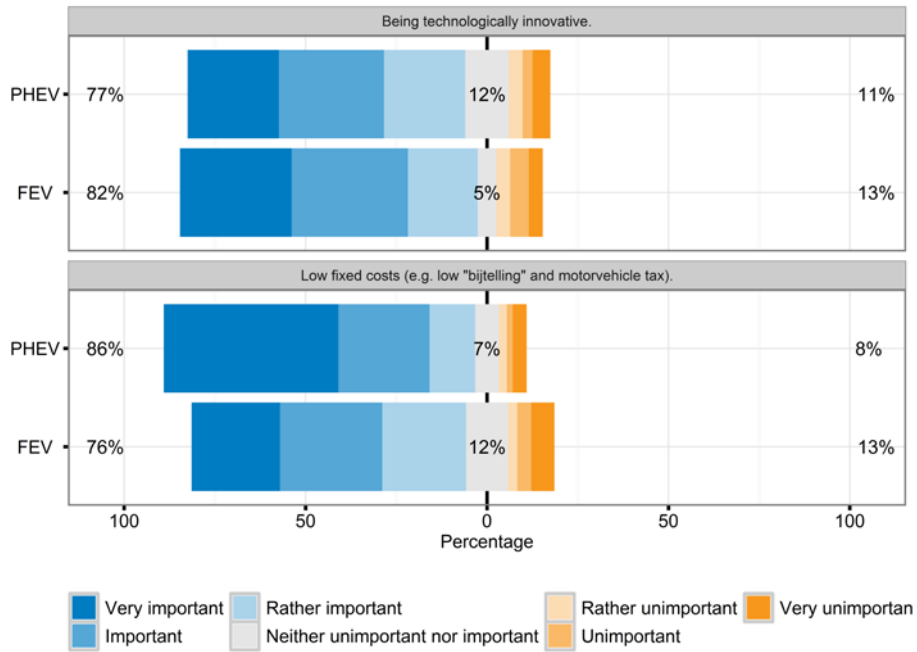







Figure 3 Stated reasons for buying an EV

3.3 Environmentally friendly pioneers with faith in new technology

Respondents see themselves as environmentally friendly pioneers (Figure 4). They like being technologically innovative , buy equipment with energy saving options , say they will buy more sustainable energy technology in the future  and want to lower carbon emissions . Not being dependent on energy from politically instable countries is less of an issue .

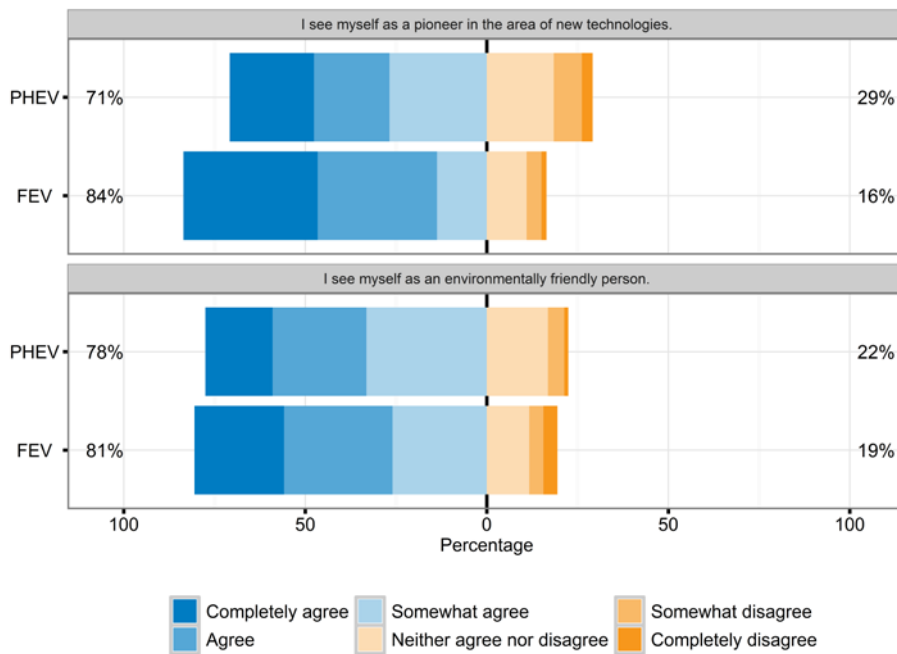



Figure 4 EV buyers see themselves as environmentally friendly pioneers

They are optimistic about technology. They think solar and wind will become cheaper than fossil fuel and that self driving cars will become a desirable option (Figure 5). They overwhelmingly think it is important that EVs stimulate the use of renewable energy . Although we did not pose the question, from the survey and focus groups we get the impression that their mental image is congruent with what is now often described as ecomodernism [31].

