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

A systematic multi-layer quantitative method for appropriate location of public charging infrastructure

Oscar Enerbäck[1], Jens Hagman, Jenny Lundahl

[1]*Oscar Enerbäck, RISE Research Institutes of Sweden, Lindholmspiren 3A, SE-417 56 Gothenburg, Sweden, oscar.enerback@ri.se*

Executive Summary

Limited access to charging infrastructure near apartment buildings could become a significant barrier for the adoption of electric vehicles. There is currently a lack of methods and knowledge for estimating where demand for public charging infrastructure will arise. Of particular interest is areas where public charging would constitute the principle means to charge. This paper is based on two projects that are investigating a method to geographically indicate where such demand is likely to occur in the future. In addition, the paper addresses challenges for increasing the installation rate of public charging infrastructure that are particularly present in smaller municipalities.

1. Introduction

Ambitious environmental goals are important drivers for the roll-out of electric vehicles (EVs). On a European level, the fleet-wide CO_2 emission regulations now require a 15% reduction from 2021 emission levels by 2025 and a 37.5% reduction by 2030. [1] As a result, every second car that rolls on Swedish roads by 2030 is estimated to be rechargeable. [2]

So far, sales and use of EVs have been concentrated to larger cities, often to high income households living in detached single-family houses. EVs are likely to become more affordable. Increased supply on the second-hand market and falling battery costs will make EV prices fall, further enhanced by affordable private leasing offers. Thus, a broader market is soon within reach for EVs, which includes lower income households living in multi-family houses and households living in rural communities.

Access to charging where the vehicle is parked most of the day, often near the owner's home, is often seen as a prerequisite for buying an EV [3]. Several government initiatives to increase access to charging have been launched, such as subsidies for charging installations and Right to Charge legislations. However, individuals living in apartment buildings still encounter many difficulties in getting access to sufficient charging infrastructure. Legal complexities, limited interest among housing associations and landlords and for those that relay on street parking, limited public charging infrastructure build-out are some examples. [4] The restricted access to charging infrastructure, if not soon addressed, could become a significant barrier to further adoption of EVs. [5] To be able to achieve the ambitious emission goals, charging solutions must be viable independently to the type of household. An important first step to improve access to charging is to understand where chargers ought to be built. This paper is based on two complementary projects that investigated future demand for public charging. In these projects the leading hypothesis have been that access to charging close to home is an important factor for buying and using an EV. The focus in both projects was/is to estimate future demand for public charging close to home, but the context differ. Project number one is based in Gothenburg, the second largest city in Sweden and the project exclusively focus on geographic plotting of future demand for public charging for 96 geographic areas. This project is still on-going and will be completed by 1st of September 2022. Project number two was completed during the fall of 2021 and was done in cooperation with a small municipality in central Sweden. The second project explored a broad selection of topics: future charging demand at the municipality level, the role of the municipality in building public charging infrastructure and ways to decrease public charging infrastructure cost was explored. Within the second project, other comparable municipalities were also investigated to learn from previous experiences.

Different methods for efficient rollout of charging infrastructure have previously been proposed in the literature. [6,7] These methods have inspired the method proposed in this report. Previous methods do however mainly focus on the rollout of charging infrastructure in larger cities and do not propose adaptations needed to also suit smaller municipalities. By smaller municipalities we mean municipalities that are less densely populated compared with major cities and thus not necessarily small in the sense of an area. Research has shown that an historic support for the expansion of charging infrastructure focused on cities has consolidated the view that EVs are city vehicles. The opinion is also due to the longer daily distances driven in the countryside [8]. The commitment of smaller municipalities to the expansion of charging infrastructure is therefore particularly important in rural areas both to reverse the view of EVs as city vehicles but also to contribute to reduced environmental impact from vehicles.

Elaborated on in this paper are proposals for how methods for a rollout of public charging infrastructure can be more effective. It also comprises aspects to consider to also suit smaller municipalities and thereby contribute to increase the EV adoption in a cost-effective and proactive way. It is especially valuable for those who for various reasons do not have the opportunity to use existing subsidies or Right to Charge type of legislation.

2. Aim

This paper intends to describe a method for estimating future demand of public charging situated close to vehicle buyers' homes. In addition, the paper will also explore various paths to analyse and interpret the results from the method. The results in this paper are to a large degree preliminary and the purpose of this paper is therefore largely to trigger discussion on possible ways for estimate, locate and subsequently build public charging infrastructure.

