

EVS27 Symposium
Barcelona, Spain, November 17-20, 2013

Data analysis on the public charge infrastructure in the city of Amsterdam

R. van den Hoed, MSc PhD, J.R. Helmus, MSc, R. de Vries, MSc¹, D. Bardok, BA²

¹University of Applied Science Amsterdam, Weesperzijde 190, 1097 DZ Amsterdam, r.de.vries3@hva.nl, www.hva.nl/cleantech

²City of Amsterdam, DIVV Nieuwevaart 5 – 9, 1018 AA Amsterdam
www.amsterdam.nl/parkeren-verkeer/amsterdam-elektrisch/amsterdam-electric/

Abstract

In recent years electric mobility has gained a great deal of attention, leading to electric vehicles on the market and development of necessary charging infrastructure. Charging infrastructure is mostly enabled through subsidies by local or national governments to overcome the chicken and egg problem, while the business case for charge stations in this early stage of development is not yet sufficient. The municipality of Amsterdam is a forerunner in the development of charge infrastructure, with over 500 public charge points available. The municipality and service providers struggle how to optimize the roll out of further charge points and how to optimize the use of the charge points. This paper gives a detailed analysis of the actual usage patterns of the public charging infrastructure in the city of Amsterdam, based on more than 109.000 charge sessions collected at the existing local charge points in 2012/2013. The conclusions from this analysis can be used to gain insight in the actual usage patterns of public charging infrastructure and may lead to recommendations concerning further roll out of charge stations, increasing effectiveness and improving the business case for charge points. The conclusions and recommendations may have implications for, and may support municipalities in the effective development of charging infrastructure.

Keywords: Electric Vehicle (EV), charge infrastructure, urban environment

1 Introduction

The Amsterdam region is one of the frontrunners worldwide in stimulating the use of electric vehicles [1] [2]. Urged by air quality problems the municipality of Amsterdam has had an active role in facilitating e-mobility within the region of Amsterdam. In recent years its policy has consisted of a combination of (amongst others) infrastructure development (e.g. subsidizing placement of hundreds of public charge stations), market measures (e.g. purchase subsidies and incentive systems such as priority in obtaining parking permits as free parking for electric vehicles) and demonstration and awareness programs. It has made the municipality of Amsterdam one of the frontrunners in electric mobility in Europe with more than 500 public charge points, more than 2000 electric vehicles

including around 300 electric “Smart For Two’s” using the charge stations, demonstration of innovative charging solutions (fast charging), and large vehicle demonstration programs for amongst others the Nissan Leaf as well as Car2Go [3, 4].

1.1 Public charge infrastructure database

In an assignment for the municipality of Amsterdam the University of Applied Sciences Amsterdam, conducted a study to analyse usage patterns of the current charging infrastructure over the years 2012/2013. The study entailed combining two databases provided by the utilities responsible for rolling out 1000 charge points by 2014. Part of the conditions set by the municipality to the utilities was to log a range of relevant parameters that may allow the municipality (but also third parties) to analyse the utilization of the charging

infrastructure and come to recommendations regarding its optimization. By early 2013 a database of approximately 109.000 charge sessions were logged, a unique dataset that allows to establish deeper insight in actual usage of charge points.

1.2 Literature on charge infrastructure for electric vehicles

A great deal of research has been carried out on the topic of charging infrastructure. However, limited research was found on real time user data of charging infrastructure in the scale as available in the dataset of Amsterdam. Mostly real time data is confined to European projects in which on limited scale (battery) electric vehicles have been demonstrated in a more or less controlled environment, e.g. in use by public transportation companies, or in small consumer demonstration projects. European projects such as CIVITAS [5] and ELCIDIS [6] have delivered a wealth of information regarding amongst others consumer behaviour, performance characteristics of electric vehicles tested, and charging characteristics. However, these projects were mostly limited to tens of electric vehicles and in which the vehicles and charging infrastructure was tested by selected end users (mostly public transportation companies). The demonstration projects are limited both in sheer numbers (amount of electric vehicles) as in terms of realistic nature (less controlled environment). No literature was found on data, on a scale like Amsterdam can provide.

More extensive is a dataset for charge stations available in the Netherlands [7], providing room for analysis of more than 2000 charge points in the Netherlands. The dataset available for the region of Amsterdam distinguishes itself in enabling to evaluate actual characteristics and load patterns of a more mature and representative charging infrastructure within a particular city region.

2 Characteristics of charge station dataset

2.1 Background for data logging

In the past years the municipality of Amsterdam has had a stimulating policy regarding the development of a charging infrastructure in the region in order to facilitate purchase and use of electric vehicles. A programme called “Amsterdam Electric” was set up by the

municipality in 2008 to set goals and implement policies to create an extensive charging infrastructure. The first ambition was to develop a public charging infrastructure of 1000 charge points by 2014. By April 2013 260 charge stations had been achieved, accumulating to 520 charge points (every charge station has 2 charge points or sockets).

The contract for development of the charging infrastructure was awarded to two consortia: Essent (infra provider) and Nuon/Heijmans (infra provider/engineering company responsible for installation). One of the contractual requirements set by the municipality for the infra providers was to monitor the actual utilization of the charge points by monitoring and logging information of the most relevant usage parameters of the charge points. With the growing infrastructure this has accumulated to a dataset of more than 135.000 charge session measurements (including data logs of a range of different parameters per charge session) over the course of one year (April 2012 to April 2013). This provides a unique dataset for establishing utilization and optimization of electric charge points in a municipality on a more representative scale.