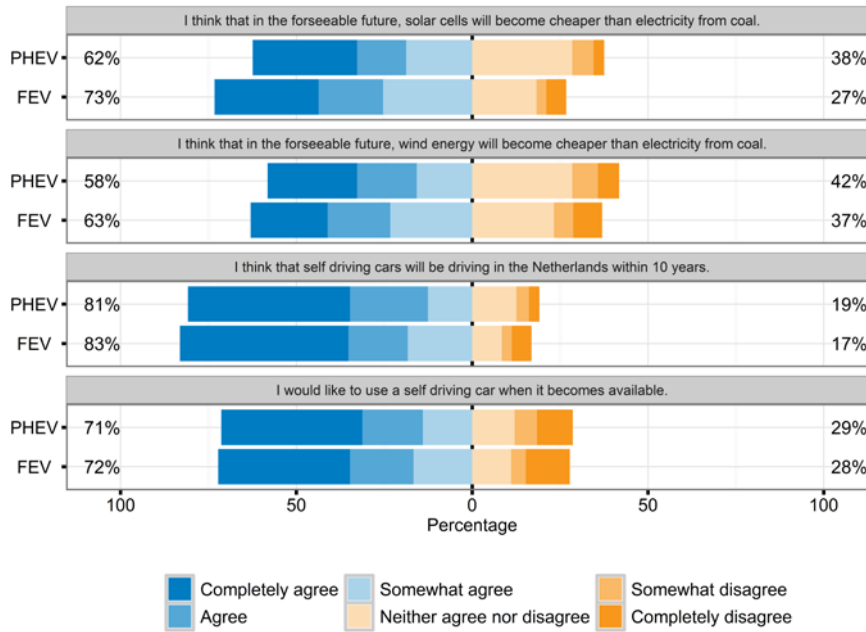


Figure 5 EV drivers are optimistic about wind, solar and self driving cars

3.4 Driving experience and silence are appreciated and the EV is recommended tot others

The respondents overwhelmingly claim that EVs are nicer to drive in and they do not miss the sound of a regular engine at all and although they agree you have to drive more carefully because the car is so silent they strongly dislike the idea of a mandatory sound (Figure 6).

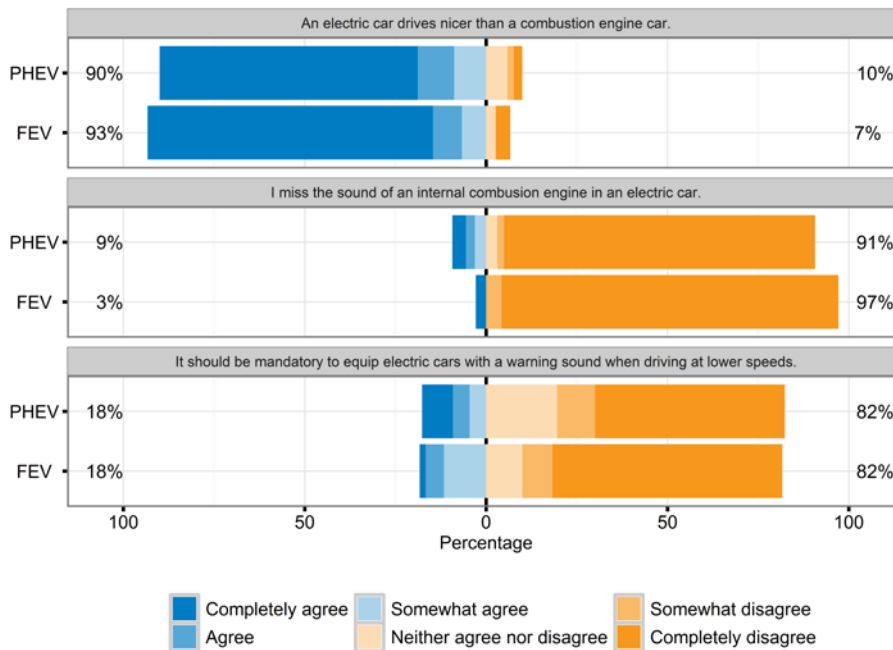


Figure 6 EV drivers are positive about driving experience

They recommend the EV to others (Figure 7) and this effect is especially strong with Tesla drivers where 88% has recommended electric driving to other people and 94% has allowed other people to try out their car at least twice.