The paper intends to describe the basis for a strategy including a model useful for smaller municipalities to expand public charging infrastructure in a cost-effective and proactive way.

2.1. Limitations

Numerous limitations exist for the proposed method of geographically plotting future public charging demand. These limitations can be divided into lack of accurate data and possible important aspects not included in the method.

Regarding accurate data, one aspect is of particular interest. The assumption that apartment buildings built pre-1956 lack access to individual parking spots. It is possible and, in some case, likely that apartment buildings built pre-1956 have obtained parking areas for their residences.

There is also no data on how many of those who have their own parking space that live in an association with a board that opposes the expansion of charging infrastructure. This is not a concern where Right to charge is regulated.

The method does not comprise aspects of the need for fast charging. A separate strategy will be needed for commercial vehicles, such as taxis, and other vehicles that need day charging to sustain their daily driving distance or for those who need to charge quickly before, for example, an unforeseen longer journey.

Most important, the results in this paper are to a large degree preliminary as the results partly rely on an ongoing project.

3. Systematic multi-layer quantitative method

Heron described is what has been called a systematic multi-layer quantitative method to estimate the appropriate location and timing for buildout of public charging infrastructure, based on assessments of future public charging demand in defined geographical areas. The results can be used by public actors such as the state and municipalities but also to attract investments from various commercial actors such as charging point operators and vehicle manufactures. These actors have an expressed need to better understand where there is a willingness to pay among users and where an expansion is appropriate.

3.1. Method

The method used in project one and to a lesser degree in project two are inspired by the work done by Oslo municipality and WSP [6] and a similar methodology proposed for the city of Brussels [7]. The basic premise of the method developed in Oslo is that a significant need for future public charging infrastructure will arise for vehicle owners that currently do not have their own designated parking spot. Their study is based on the analysis of numerous data sources plotted into existing geographical areas for the municipality of Oslo. These variables include housing type, available public charging infrastructure and its usage and the number of passenger vehicles of different drivetrains. These variables also form the basis for the method in this paper, with some slight modifications and additions. Below is a description of the variables used in project one.

Geographical areas: Like Oslo this paper used an existing geographical division for the city of Gothenburg. There are a total of 96 primary areas in the city of Gothenburg, a primary area is an area consisting of approximately 5000 inhabitants. All subsequent variables were plotted into each of the 96 primary areas to enable a comparative analysis between the primary areas. See Figure 1 for an illustration of the 96 primary areas in Gothenburg municipality.

