EVS35 Symposium
Oslo, Norway, June 11-15, 2022

WILLING TO PAY? SPATIAL HETEROGENEITY OF E-VEHICLE CHARGING PREFERENCES IN GERMANY

Stefanie Wolff[1,2], Reinhard Madlener[1,3]
[1]*Institute for Future Energy Consumer Needs and Behavior (FCN), School of Business and Economics / E.ON Energy Research Center RWTH Aachen University, Mathieustrasse 10, 52074 Aachen, Germany, Tel. +49 241 80 498, Stefanie.Wolff@now-gmbh.de (corresponding author), RMadlener@eonerc.rwth-aachen.de*
[2]*Now at: National Organisation Hydrogen and Fuel Cell Technology (NOW GmbH), Fasanenstrasse 5, 10623 Berlin, Germany,*
[3]*Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology (NTNU), Sentralbygg I, Gløshaugen, 7491 Trondheim, Norway*

Executive Summary

We combine a Discrete Choice Experiment on charging preferences with a data set of public charging spots to spatially map the willingness to pay for charging options according to the availability of public charging spots. The results show spatial heterogeneity, i.e. respondents' choices depend on the quantity of public charging spots available to them. Non-availability of public charging spots in the vicinity has a larger effect on the choice probability than 1, 2, or 3 charging spots have. This could be evidence for charging infrastructure awareness.

1 Introduction

In economics, electric vehicle (EV) charging spots – a spatial combination of parking and refueling – are rival goods [9]. A better fit of EV charging supply to user expectations, needs, and behavior has yet to be found [2, 9]. This, in turn, hinders the uptake of EV diffusion. Further, users' *actual* EV charging spot usage may differ from previously anticipated *perceived* usage. Thus, the efficient alignment between the spatially heterogeneous supply of EV charging spots and (perceived) demand calls for a better understanding of private EV users' *expected* as well as *actual* recharging behavior. In Germany, the ratio of EVs per charging spot seems sufficient for reducing range anxiety to an acceptable level. Yet, these charging spots are not evenly distributed across regions (Fig. 1), partly reflecting the spatially heterogeneous EV diffusion patterns and population densities. Thus, balancing the spatial supply of and (perceived) demand for charging infrastructure efficiently is imperative for a successful sustainable mobility transition.

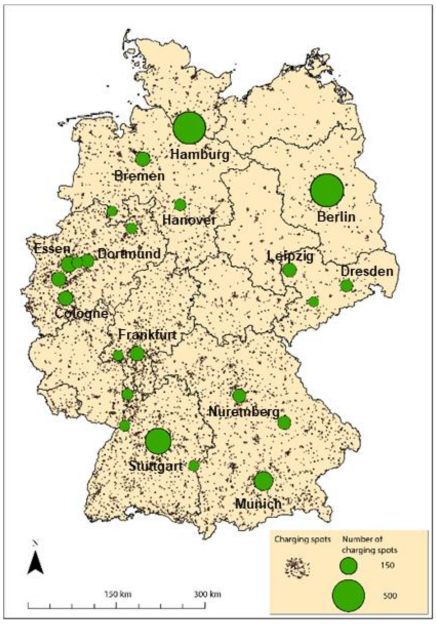

Figure 1: Distribution of charging spots across the 16 German Federal States with clusters in urban agglomerations marked in green. Source: ChargeMap.com (2019), own illustration, as of October 2019.

Few studies have so far determined the spatial development of and need for charging infrastructure. [9] analyze the determinants of charging session length while differentiating between connection time and total occupancy time (dwelling time) in the Netherlands. Depending on the EV range, [1] determine home and at-work charging to be the most requested charging locations. Interestingly, the density of charging spots plays a minor role compared to duration [4]. The demand side – determined by the EV user charging behavior – has been analyzed for Germany by [7], [5], [8], [6], [3], and [10] but has not been contrasted with the actual supply of charging infrastructure and recent trends. Depending on the number of public charging spots available, we locate charging preferences of current and potential future EV drivers and calculate the willingness to pay (WTP) for them, i.e. a reduction of the charging duration by 1 min is worth X Euros to consumers. Thus, to the best of our knowledge, this study is the first of its kind to spatially map the WTP for different attributes of the charging process in correlation to the available public charging infrastructure. More importantly, we identify spatial heterogeneity in the WTP for charging location subject to charging spots available in those regions. From that, we derive implications for charging infrastructure planning, e.g. regarding the expected break-even points for rolling out charging infrastructure and the provision of green energy. Thus, our results could be useful for charging infrastructure operators.

