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

The impact of charging infrastructure on local emissions of nitrogen oxides

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Summary

Benefits from EV and e-mobilty include the reduction of local emissions of pollutants, in particular from particulate matter and nitrogen oxides. This abstract presents results from a corporate research project in Baden-Wuerttemberg, Germany (LINOx BW) installing 2.358 charging points within 178 different sub-projects in 23 different cities, spanning a period of four years. Utilizing several different survey waves, data about outgoing current from the publicly sponsored charging infrastructure is gathered. Converting this data utilizing car-classifications and emission classes (HBEFA), the reduction of local nitrogen oxides is derived.

Keywords: BEV (battery electric vehicle), charging, infrastructure, pollution, research

1 Introduction

Limit values for nitrogen oxide emissions were adopted by the European commission in 2008 and are mandatory for all member countries since 2010 [1]. By 2017, 65 different cities in Germany measured nitrogen oxide values far greater than the threshold of 40 µg/m³on a daily basis [2]. Cities exceeding this threshold for a certain amount of time are legally responsible to adopt measures to reduce nitrogen oxide emissions, e.g., driving bans for diesel cars in city centers. Addressing this problem, the German Federal Ministry for Economic Affairs and Climate Action (BMWK) released a funding program for the construction of charging infrastructure for the impacted cities in 2017 (Sofortprogramm "Saubere Luft 2017-2020").

The corporate research project LINOx BW consists of 178 recipients from 23 different cities in Baden-Württemberg [3]. Grant applications for interested proposers from the impacted cities in Baden-Württemberg were bundled within the research project to simplify administrative processes. Additionally, accompanying research for all recipients is conducted consistently by two research institutes. By April 2022, 2.358 charging points were funded within the research project – utilizing around 10 million euros of federal support money. Figure 1 reveals the amount of charging points within each city.

Presented results in the paper rest upon data from the cutoff date 27.04.2022. The official project end is set for30.09.2022, but all recipients and project partners are working towards a self-financing project extension until 31.12.2023 due to delivery bottlenecks for charging infrastructure and thus reduced depreciation periods for the recipients. An approval is to be expected. First project results for parking lots and private areas were already published in German [4].