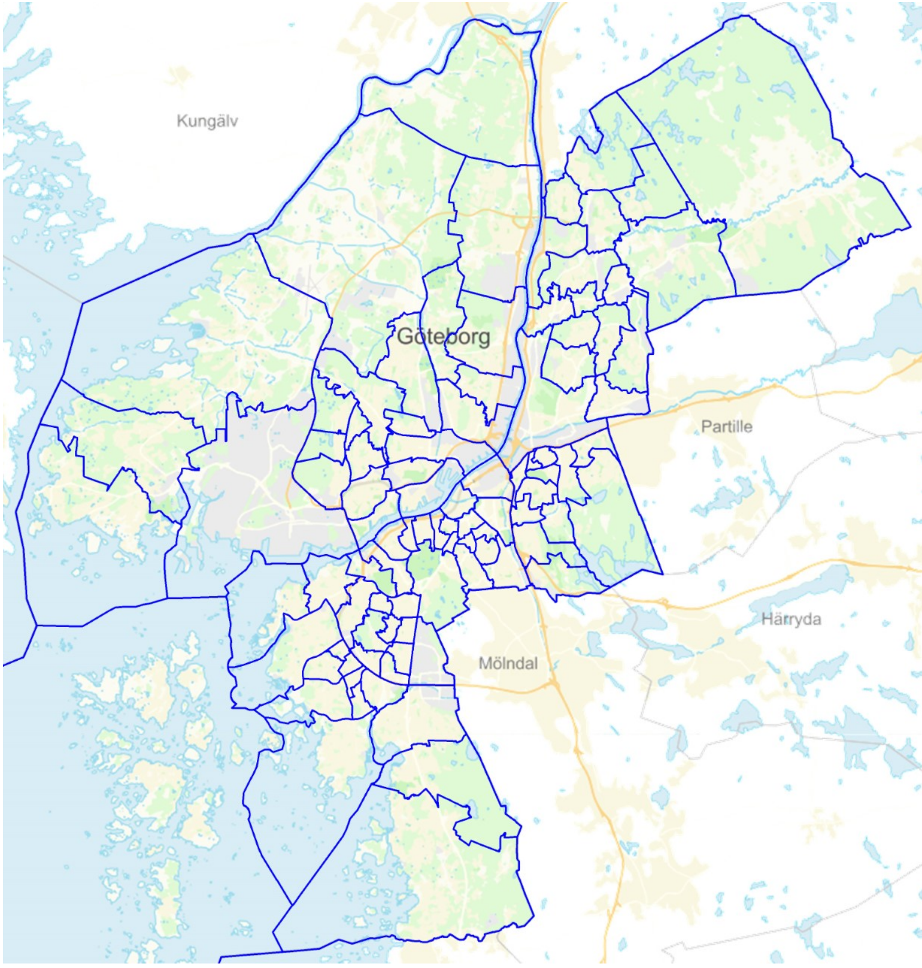

Figure 1 – Primary areas in Gothenburg Municipality

Housing type: Housing types were divided into apartments and detached houses. Apartments were separated into two groups according to year of construction: pre-1956 and post-1956. The year of 1956 was when national legislation first mandated that parking should be included for newly constructed apartment buildings. Apartment buildings built pre-1956 is thus assumed to not have designated parking space for its inhabitants. Data was extracted from Statistics Sweden and represent the housing stock for the year of 2021. The statistics database present year of construction in 10-year intervals. The most practical solutions to extract the two groups was deemed to divide the 1950-s interval in half.

Vehicle fleet (private): The composition of the vehicle fleet for each primary area was extracted from the Swedish Transport Board national vehicle registration database. Data that will be used in the analysis include fuel type (gasoline, diesel, plug-in hybrid (PHEV), and battery electric (BEV)) and vehicle age. One weakness with the data is that it does not include the address for the user of company owned vehicles.

Vehicle fleet (corporate): To address the lack of user location data for corporate vehicles in the dataset from the Swedish Transport Board, the project will obtain geographical data from company vehicles from a major vehicle OEM.

Permits for long-term street parking: Extracted from the city of Gothenburg and complemented with parking permits from the municipal parking company. Like the housing type variable can the number of permits for long-term street parking act as a proxy variable for the number of households/individuals that do not have access to a designated parking spot.

Total number of public parking spots: Obtained from the municipal parking company. Gives further proxy to the degree of street parking in an area.

Household income: Data obtained from Statistics Sweden. Will be used in the analysis to estimate purchase power and possibly the speed of transition to EVs in each primary area.

Public chargers (all): Number of public chargers in each primary area. Obtained from a national database of public charging infrastructure. The dataset includes number and type of charger but not the usage rate.

Public chargers (municipal parking company): Complementary dataset for the public chargers situated at land operated by the municipal parking company. This dataset also contains usage rate per charging station. Usage will be divided into day and night charging.

An individual as well as a comparative analysis for each primary area will be conducted in the project. Since the project is still in a data gathering phase, this analysis has not yet been completed. The analysis plan for project one is as follows.

First, compute the number of apartments that are built before 1956 in each primary area, and thus are likely to lack a designated parking spot. The total number of vehicles registered in the area is then divided by the total number of households in the same area. This will yield an average vehicle ownership per household. Average vehicle ownership per household will be multiplied with the number of households living in pre-1956 apartment buildings. This number could be argued to constitute and estimation of the maximum number of vehicles that in the future would need public charging. A complementary datapoint is the number of issued long-term parking permits in the area, which is likely the minimum number of vehicles that in the future will need public charging. These two estimates will provide insights into long-term demand for public charging which can be timestamped according to national goals to achieve fossil free transport. However, these estimates do not provide further insights on the timing and urgency of providing public charging infrastructure in the near to medium-term. To assess near and medium time urgency the project will use data about geographical locations of public chargers as well as usage rate of a subset of these public chargers. This charger data will be mapped against the existing and possible EV fleet in each primary area. The project will calculate public chargers per vehicle as well as estimating the chargers per vehicles relying on street parking in the primary area. These ratios will be combined with the usage rate of public chargers during evenings and nights in the analysis to enable an assessment of the urgency in installing new/additional public charging in each primary area.