2 Methods

Our three research questions are: (1) Does the number of existing charging spots affect the EV charging preferences? (2) Depending on the number of charging spots, what is the WTP for certain attributes of the EV charging process? For example, how much is 1 minute less in charging duration worth? Following from that: (3) What are the implications for charging infrastructure policy and planning with consideration of the spread of charging infrastructure? Due to the low share of current EV users in Germany, investigating consumers' EV charging infrastructure preferences and their WTP for it based on real usage data is challenging. Therefore, we conducted a Discrete Choice Experiment to assess (current and future potential) EV drivers' valuation of six different attributes of the charging process: charging speed, location, share of renewables, waiting time for an available charging station, charging technology, and price. From the choice experiment, we derived the WTP for EV charging options and spatially map it against the availability of public charging spots. We matched *N* = 4,101 respondents living in 1,718 cities with 10,732 public charging spots in those cities. Subsequently, we obtained the WTP for the charging attributes when interacting with charging spots.

3 Results

The results show spatial heterogeneity, i.e. respondents' choices depend on the quantity of public charging spots available to them. A reduction of the charging duration by 1 min is worth 0.15-0.17 €/month to consumers – depending on the number of charging spots in situ. The non-availability of public charging spots in the vicinity has a larger effect on the choice probability than 1, 2, or 3 charging spots have. This could be evidence for charging infrastructure awareness. For the charging locations, we find marked spatial heterogeneity in the willingness to pay subject to the number of available public charging spots (Fig. 2): with every additional public charging spot, respondents are more likely to charge away from home.

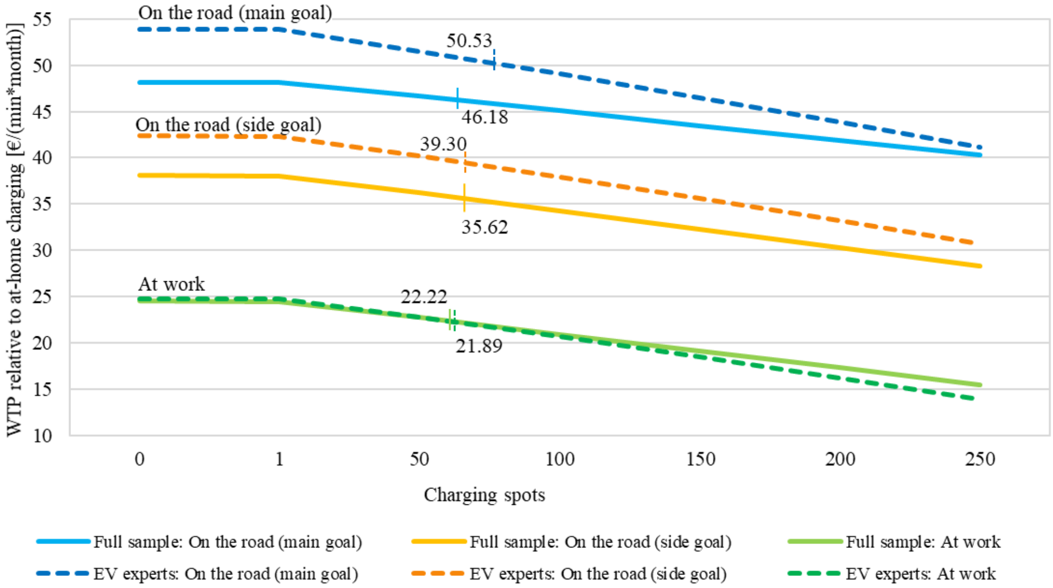

Figure 2: WTP for charging at home instead of indicated location when location is interacting with the number of charging spots and intersections with average WTP. Note: Full sample, EV experts.

This holds until the number of charging spots has reached a tipping point at which respondents become indifferent between home and work charging. When the tipping point is exceeded, respondents rather charge at work than at home. Thus, with increasing numbers of charging spots, public chargers near home are less relevant than those near work. Eventually, public chargers away from home become more attractive. Also, with increasing numbers of charging spots our results reveal a fivefold greater willingness to pay for reducing waiting time (for a charging spot to become available) than for accelerating charging speed. Thus, charging point operators could charge a higher price for implementing a booking scheme than for offering fast-charging.

4 Conclusions

We find charging preferences and the WTP for them in relation to charging infrastructure awareness. Our results show spatial heterogeneity, i.e. respondents' choices depend on the quantity of public charging spots available to them. Non-availability of public charging spots in the vicinity has a larger effect on the choice probability than 1, 2, or 3 charging spots have. This could be evidence for charging infrastructure awareness. From the findings, we derive implications for charging infrastructure policy, business model design, and infrastructure planning. Thus, our results seem very useful for charging infrastructure operators such as car manufacturers, state, government (or some governmental agency), municipalities, or energy companies, e.g. regarding the expected break-even points for rolling out charging infrastructure and the provision of green energy.