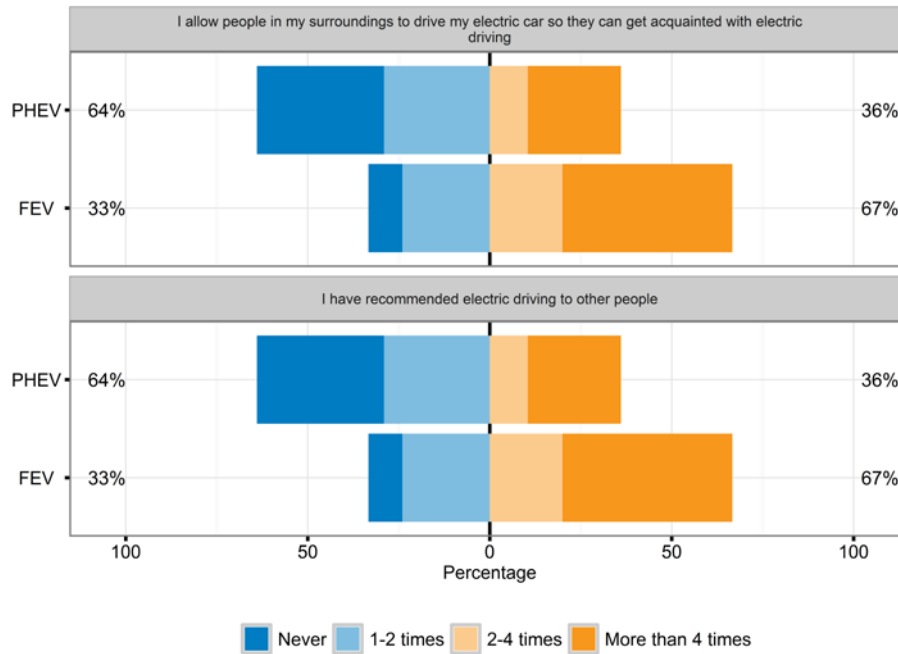


Figure 7 EV drivers promote their EV to others

3.5 Limited range is currently a problem but a range of 250-500 km will be sufficient

In this survey 58% of respondents have a household with more than one car while 12% is average in the Netherlands. We asked the FEV drivers whether they would have bought the car if it had been the only car in the household. We assumed the limited range of an FEV could be a problem and the answers seemed to indicate it was. The Nissan Leaf drivers indicated they had a real range of around 110 km and 66% of them indicated that they would probably not have bought the car if it had been the only car in the household. The Tesla drivers in our survey indicated an average real range of around 375 km and only 33% of them said they would probably not have bought an FEV if it had been the only car in the household.

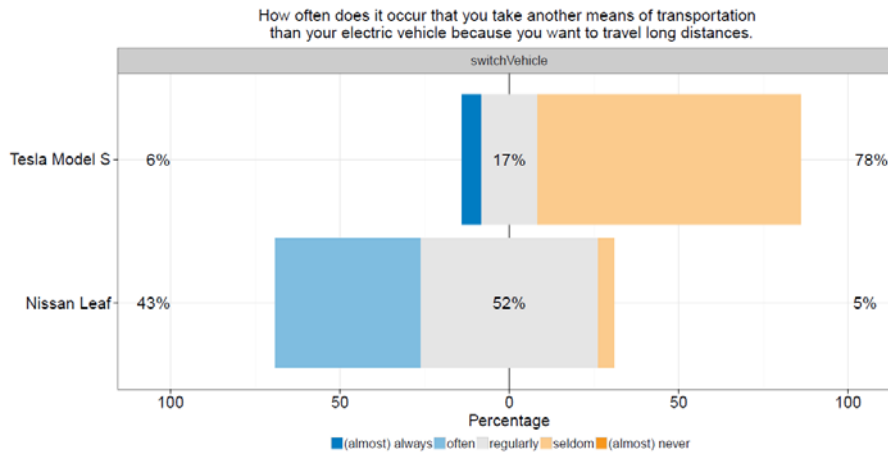


Figure 8 How often EV drivers have to change transportation: range matters

Analysis of Dutch driving data shows that with an FEV that has a range of 120 km the average driver needs a destination charger away from home or a fast charger about a hundred times a year. With a range of 350 km this is reduced to 10 times a year. To see how this compared to opinions of drivers we asked how often it occurs that they take another means of transportation because they have to travel long distances. Of the Nissan Leaf drivers 95% indicated this happens regularly while for the Tesla drivers this was only 23% (Figure 8).

We then asked the drivers if they were satisfied with their range (Figure 9). Interestingly enough, PHEV drivers were even more unsatisfied than FEV drivers. Their average real range was only 50 km but we had more or less expected that they would not care very much about range because they will automatically

switch to gasoline and most distances in the Netherlands are fairly short. Apparently they wanted to drive more electric kilometers. Of the FEV drivers only 38% of Nissan Leaf drivers (real range about 120km) was satisfied but over 83% of the Tesla drivers (real range around 400km) was satisfied.

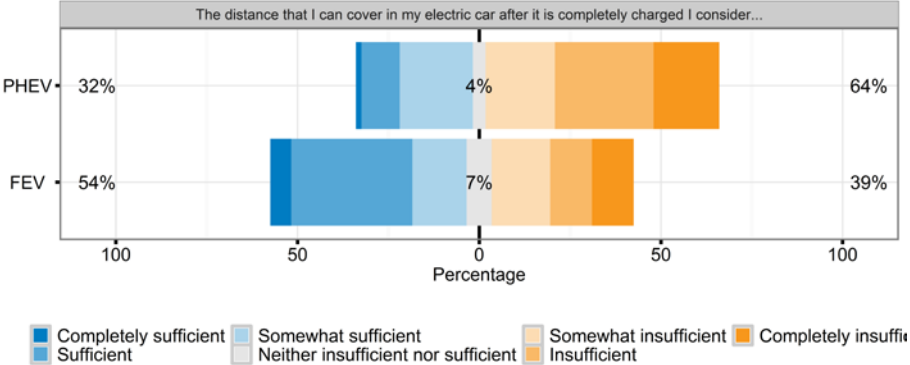


Figure 9 Satisfaction with current EV range

We also asked the drivers what range they desired (Figure 10). What struck us that very few respondents wanted ranges above 500 km. And although e.g. Tesla Model S drivers had somewhat higher requirements than e.g. Renault Zoe and Nissan Leaf drivers (which is to be expected because the Tesla’s range is already 400 km and it operates in an expensive market segment) everybody seemed to be expecting a range between 250 km and 500 km.