4. Preliminary results

As stated earlier, this paper is to a large degree based on on-going work in project one. The results presented in this paper should therefore be considered as preliminary. Further iterations and knowledge creation is likely to occur during the duration of the project. This section presents some of these preliminary results from project one as well as several results from the completed project two.

4.1. Suitable areas for public chargers

With the many PHEVs in Sweden the idea behind placement of public chargers has previously been to increase the range and miles driven on electricity. Chargers have also been placed where there are many visitors to increased public awareness of the environmental initiatives taken by the municipality [8]. Chargers have therefore been placed near points of interest, such as train stations and shopping centers where visitors can top up the BEV battery or refill the PHEV battery to enable an emission free journey back home.

Even if points of interest are visited by many, it is argued that it is of little importance to the average car buyer's ability to buy an EV [9]. The premise of the proposed method is however, mainly to investigate the need for public charging close to homes.

Charging close to an individual’s place of residence is argued to be an important factor for purchasing an EV and thus could constitute and important enabler for further adoption of EVs [5]. Thus, the chargers are not aiming at serving those who have already bought an EV but instead focuses on those that would buy one if they had someplace to charge the vehicle on a daily- or at least weekly basis. Charging where the vehicle is parked most of the time has been considered crucial to buy and own an EV. This is probably especially difficult for those living in an apartment building built pre-1956, as previously mentioned, whom probably to a lesser extent can install a charging station and are therefore to a greater extent are dependent on public charging infrastructure.

The complete results of project one is expected to contain estimates of future public charging demand for each primary area. Demand can however be quantified in several different ways. The most likely results from project one is an indication of the number of vehicles and households that are likely to be dependent on public charging in the future. Number of vehicles can thereafter be used to estimate daily energy needs and suggestions for number and types of chargers. Further expected results include and assessment on which areas that ought to be of high vs low priority for further installations of public charging infrastructure, based on current vehicle fleet and access and utilization of current public charging infrastructure. An important consideration when interpreting the results is the possibilities of having multiple use cases for public charging infrastructure.

A charger that is built where it will be used every night or several times a week will likely not only be more economical but also beneficial from an environmental perspective. If it is possible to identify geographical areas and eventually parking areas that combine the use form residents parking during the night and visitors using the charger during the day, then that would be ideal. The environmental benefit is twofold, both the number of electric kilometres charged but also number of EVs that it enables. Chargers should also not be located more than 350-400 meters from where the user lives to be attractive [7].

The excavation work to connect to the electricity grid is commonly a major part of the total cost of installing a charger. Identifying sufficient available power in a nearby substation could sometimes also be expensive and time consuming. To reduce installation time and cost it can be possible to share an already existing power supply. Identifying businesses, close to the residents and preferably owned by the municipality, that has a large grid connection that is used only during the day could be a relevant task for the municipality. Such examples could be a school or sports facility where there also could be a parking lot that is not used during the night.

Building charging infrastructure in parking garages can be a strategy for moving cars out of crowded areas in cities. It can also be cost-effective to install charging infrastructure in existing parking garages as much of the excavation work can be avoided. In smaller cities, it is not certain that there are parking garages and congestion may not be such a big problem. Placing public charging infrastructure a bit outside the city center could be an alternative that adds similar benefits. For example, it may be closer to where the electricity infrastructure is located, less likely that the parking spaces are occupied, the attractive area in the city center can be used for other than long-term parked cars.

Preparing for charging infrastructure while constructing new buildings is also appropriate. With electrical conduits under the parking spaces and by preparing the substations for a high future power output, it is possible to quickly build out the charging infrastructure when needed.

This can also be done without any high upfront costs. Unfortunately, public chargers near new buildings does not add up to the present expansion rates needed. The municipal initiative and the requirements put on building companies for the expansion of charging infrastructure therefore preferably should exceed the minimum legal requirements.

4.2. Financing the cost for build-out – challenges and recommendations for small municipalities

To achieve a proactive and cost-effective expansion of charging infrastructure, that accelerates the transition to a sustainable vehicle fleet, it is especially important for smaller municipalities to have a strategy for the rollout. The cost of just installing chargers could be a hefty expense for a smaller municipality. There is also a risk that each charger built will gradually become more expensive as the cheapest installations are established first. It is therefore preferable if costs can be shared with private companies.