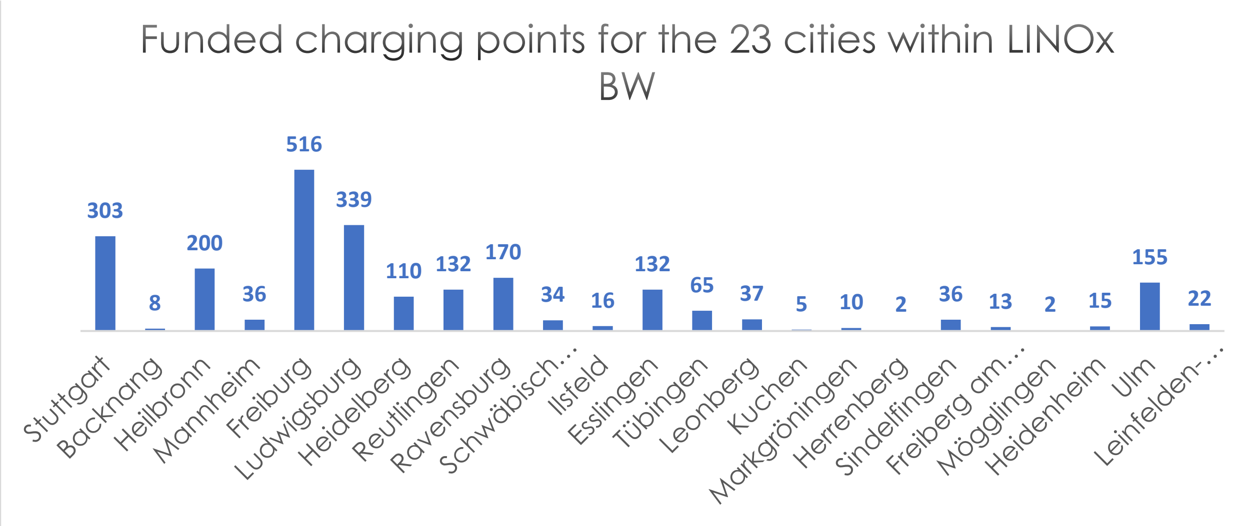

Figure 1: Funded charging points for the 23 cities within LINOx BW

2 Research Design

Charging infrastructure projects by the funding recipients were categorized in seven different use cases by researchers based on potential EV driving patterns (and therefore different charging opportunities) or different spatial boundary conditions: residential quarter, semi-public space, parking lots and park & ride, private on-site parking, nursing services, tourism and pedelecs. Utilizing a mixed methods approach consisting of quantitative and qualitative surveys, all recipients received a t_0 survey at the start of their respective project about their status quo containing questions, among others, relating to their vehicle fleets, existing charging infrastructure, parking lot size and enterprise size. A different questionnaire was set up including specific questions for each use case. Additionally, hand-picked recipients planning exceptionally large or special charging infrastructure projects were chosen for a one-hour telephone interview and are referred to as lead-partners. The semi-structured interview guideline comprises of four main sections: decision-making and communication procedures, cost, revenue, and operator models, use intensity of charging infrastructure and use case specific aspects. These use case specific questions allow for accommodation of use cases like nursing services or tourism, which are very different from private on-site parking, the use case that is encountered most often in the funding program. Results from the qualitative data will be published in forthcoming research papers as well [5].

One of the goals of LINOx BW is to quantify the reduction of local nitrogen oxides when charging infrastructure is built. The data needed to achieve this could not be collected fully just yet. Due to the request for a self-financing project lengthening, the schedule for the t_1 survey was postponed. The goal of the research project is to gather as much information from user experiences, vehicle fleets and amount of electricity delivered from all recipients as possible, thus resulting in delaying the t_1 survey. As of now, the time frame of the potential project lengthening is unknown – a new timetable for the substantial t_1 survey will be presented in Oslo. To collect information for this paper, a small number of recipients were chosen to complete a short survey containing data of the current charged electricity of the funded charging infrastructure (bundled with the respective commissioning date of the charging infrastructure) and information about their respective vehicle fleets. This survey was not mandatory. However, nine recipients responded and delivered extensive data.

The amount of electricity delivered by the funded charging points is the key variable to quantify the impact of charging infrastructure on local emissions of nitrogen oxides. Utilizing these values, the amount of electricity is converted to electric vehicle kilometers based on average consumption values of kWh/100km for different car-classifications from electric car data bases. From the collected data, two results are derived: 1) the maximal NO_x-reduction based on a 1:1 substitution for all cars in the respective vehicle fleets (gathered data from the t_0 survey) utilizing emission factors for ICEV based on the Handbook Emission Factors for Road Transport (HBEFA, [6]); 2) the current NO_x-reduction based on the amount of electricity of the funded charging infrastructure divided by the average consumption value. For this paper, 18,4 kWh/100km is utilized, based on literature [7: 17]. To derive the amount of NO_x reduction, an average NO_x-factor (g/km) based on the average German fleet composition (2022) included in the current version of HBEFA and the HBEFA traffic scenario “D Ø UBA 2021” is utilized. Figure 2 summarizes the research design for this paper:

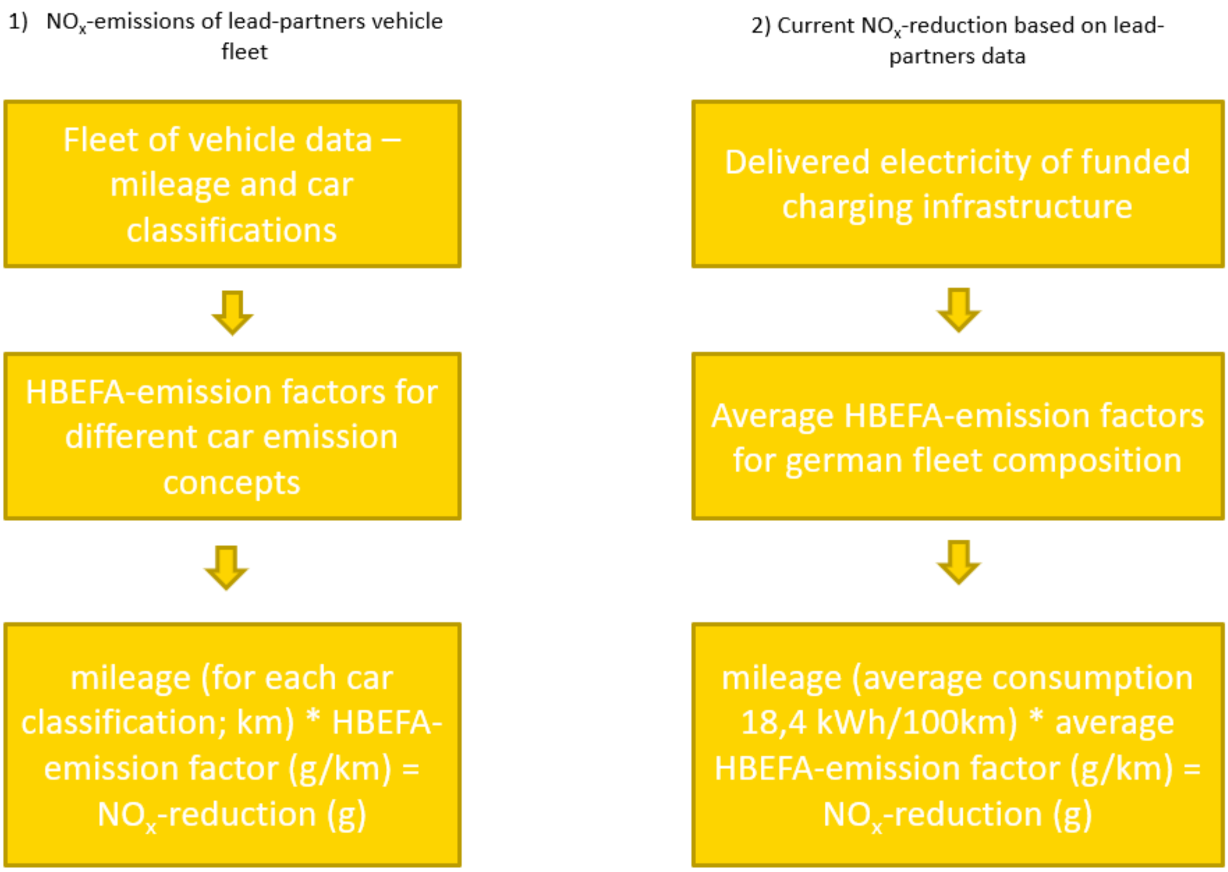

Figure 2: Research design of LINOx BW for classifying the impact of charging infrastructure on local emissions of nitrogen oxides

Referring to 2), for lead-partners where car emission concepts are unknown, average emission factors are calculated based on HBEFA and utilized for NO_x-reduction values.

Assuming the approval of the project extension will be granted, all recipients will receive the t_1 survey containing questions about their fleet of vehicles by the end of the project as well as the amount of electricity delivered by the funded charging points within project duration by June 2023. The t_1 survey is mandatory for all recipients leading to a substantial database gathered within the project. Independent scientific tracking of all funded charging points could not be provided within the research project; thus, research is dependent on survey data from funding recipients collecting the amount of electricity delivered by the charging infrastructure.