So both from the analysis, the reporting on real usage and the desired range a clear picture emerges: above about 250 km range the perceived problems become a lot less and more than 500 km range is unnecessary.

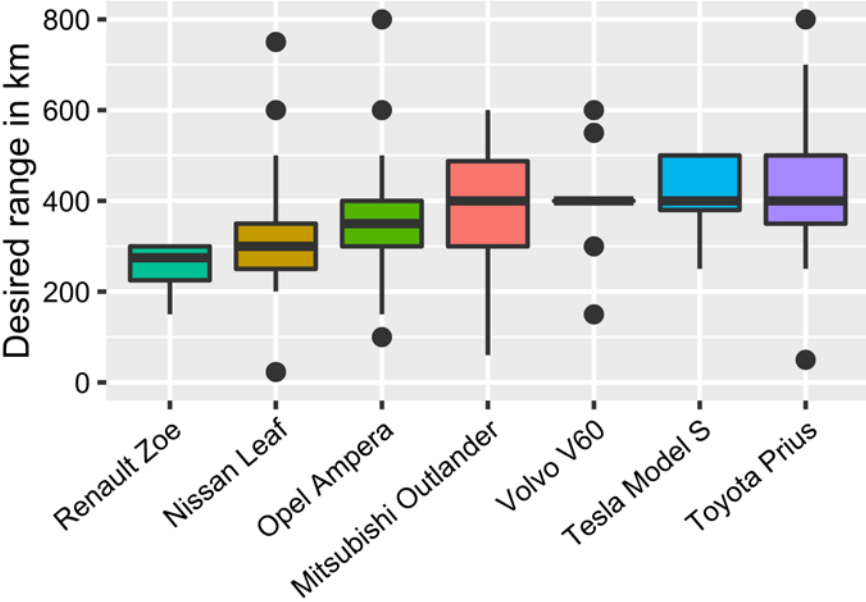


Figure 10: Desired range for drivers of different types of EVs

We assume that if you ask EV drivers to take the battery costs associated with extra range into consideration the desired range will go down. In the focus groups the consensus was that battery size would be less of an issue and desired range would decrease if fast chargers would be abundantly available, especially if this fast charging infrastructure would become 350 kW as is currently rolled out by the German automakers.

3.6 Public charging will become increasingly important

From our survey (Figure 11) it becomes clear that almost all EV drivers (especially FEV drivers) can charge at home and this confirms the discussions in the focus groups where participants stressed that an EV without the opportunity to charge at home is simply not an option potential buyers would consider.

Public charging infrastructure is a much discussed topic in the Netherlands because at least 2/3 of households in the Netherlands does not have access to a private parking place and thus can never use a private charger to charge at home. The current EV drivers are atypical in that only 1/3 does not have access to private parking. As EVs become mainstream the percentage of EV drivers requiring a public charger will increase.

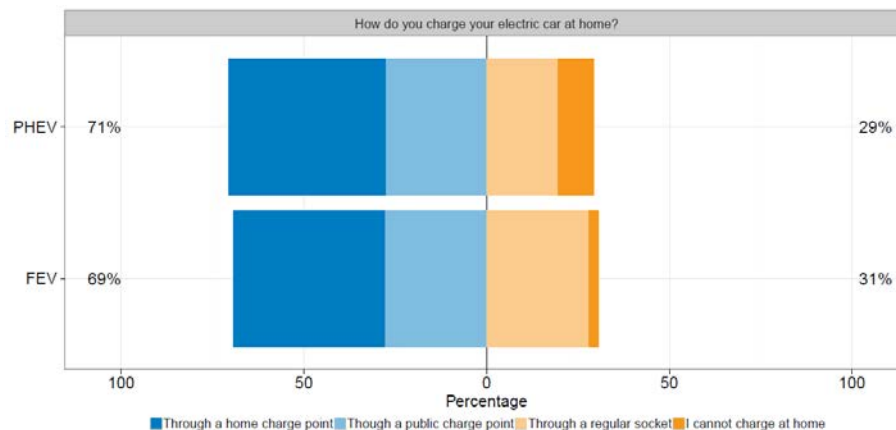


Figure 11 Chargers used at home and at work

Around 50% of the EV owners in our study indicated they could charge at work but they currently do not consider this a replacement for public chargers. We have hypothesized in other work that this could change in the future [23].

3.7 The business case for public chargers will improve with range

In our study PHEV drivers charge slightly more often than FEV drivers but Tesla Model S drivers charge much less often than e.g. Nissan Leaf drivers (Figure 12). The explanation is simple: when you have a larger battery it depletes more slowly.

This is important information for charge point operators (CPOs) because it means that the number of kWh per charge will increase: a large battery charges less often but when it charges, it charges a large amount. Since the business case of a CPO is based on a margin per kWh [32] this means that their margin on charge points increases with EV battery size.

This is also important information for national and municipal governments because extrapolation of the current trends in adoption and battery capacity seems to indicate that public charge points might soon be feasible without government subsidies [32].