In [7], the operator is identified as the one to bear the costs. One risk is that the buildout will not go fast enough in less densely populated urban areas, as charging operators probably have more lucrative places in cities with a larger population of EVs. Smaller municipalities cannot rely on private companies taking the initiative for the buildout in the same way as in larger, more densely populated cities. New technologies are often focused where there is a high willingness to pay. For a comparison, other technological shifts, such as introduction of carpools and electric scooters, have historically started in larger cities. Municipalities with a smaller population and with a smaller proportion of EVs and thus fewer potential users probably need to increase the efforts to be at the forefront of attracting potential investors when or before the number of EVs increases. A municipality could for instance make it easier for private companies to establish charging infrastructure by preparing information about where there is an expected user demand, where there is a sufficient electricity connection and also suitable municipal land that could be used. It is also possible to imagine a situation where the costs are shared and that, for example, the excavation work is carried out by the municipality.

Another possibility to expand the infrastructure without significantly burdening the municipality's budget is to point out to businesses with visiting customers the value of establishing charging infrastructure. Businesses offering charging while shopping is already quite common at larger shopping malls, but the initiative could be spread to smaller businesses as well. It could serve a dual purpose as it would benefit the company's operations by attracting customers but would also contribute to a free expansion of chargers from the municipality's perspective.

Municipalities can also utilize municipality owned companies to speed up and expand the public charging offer. This could for instance mean to ensure that the municipal housing company is given directives and a mandate to investigate the possibility and cost for a buildout of charging infrastructure on the properties. Based on the information the housing company could provide residents with concrete offers on how, when and to what cost access to charging infrastructure can be obtained. The offer could also be used by others who do not live in the municipal housing company if the parking spaces have a low degree of utilization. In either case, it is important that the costs for subscription of the charging infrastructure end up with the tenant, or citizen who uses the parking space, in order not to overburden the municipality's finances. In this way, buildout could be based on demand and thereby reducing the risks of establishing charging infrastructure that is underutilized.

It is also important to stress that the cost for using the chargers should not be free, which previously has not been uncommon, or only corresponding to the electricity cost. It must also include installment for the installation as well as the expected costs for future strengthening of the electricity connection. In that way it does not suddenly become too expensive to offer additional people an opportunity to get access. Furthermore, establishing chargers on parking spots clustered together requires less excavation work than if they were spread out. Switching to a flexible parking scheme could therefore be considered as part of the contract when the chargers are established, even if flexible parking spaces generally are less appreciated than having a fixed parking spot.

4.3. Number of public chargers needed

The method described in the paper can also be used to estimate the number and approximate geographical location of new public charging infrastructure needed. There are several possible paths to translate these results into a quantifiably number of charging points. Below is an example based on an unnamed municipality in Sweden in 2021 investigated in project two.

Public data exists for the number of private vehicles registered in any specific area in Sweden. In a smaller municipality studied there were roughly 24 000 vehicles in total and of which around 200 were BEV and 350 were PHEV. In total 2,3% of the vehicles were either PHEV or BEV. The average for all of Sweden were 3,6 %. New registration of EVs was 17,2% in the municipality and 31% in total in Sweden.

According to [2], forecasts predict rechargeable cars in 2025 to represent 22% of the total fleet in Sweden and 50% in 2030. Assuming similar market shares as the national average and no change in the municipality total passenger vehicle fleet, the number of EVs in the municipality may be over 5,000 by 2025. In 2030, the corresponding figure is over 12 000 EVs.

Earlier EU recommendation was 10 EVs per public charger, which in this example would correspond to 1 200 public chargers. The reworked succeeding AFIR regulation instead suggests an installed peak power per EV. The implementation of the updated regulations will also be mandatory for the member countries. The requirement is now a 1 kW peak power installed per BEV and 0.66 kW peak power installed per PHEV [10].

If the 12 000 vehicles in 2030 consists of an equal number of BEV and PHEV would require approximately 10 000 kW to be installed (6 000 kW + 3 960 kW). Assuming furthermore that the average peak power of chargers is 11 kW means that around 900 public chargers should be installed in the municipality by 2030.