Acknowledgments

This study was enabled by the project grant A89 "E-Mobility Charging Behavior" from E.ON SE. The authors are thankful for research assistance provided by Hendrik Schmitz of FCN. The authors would like to thank participants of the 13th International Workshop on Empirical Methods in Energy Economics (EMEE 2020), January 13-14, 2020, Zurich, Switzerland.

References

[1] Debapriya Chakraborty, David S. Bunch, Jae H. Lee, and Gil Tal. 2019. Demand drivers for charging infrastructure-charging behavior of plug-in electric vehicle commuters. *Transportation Research Part D: Transport and Environment* 76, 255–272. DOI: https://doi.org/10.1016/j.trd.2019.09.015.

[2] Nicolò Daina, Aruna Sivakumar, and John W. Polak. 2017. Electric vehicle charging choices: Modelling and implications for smart charging services. *Transportation Research Part C: Emerging Technologies* 81, 36–56. DOI: https://doi.org/10.1016/j.trc.2017.05.006.

[3] Simon Á. Funke, Frances Sprei, Till Gnann, and Patrick Plötz. 2019. How much charging infrastructure do electric vehicles need? A review of the evidence and international comparison. *Transportation Research Part D: Transport and Environment* 77, 224–242. DOI: https://doi.org/10.1016/j.trd.2019.10.024.

[4] Joachim Globisch, Patrick Plötz, Elisabeth Dütschke, and Martin Wietschel. 2019. Consumer preferences for public charging infrastructure for electric vehicles. *Transport Policy* 81, 54–63. DOI: https://doi.org/10.1016/j.tranpol.2019.05.017.

[5] Till Gnann, Simon Funke, Niklas Jakobsson, Patrick Plötz, Frances Sprei, and Anders Bennehag. 2018. Fast charging infrastructure for electric vehicles: Today's situation and future needs. *Transportation Research Part D: Transport and Environment* 62, 314–329. DOI: https://doi.org/10.1016/j.trd.2018.03.004.

[6] Scott Hardman, Alan Jenn, Gil Tal, Jonn Axsen, George Beard, Nicolo Daina, Erik Figenbaum, Niklas Jakobsson, Patrick Jochem, Neale Kinnear, Patrick Plötz, Jose Pontes, Nazir Refa, Frances Sprei, Tom Turrentine, and Bert Witkamp. 2018. A review of consumer preferences of and interactions with electric vehicle charging infrastructure. *Transportation Research Part D: Transport and Environment* 62, 508–523. DOI: https://doi.org/10.1016/j.trd.2018.04.002.

[7] Tamer Soylu, John E. Anderson, Nicole Böttcher, Christine Weiß, Bastian Chlond, and Tobias Kuhnimhof. 2016. Building Up Demand-Oriented Charging Infrastructure for Electric Vehicles in Germany. *Transportation Research Procedia* 19, 187–198. DOI: https://doi.org/10.1016/j.trpro.2016.12.079.

[8] Johannes Wirges, Susanne Linder, and Alois Kessler. 2012. Modelling the Development of a Regional Charging Infrastructure for Electric Vehicles in Time and Space. *European Journal of Transport and Infrastructure Research* 12, 4, 391–416.

[9] Rick Wolbertus, Maarten Kroesen, Robert van den Hoed, and Caspar Chorus. 2018. Fully charged: An empirical study into the factors that influence connection times at EV-charging stations. *Energy Policy* 123, 1–7. DOI: https://doi.org/10.1016/j.enpol.2018.08.030.

[10] Stefanie Wolff and Reinhard Madlener. 2019. Charged up? Preferences for Electric Vehicle Charging and Implications for Charging Infrastructure Planning. *FCN Working Paper* 3/2019.

Presenter Biography

Dr. Stefanie Wolff is an energy economist working for the National Organisation Hydrogen and Fuel Cell Technology (NOW GmbH) in Berlin, a federally-owned company, as a Programme Manager Electromobility. There, she takes assignments in the area of sustainable mobility and energy supply from top-level German federal authorities, i.e. federal ministries. Stefanie Wolff is mostly responsible for assignments by the German Federal Ministry of Digital and Transport (BMDV) which entail the implementation and coordination of funding programmes for electric vehicles' uptake in Germany and the federal law of electromobility. She obtained her PhD in 2021 from the Institute for Future Energy Consumer Needs and Behavior at the E.ON Energy Research Center, as part of the School of Business and Economics at RWTH Aachen University, Germany.