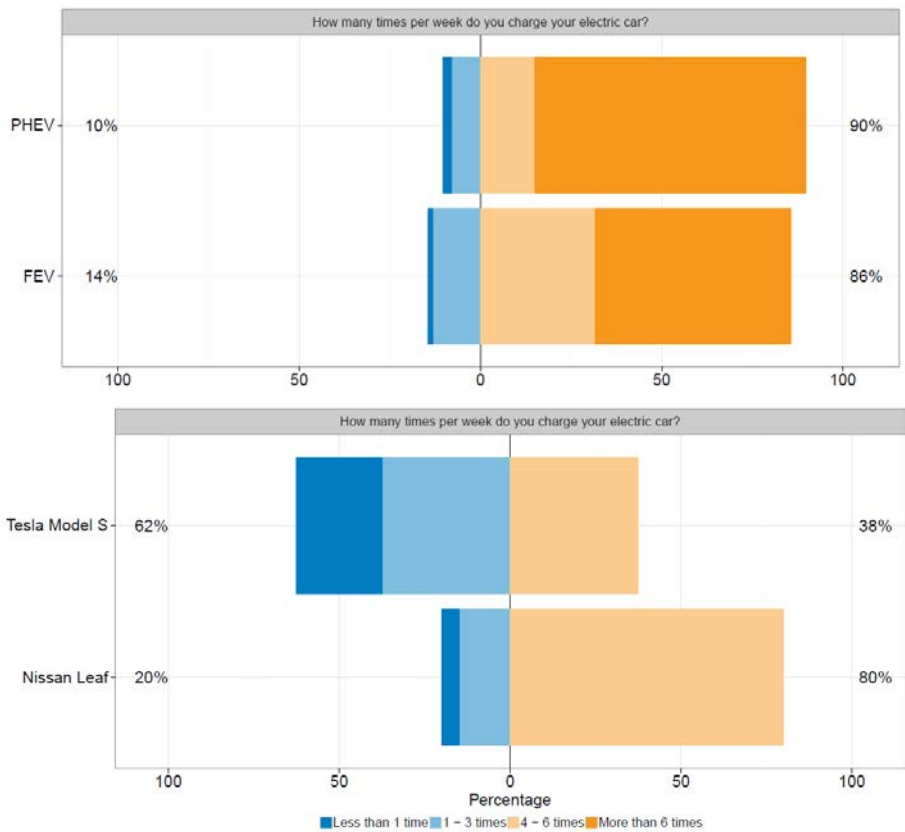


Figure 12 Charging frequency is correlated to battery size

3.8 Fast charging is a good range extender but does not replace destination charging

Fast chargers are another important requirement in the adoption process of EVs. From the survey results we can derive that more than 90% of FEV drivers considers fast chargers a good way to increase range and more than 70% (including Tesla drivers with their longer range) even consider them *essential* for an FEV. It's also interesting to note that Tesla Model S drivers use fast chargers more frequently than e.g. Nissan Leaf drivers (Figure 13).

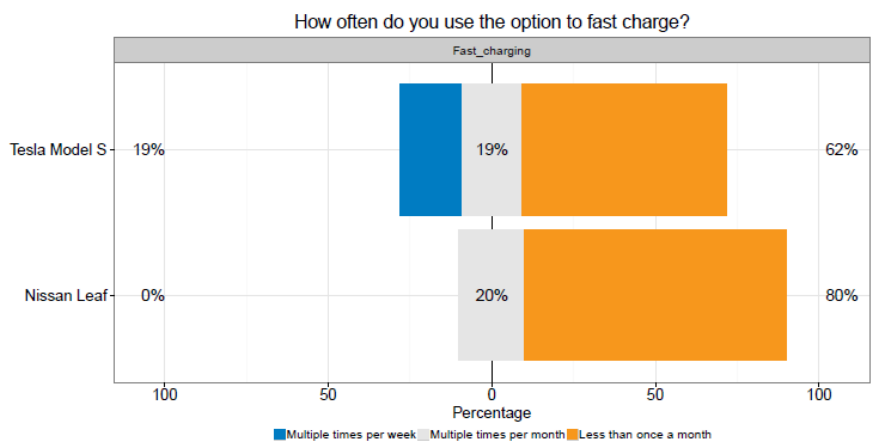


Figure 13 Frequency of fast charger use

Figure 14 shows a range of opinions on fast charging. It is clear that FEV drivers are somewhat more satisfied and better acquainted with fast chargers although the difference is small. All drivers strongly disagree with the idea that fast chargers can replace regular chargers.