However, ICCT [11] suggests that the installed power should correspond to the size of the EV fleet. The proposal is that the installation pace should be higher initially and gradually ramped down when the share of EVs increases. With only 10-20 % of the entire vehicle fleet is EVs the demand should be 1,3 kW/BEV and correspondingly 0,66 kW/PHEV. At 30% of the fleet consisting of EVs the demand should be similar to the proposed AFIR at 1 kW/BEV and 0,55 kW/PHEV. Taking the proposal into account means that for 2025 the 5 000 vehicles, again assumed to contain an equal amount of PHEV and BEV, would require 4 900 kW (3 250 kW+1 650 kW) of installed peak power. That corresponds to 445 chargers with an average 11 kW each should be installed in the municipality by 2025.

It is also possible to read from the data if the vehicles belong to an address with apartments or smaller houses. In total there are 8838 apartments in the before mentioned municipality, consisting of a mix of rental apartments and condominiums. As previously mentioned, buildings built prior to 1956 have generally not arranged parking, e.g., through garage or parking spaces. 1,237 (14%) of the apartments were built prior to 1950 and an additional 1,407 apartments were built between 1951–1960 (16%). Up to roughly 22% (14+8%) of the total apartments may therefore lack access to their own parking spaces and thus lack the opportunity to install chargers for residents. For example, if vehicle ownership is 0,2 per apartment, there will be approximately 400 vehicles out of which 85 (22 % in the year of 2025) are EVs in the municipality that could need to rely on public charging infrastructure to sustain their driving needs. These 85 vehicles might be clustered in certain geographical areas with high concentration of pre-1956 apartment buildings, areas that thus need to be prioritized for installations of public charging infrastructure.

5. Discussion

There are similarities with larger and smaller municipalities – uncertainties in where and how fast the expansion of public charging infrastructure will take place. Below are a few aspects to consider when applying methods developed for larger cities to smaller municipalities:

In [7], it is assumed that wealthy areas are early adopters of EVs and thus need public charging first. One may question whether it is the wealthy areas that need an expanded public charging infrastructure or whether it is common to have access to a private parking space in these areas and therefore do not directly have a need for additional charging options. There is reason to consider whether investments should be targeted to other often overlooked areas or users. That could enable increased assurance among its residence that an EV could sustain their transportation needs. Similarities can be found in [6] in the argumentation that public charging infrastructure should be evenly distributed among districts to achieve the environmental goals and that the focus may therefore need to be where EVs do not exist today.

Speaking on the assumption of the increasing EV fleet, and thus the need for public charging infrastructure, will be greatest where the number of EVs today is small. This might be true in the capital city in the world's most developed EV country, with strong incentives to buy an EV. A policy context that creates opportunities for a large share of Norwegians to buy an EV already today. In smaller municipalities in other less developed EV countries, investments in charging infrastructure might need to be more focused, especially where there is a larger proportion who lack access to their own parking space. This may include those in rental apartments although they may have access to a parking space, although the landlord dictates whether charging should be provided or not.

Empirical data on how chargers are used could be very valuable and access to this could help stir interest among financiers of charging infrastructure. In Oslo, chargers with high utilization are indicated and the information is used as a marker of where there is an imminent need for grid reinforcement and additional installations of public chargers. However, this possibility does not exist in smaller municipalities, at least not at first, as there might be none or very few public chargers installed. The number of residential parking permits combined with the composition of apartments can be a better indicator for understanding the number of vehicles that could be dependent on public charging infrastructure.

6. Conclusion

With these preliminary results of a systematic multi-layer quantitative method, we intend to broaden the discussion on how the method for identifying appropriate locations for building public charging infrastructure can be refined. With similar methods in mind that exists in the literature, it is important to consider the unique context that exist in a particular city and to think about what aims that are important to achieve with the expansion. For example, increased electric miles driven and/or increasing the opportunity to buy an EV. This paper discusses how methods to estimate public charging demand can assist smaller municipalities in planning and establishing public charging infrastructure.

The proxy variables used to estimate household and vehicles that lack a designated parking spot, including the identification of multi-family houses build pre-1956 and parking permit holders is at this point in time likely the best means to estimate future demand and geographical concentration for public charging infrastructure close to individuals' homes. Although, it is likely that the method could be improved with more accurate data and additional variables to more accurately predict when and where public charging infrastructure is needed to assist the transition towards EVs for households relying on street parking.

The presented method and the results from its implementation could be used by city officials, developers and other stakeholders when planning the build-out of public charging infrastructure. It could be especially useful in smaller municipalities. The role of the municipality in the build-out could vary but it is likely that and improved understanding of where and when public charging infrastructure is needed could help in the investment decisions of various commercial actors such as charging point operators and vehicle manufactures.