3 Results

The collected data from the hand-picked recipients is shown in Table 1. Data quality varies greatly between lead-recipients. Vehicle fleet data is based on the t_0 survey which was gathered at the start of their respective project, thus leading to vehicle fleet data ranging from 2018 to 2021. The possibility of lead-recipients adding electric cars to their respective vehicle fleets since conducting the t_0 survey is given. Some lead-recipients provided their charged electricity data from the beginning (the first day of implementing the charging infrastructure), others sent data for the time span of one year. Accessibility of the funded charging infrastructure is also derived from t_0 survey data and might change over time in real-life settings. The charged electricity values from lead-recipients with semi-public accessibility for their respective charging infrastructure might include the charging of other electric cars where the amount of charged electricity and vehicle fleet data are unknown thus leading to possible inaccuracies. Since LINOx BW is a research project promoting the funding of charging infrastructure in real-life-conditions in either existing buildings or existing companies, the task of standardizing the gathered data from all recipients is and remains difficult – particularly for the forthcoming t_1 survey.

The collected data was anonymized, recipients were given consecutive numbers. Fleet data is available for all but one of the lead-recipients, 05, a homeowners' association. It is responsible for the construction of the charging infrastructure at the respective parking lot. Vehicle fleet data of the tenants living there is (and will be) unknown to the association. 83 tenants recorded their interest in utilizing a charging infrastructure for their respective car leading to the amount of 83 cars as vehicle fleet size. To calculate the NO_x-emissions the average German fleet composition from 2022 from HBEFA is utilized.

Table1: Collected data from hand-picked recipients

Applicant-number	Funded Charging points	Charged Electricity (kWh)	Days of data acquisition of charged electricity	Vehicle fleet data	Mileage (sum in km)	Accessi-bility	Miscella-neous
01	62	86.866	761	28 cars (20 diesel, 8 petrol)	888.467	Private	Official vehicle fleet of a munici-pality
02	4	4.221	799	1 car (petrol)	10.000	Private	Tourist attraction
03	10	37.431	365	40 cars (39 petrol, 1 electric)	221.000	Semi-public	Nursing service
04	4	7.195	309	17 cars (17 petrol)	127.500	Private	Nursing service
05	83	21.630	100	83 cars (unknown)	1.137.100	Private	Home-owners' association
06	8	33.682	1075	2 cars (2 petrol)	40.000	Semi-public	Electric carsharing
07	24	8.370	365	36 cars (18 petrol, 18 diesel)	1.060.000	Semi-public	Car dealership
08	50	156.258	567	20 cars (20 electric)	253.000	Semi-public	Electric carsharing
09	18	38.051	1106	50 cars (16 petrol, 11 diesel, 15 PHEV, 8 electric)	847.000	Semi-public	11 different spatial locations

Deriving the NO_x-emissions based on collected data from hand-picked recipients is the next step and is shown in Table 2. The research design from Figure 2 is utilized for the respective calculation.
Lead-applicant 01 possesses huge potential for reducing the emissions if substituting their entire vehicle fleet. Since conducting the t_0 survey, electric cars must have been added to the vehicle fleet, because the accessibility of the charging infrastructure is private.
Lead-applicant 02 allows their employees to charge their private electric cars at the funded charging infrastructure leading to an already higher emission reduction than the emission of their vehicle fleet.
Lead-applicant 03 as a nursing service already owns many electric cars in their vehicle fleet, leading to already almost maximizing the potential reduction. The factor of permitted semi-public charging will be quantified with data from the t_1 survey.
Comparing lead-applicant 04 to lead-applicant 03, the number of electric cars in their vehicle fleet is lower.
Emission reduction from lead-applicant 05 (and homeowners' associations in general) is based extensively on assumptions of vehicle fleet data calculating results for research design 1). Deriving the current emission reduction based solely on the charged electricity seems to be well-suited for lead-recipients with unknown current vehicle fleet data and low probability of gathering better vehicle fleet data.
Lead-applicant 06 offers electric carsharing; vehicle fleet data and mileage for carsharing differs greatly over the course of time. Correct mileage data can include business secrets as well, leading to unknowns in deriving emission reduction. The factor of permitted semi-public charging is already huge but will be quantified even more with data from the t_1 survey – for all use-cases.
The biggest potential of emission reduction belongs to lead-applicant 07. As a commercial car dealership, enormous amounts of data from vehicle fleet data and mileage were collected. The number of electric cars in their respective vehicle fleet as well as the amount of semi-public charging from visitors or others is low.
It is known from the t_0 survey that lead-recipient 08 started the acquisition of cars for the carsharing after the installation of charging infrastructure. They are utilizing electric cars for the carsharing offer solely, thus leading to the value '0' in research design 1).
Lead-applicant 09 installed charging infrastructure at 11 different spatial locations and already possesses lots of PHEV and BEV cars in their vehicle fleet. The iterative substitute of their vehicle fleet is only a matter of time.