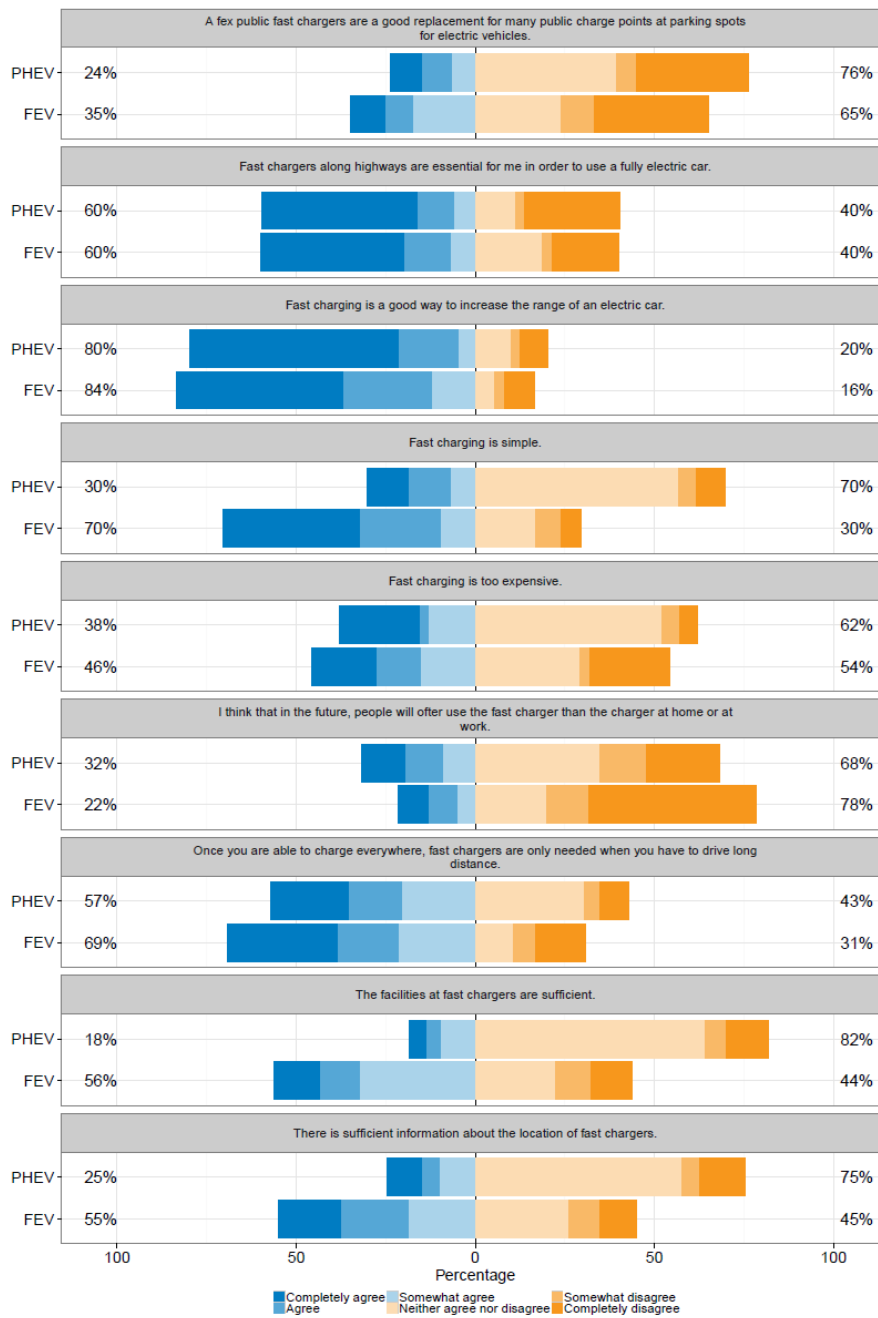
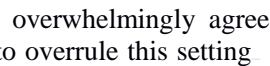
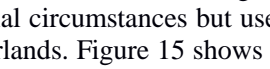
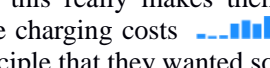


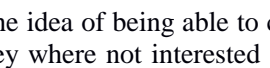
Figure 14 Opinions about fast charging

In focus groups the EV drivers expressed the idea that fast chargers are one of the best and least expensive ways to increase EV adoption. They expressed puzzlement that a lot of money is spent promoting electric cars but that road signs announcing fast chargers and permission to sell food at fast chargers were absent.

3.9 Enthusiastic about *smart charging* as long as “override button” is available

A concept that is gaining more and more traction in the Netherlands is “smart charging”. Smart charging means a car does not charge immediately when it is plugged in (e.g. at home or at work) but at the most suitable moment (e.g. when there is plenty of cheap renewable energy from solar and wind and the grid is not overtaxed). Many initiatives exist to take this further. USEF [33] has developed a framework for implementing this and the new OCPP standard [34] standardizes smart charging communication with charge points. The initiative to make smart charging a default through the use of these open protocols is supported by governments and grid operators but we wanted to find out what the users think.

Respondents overwhelmingly agree to allow default smart charging at home  if they have the opportunity to overrule this setting . From focus groups we know this is about being “in control” in case of special circumstances but users think they will hardly ever use this “override button” as it is called in the Netherlands. Figure 15 shows their opinions on three elements of smart charging. From focus groups we know that there is an added subtlety to these answers. They consider overloading the electricity grid in a way that is akin to what Herzberg would call a hygiene factor: they do not want to cause outages or unnecessary grid investments but it does not really motivate them. Using more renewable energy is akin to a motivator: this really makes them enthusiastic [8]. The respondents also prefer that smart charging decreases the charging costs  but from focus groups it seemed that the amount was less important than the principle that they wanted something in return for their flexibility as a matter of principle.

They liked the idea of being able to charge faster during non-peak hours  but the focus groups made clear that they were not interested in small increases but in e.g. doubling or tripling the charging speed. This is interesting because the electricity grid only has occasional peaks but on average has 81% excess capacity (in the Netherlands) so offering faster charging speeds in return for occasional limits on charging speeds actually makes a lot of sense from a cost perspective.