References

[1] EU, *Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations* (EC) No 443/2009 and (EU) No 510/2011, OJ L 111, 25.4.2019, p. 13-53. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0631

[2] PowerCircle 2021, Available at: https://press.powercircle.org/posts/pressreleases/nu-over-200-000-laddbara-fordon, accessed on 2021-12-16.

[3] Bailey, Joseph, Amy Miele, and Jonn Axsen. (2015), *Is awareness of public charging associated with consumer interest in plug-in electric vehicle*s? Transportation Research Part D: Transport and Environment 36 1-9

[4] Energimyndigheten. *Regeringsuppdrag – bättre tillgång till laddinfrastruktur för hemmaladdning av laddfordon.* https://www.energimyndigheten.se/nyhetsarkiv/2021/ny-rapport-om-battre-tillgang-till-laddinfrastruktur-for-hemmaladdning-av-laddfordon/, accessed on 2021-12-16.

[5] Ge, Yanbo, et al. *There's No Place Like Home: (*2021), *Residential Parking, Electrical Access, and Implications for the Future of Electric Vehicle Charging Infrastructure*. No. NREL/TP-5400-81065. National Renewable Energy Lab. (NREL), Golden, CO (United States),

[6] Oslo Kommune, (2019), *Kartlegging ladebehov i Oslo kommune, Available at:* https://www.oslo.kommune.no/getfile.php/13354701-1576848117/Tjenester%20og%20tilbud/Gate%2C%20transport%20og%20parkering/Parkering/Kartlegging%20av%20ladebehov%20i%20Oslo%20kommune.pdf

[7] De Clerck Quentin, Vanhaverbeke Lieselot, (2021), *Possible models for the roll-out of a public charging infrastructure for electric vehicles in the Brussels-Capital Region*, Brussels Studies, General collection, no 162, *Available at*: http://journals.openedition.org/brussels/5809

[8] Olsson Linda, Eriksson Linnea, (2021) *Spridning av laddbara bilar och laddinfrastruktur på landet och i mindre orter*, RISE Report 2021:22 ISBN: 978-91-89385-06-1 Linköping, Available at https://www.diva-portal.org/smash/get/diva2:1531306/FULLTEXT01.pdf

[9] Skövde municipality (2019) *Plan för laddinfrastruktur*, KF 2019-04-29 §53 Available at: https://skovde.se/globalassets/forfattningssamling/01.-kommunfullmaktige/kommungemensamma-styrdokument/planer/plan-for-laddinfrastruktur-skovde-kommun-reviderad-2021.pdf

[10] European Commission. (2021) *Proposal for a regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive* 2014/94/EU of the European Parliament and of the Council.

[11] Rajon Bernard Marie, Nicholas Michael, Wappelhorst Sandra, and Hall Dale (2022) *A review of the AFIR proposal: how much power output is needed for public charging infrastructure in the European union?*. ICCT. Available at: https://theicct.org/wp-content/uploads/2022/03/europe-ldv-review-of-afir-proposal-how-much-power-output-needed-for-public-charging-infrastructure-in-the-eu-mar22-2.pdf

Presenter biography

Oscar Enerbäck is a senior researcher and has been working within the Electromobility unit at RISE since 2011. He holds a M.Sc. in Industrial Engineering and Management from Chalmers University of Technology in Gothenburg. His research focuses on reducing barriers for electric vehicle usage for fleet owners and private consumers. His primary research area includes system requirements and technical solutions for charging infrastructure for electric vehicles.

Jens Hagman has been working as a senior researcher within the Electromobility unit at RISE since 2021. He holds a Ph.d. in Machine Design from the Royal Institute of Technology, a M.Sc. in Economics from Jönköping International Business School and a M.Sc. in Entrepreneurship from Lund University. His research areas include charging infrastructure, consumer and fleet barriers and cost estimations for transitions to electric vehicles.

Jenny Lundahl is a senior researcher and legal expert at the Mobility in Transformation unit at RISE. She holds a Master of Law exam (Sw. jur. kand) from the University of Gothenburg. Before joining RISE she worked as a legal expert at the Government Offices and before that as an assessor (a deputy judge) at the Court of Appeal. Her research areas include the legal perspective on a connected and automated road transport system, and legal issues in the field of energy with regard to, for example, energy communities and charging infrastructure for electric vehicles.