Table2: NO_x-emissions based on collected data from hand-picked recipients

Applicant-number	1) NO_x-emissions of lead-recipients vehicle fleet (kg)	2) Current NO_x-reduction based on lead-recipients' data (kg)
01	1.008,94	151
02	2,00	2,09
03	19,66	18,57
04	11,63	3,57
05	766,26	37,6
06	10,75	16,71
07	371,01	14,55
08	0	271,62
09	292,61	66,14
Sum	2.482,88	581,85

4 Discussion

First results underline the important task of standardizing the gathered data from all recipients following the t_1 survey. Most of the recipients participating in LINOx BW are unfamiliar with research projects leading to uncertainties when it comes to filling in the survey. Additionally, certain data in the respective applicant's organization is unavailable. The possibility for each applicant to be able to derive electricity data of their funded charging infrastructure could not be made mandatory due to funding guidelines. Conducting the final results of the project, standardizing and verifying the collected data and quantifying the number and the respective amount of side effects like the allowance for semi-public or employee charging will be key.

Final calculations for the emission reduction potential need data from the t_1-survey, in particular from the respective vehicle fleets. The substitution of ICV to BEV or PHEV differs from applicant to applicant and is also based on other effects like depreciation periods of currently utilized cars. Quantifying the reduction from recipients with private charging only will be rather simple.

In 2020, the German emissions of NO_x reached the total of 978.000 tons, with 390.300 tons belonging to the traffic sector [8]. The current gathered LINOx BW data adds up to 581,85 kg and is partly collected from several different years. For scientific comparison, potential emission reductions must be calculated on a yearly basis. Not all lead-partners had their charging infrastructure installed by 2020, thus a comparison is questionable. Overall, the presented results utilized data from 195 charging points (the whole project funds 2.358 charging points). Effects will increase with time, leading to the integration of more electric cars into vehicle fleets as well as more electric cars in general in Germany, thus leading to an increased usage from semi-public charging infrastructure.

The original task to quantify the reduction for nitrogen oxide measurement sites to prevent cities from adopting legal measures for their municipality is not possible for various reasons. Selective measurement sites on certain streets are utilized for statements for whole municipalities, while the specific driving patterns from electric cars are unknown. Added up results for the whole research project in comparison to overall German values seem to be a better way to quantify the success of the project. Nevertheless, the funding of 2.358 charging points in various real-life settings remains a success.

Acknowledgments

The authors thank the project partners of LINOx BW: the Association of Cities Baden-Württemberg (Städtetag Baden-Württemberg), the Verband Region Stuttgart, the State Agency for New Mobility Solutions and Automotive (e-mobil BW) and the Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW). Furthermore, we would like to thank everyone who participated in phone interviews and thus helped us to gain insight into their respective institutions.

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Presenter Biography

Karsten Hager is a managing director at Institut Stadt | Mobilität | Energie (ISME) GmbH, a planning office addressing research on and the implementation of sustainable mobility in various forms. He holds a Bachelor and Master of Science degree in Geography and Landscape System Science from the University of Tübingen. His current projects include the diffusion of electric mobility in small and medium municipalities, LINOx BW (funded by BMWK), sustainable logistics and unmanned aerial vehicles utilized for measurements of air pollutants.

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