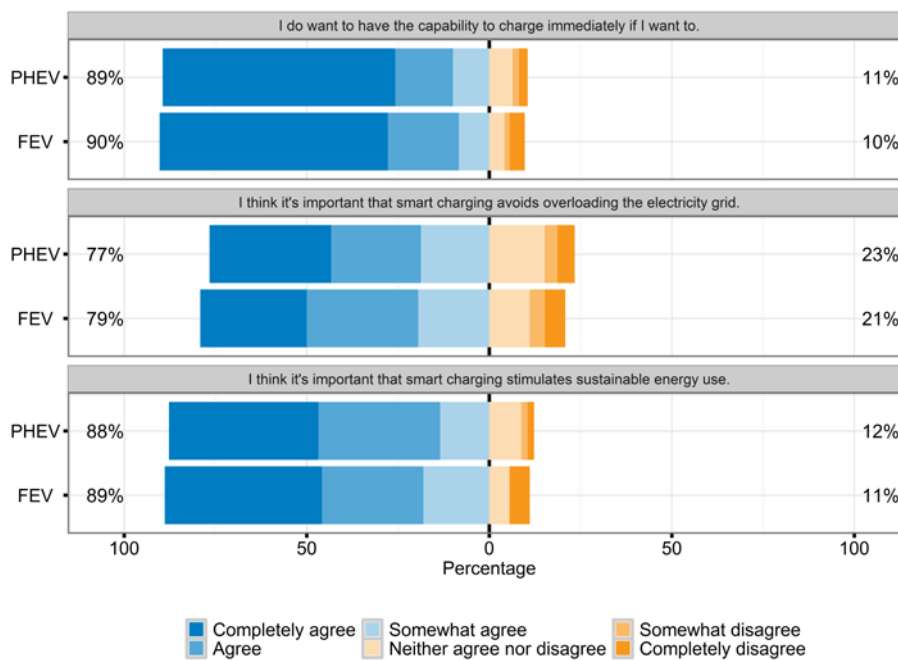


Figure 15 Agreement with reasons for smart charging

4 Conclusions

EV drivers are found to be middle aged males with high education levels and incomes who purchased the EV because tax incentives made them cost effective and because they like to try new technology. They see themselves as environmentally friendly and have positive expectations of new technologies like solar panels, windmills and self driving cars. After driving an EV for an average of three years they really enjoy the driving experience and the absence of the internal combustion sound and actively recommend the EV to others.

Only the Tesla Model S drivers are satisfied with the (~400km) range of their vehicle. PHEV drivers are especially unsatisfied. FEV drivers with limited range often use the EV as a second car and often have to switch to either another car or public transport. However, range issues become less once the range is more than ~250 km and few drivers desire a range of more than ~500 km. They would rather like good fast charging infrastructure.

Public charging will become increasingly important and the business case will improve with the size of the batteries because this will lead drivers to charge less often but more per charging session. Fast chargers are deemed important and higher charging speeds, better road signs and more facilities at fast chargers are requested. However, fast chargers are not viewed as a suitable replacement for chargers at the parking location. Smart charging is met with enthusiasm – as long as the driver has the ability to overrule it – which bodes well for the synergy between EVs and the renewable electricity grid.

5 Discussion

This research mapped the experience of a relatively small group of EV users. It would be more accurate if the group were larger and the survey regularly repeated. To initiate such a survey might be cost effective because it would only cost a fraction of the subsidy being spent on EVs and it would provide a more accurate picture of the most cost-effective application of those subsidies. It would also reveal in more detail what approaches are most effective in promoting the transition to EVs. E.g. (fast) charging infrastructure, smart charging, total cost of ownership information, et cetera. Collaboration with front runners like Norway and California might further improve the accuracy and the ability to generalize the results.

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References

- [1] R. K. Pachauri, L. Mayer, and Intergovernmental Panel on Climate Change, Eds., *Climate change 2014: synthesis report*. Geneva, Switzerland: Intergovernmental Panel on Climate Change, 2015.
- [2] International Energy Agency, “Global EV outlook 2016: Beyond one million electric cars.” OECD/IEA, 2016.
- [3] S. Y. Searle and C. J. Malins, “Waste and residue availability for advanced biofuel production in EU Member States,” *Biomass Bioenergy*, vol. 89, pp. 2–10, Jun. 2016.
- [4] Tim Searchinger and Ralph Heimlich, “Avoiding Bioenergy Competition for Food Crops and Land,” World Resources Institute, Jan. 2015.
- [5] D. Dimick, N. G. A. 21, and 2014, “If You Think the Water Crisis Can’t Get Worse, Wait Until the Aquifers Are Drained,” *National Geographic News*, 21-Aug-2014. [Online]. Available: <http://news.nationalgeographic.com/news/2014/08/140819-groundwater-california-drought-aquifers-hidden-crisis/>. [Accessed: 23-Jul-2017].
- [6] F. Danielsen *et al.*, “Biofuel Plantations on Forested Lands: Double Jeopardy for Biodiversity and Climate,” *Conserv. Biol.*, vol. 23, no. 2, pp. 348–358, Apr. 2009.
- [7] E. B. Fitzherbert *et al.*, “How will oil palm expansion affect biodiversity?,” *Trends Ecol. Evol.*, vol. 23, no. 10, pp. 538–545, Oct. 2008.

- [8] “Only 60 Years of Farming Left If Soil Degradation Continues,” *Scientific American*. [Online]. Available: <https://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/>. [Accessed: 23-Jul-2017].
- [9] “Soil Erosion and Degradation | Threats | WWF,” *World Wildlife Fund*. [Online]. Available: <https://www.worldwildlife.org/threats/soil-erosion-and-degradation>. [Accessed: 23-Jul-2017].
- [10] J. Ziegler, “Burning food crops to produce biofuels is a crime against humanity,” *The Guardian*, 26-Nov-2013.
- [11] “The Great Food Crisis of 2011,” *Foreign Policy*. .
- [12] B. G. Henning, “The Ethics of Food, Fuel & Feed,” *Daedalus*, vol. 144, no. 4, pp. 90–98, Sep. 2015.
- [13] D. M. Lapola *et al.*, “Indirect land-use changes can overcome carbon savings from biofuels in Brazil,” *Proc. Natl. Acad. Sci.*, vol. 107, no. 8, pp. 3388–3393, Feb. 2010.
- [14] E. F. Lambin and P. Meyfroidt, “Global land use change, economic globalization, and the looming land scarcity,” *Proc. Natl. Acad. Sci.*, vol. 108, no. 9, pp. 3465–3472, Mar. 2011.
- [15] P. Meyfroidt, E. F. Lambin, K.-H. Erb, and T. W. Hertel, “Globalization of land use: distant drivers of land change and geographic displacement of land use,” *Curr. Opin. Environ. Sustain.*, vol. 5, no. 5, pp. 438–444, Oct. 2013.
- [16] S. Tokgoz and D. Laborde, “Indirect Land Use Change Debate: What Did We Learn?,” *Curr. Sustain. Energy Rep.*, vol. 1, no. 3, pp. 104–110, Sep. 2014.
- [17] O. Edenhofer, Intergovernmental Panel on Climate Change, and Working Group 3, *Renewable energy sources and climate change mitigation: summary for policymakers and technical summary: special report of the intergovernmental panel on climate change*. New York?: [Cambridge University Press?, 2011.
- [18] IRENA, “The Power to Change: Solar and Wind Cost Reduction Potential to 2025,” IRENA, 2017.
- [19] J. D. Farmer and F. Lafond, “How predictable is technological progress?,” *Res. Policy*, vol. 45, no. 3, pp. 647–665, Apr. 2016.
- [20] B. Nykvist and M. Nilsson, “Rapidly falling costs of battery packs for electric vehicles,” *Nat. Clim. Change*, vol. 5, no. 4, pp. 329–332, Mar. 2015.
- [21] Argonne National Laboratory, “BatPaC - Battery Performance and Cost model - Home.” [Online]. Available: <http://www.cse.anl.gov/batpac/index.html>. [Accessed: 30-Sep-2016].
- [22] Bloomberg Finance, “Electric Vehicle Outlook 2017,” Bloomberg New Energy Finance, Jul. 2017.
- [23] Maarten Cuijpers, Auke Hoekstra, and Wouter Bakker, “Toekomstverkenning Elektrisch Vervoer,” 06-Dec-2016. [Online]. Available: <https://www.rijksoverheid.nl/documenten/rapporten/2016/12/06/eindrapport-toekomstverkenning-elektrisch-vervoer>. [Accessed: 17-Feb-2017].
- [24] Rijksdienst voor Ondernemend Nederland, “Cijfers elektrisch vervoer,” Jan-2017. [Online]. Available: <http://www.rvo.nl/onderwerpen/duurzaam-ondernemen/energie-en-milieu-innovaties/elektrisch-rijden/stand-van-zaken/cijfers>. [Accessed: 17-Feb-2017].
- [25] P. Haugneland and H. H. Kvisle, “Norwegian electric car user experiences,” in *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*, 2013, pp. 1–11.
- [26] E. Figenbaum, T. Assum, and M. Kolbenstvedt, “Electromobility in Norway: Experiences and Opportunities,” *Res. Transp. Econ.*, vol. 50, no. C, pp. 29–38, 2015.
- [27] ElaadNL, “FlexPower,” 2017. [Online]. Available: <https://www.elaad.nl/flexpower/>. [Accessed: 03-Sep-2017].
- [28] E. Tufte, *Sparkline theory and practice Edward Tufte*. Online, 2014.
- [29] “LaTeX sparklines from R,” *James Black*. [Online]. Available: <https://epijim.uk/code-snippets/sparklines/>. [Accessed: 14-May-2016].

- [30] Quirijn Visscher, “Particulier is klaar voor de stekkerauto,” *Trouw*, 14-Mar-2016.
- [31] J. Asafu-Adjaye *et al.*, “An ecomodernist manifesto,” 2015.
- [32] NKL, “Benchmark Cost Charging Infrastructure (Dutch),” 2016.
- [33] “Usef Energy – Universal Smart Energy Framework.” .
- [34] “Open Charge Alliance.” [Online]. Available: <http://www.openchargealliance.org/>. [Accessed: 03-Sep-2017].

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