Until recently the datasets of both infra providers were only used to evaluate progress in *charged energy* and the *amount of charge sessions* each month. Recently the “University of Applied Sciences Amsterdam” was asked to combine the two datasets and analyse which other parameters could be used to show the progress of the public charging infrastructure in Amsterdam, for instance development in connection time, charging time and provided electricity per time unit. Given that both datasets had different formats, a protocol was created together with the two infrastructure providers. The data is now delivered in a uniform way so analysis can be done in one combined database to see the progress over the entire city of Amsterdam. For the purpose of this study a database programme was used (MS Access).

2.2 Parameters in the dataset

Table 1 provides an overview of the most relevant parameters that are logged for each charging session by the infra providers and are collected in the database. As can be seen per charging session the address, operator, time details (data, start and connection time), amount of electricity and charging card/RFID used by the EV-user (radio frequency identifier) is available.

The parameter ‘*Address information*’ of charge points provides the opportunity to evaluate

differences in charging behaviour among districts. Analysis could lead to optimization of the charging infrastructure by providing recommendations where to extend, retain or reduce the existing infrastructure.

'Details of time' provide opportunities to analyse charging congestion in time slots (relevant for energy companies), but also determine periods of low utilization of charging infrastructure (relevant for municipality). Both actual charging time as well as connection time can be distinguished; 'connection time' relating to the amount of hours a car was plugged in the charge point, and 'charge time' relating to the actual amount of hours that charging of the electric vehicle took place. These parameters provide the opportunity to evaluate the efficiency of use of individual charge points, which is operationalized in the variables 'capacity utilization' and 'charge utilization'. With this knowledge, the municipality can decide if measures need to be taken to increase the efficiency of the network. An example of such measures could be; increase the price of parking when a vehicle is fully charged but still connected.

'Capacity utilization' is defined as the time a charging pole is occupied by an electric car, divided by the total time the charge point was available (e.g. per day or per day). In our analysis capacity utilization was calculated per month, so as to establish which percentage of time the charge point was actually occupied. This parameter provides an indication of the effectiveness of the charging infrastructure and individual charge points. Waiting times for other vehicles can be simulated when knowing expected arrival times. Because charge stations consist of two charge points, and given that these charge points could not be accurately separated in the database, the capacity utilization can theoretically be 200%, when two electric vehicles are connected at all time.

'Charge utilization' is defined as the time an electric vehicle is actually charging, divided by the time the car is connected. This can be used to measure effectiveness of the charging infrastructure. In case the connection time is very high compared to the actual charging time, measures could be considered to let the user move the vehicle.

'Amount of electricity' charged is helpful for both energy companies (evaluating the business case) as well as the municipality (make estimations on the amount of emission free

kilometres enabled by the charging infrastructure, and thus making estimations on the contribution to air quality). Lastly, user information (with **'RFID'**) could in theory provide information on typical trajectories made by users; RFIDs of Car2Go cars are available so that these can be linked to the type of car (Smart). Other RFIDs can not be linked to vehicle types.

Table 1: Parameters

Parameter	Example	Explanation
Charge point address	Admiralengracht 44	Address of the charge point
Charge point operator	Nuon	Owner of the charge point
Charging service provider	Essent	Owner of the used charging card
Charge point city	Amsterdam	
Charge point postal code	1057EW	ZIP code of the area of the charge point
Volume	0,86	Charged energy [kWh]
Connection time	0:14:23	Time the car was connected
Start Date	18-04-2012	Date the session started
End Date	18-04-2012	Date the session ended
Start Time	23:20:55	Time the session started
End Time	23:35:18	Time the session ended
Charging time	0:14:23	Time the car is actually charging
RFID	60DF4D78	RFID code of a charging card

2.3 Data cleansing before use

The raw data consist of around 135.000 records of charge sessions for the period April 2012 to April 2013. In order to filter possible invalid records, the database was evaluated using a number of search algorithms. Several errors in the database were identified and filtered, so as to build a reliable set of data ready for data analysis. Errors include records that have 'empty fields' (without value 'null') for instance related to the variable of "RFID" or "Address", and as such can not be traced to a vehicle or address. Records with 'null'-value were removed. Also 'double records' (e.g.

records with the same RFID and starting time) were identified and filtered. One record in which the 'end time' was earlier than 'start time' appeared to be related to summer/winter time settings; and was maintained. A particular error in the raw data related to instances in which the duration of a charge session was very short (1 to 5 minutes), and was shortly followed by a renewed change session with the same RFID and on the same address (again for a short period of time); in some cases this occurred more than 10 times in a row. Using an algorithm that identifies short adjacent records with the same RFID on the same location, a range of records that likely relate to only one actual charge session were joint together to form one charge session. After filtering out above errors, the database consisted of 109.000 records. The algorithms used to filter errors from the raw data are now used standard for more recent records, thereby increasing the quality of the database. Based on the algorithms and tests carried out the most crucial errors were filtered, allowing more detailed data analysis. In discussion with the infra providers (also responsible for providing the raw data) possible origins of errors will be discussed in order to identify improvements in measuring.

2.4 Starting points and assumptions of this analysis

In the analysis this paper presents real-time charging behaviour in the region Amsterdam. In some cases the analysis will focus more on charging behaviour in the *four main districts* in Amsterdam (East, West, Centre, South) where the charge infrastructure is particularly well developed. The database also consists of measurements in three other districts with a (very) limited charge infrastructure. Combining the results of all districts gives a complete picture of the region, however also provides a mixed picture. In this paper it was chosen to focus on the four districts with an extensive infrastructure in order to evaluate the charging behaviour of a municipality in which a well-functioning charge network is present. And thus also to be able to get a clear view on possible synergy effects in which unique users use different charge stations. This analysis focuses on *public* charge stations; and thus not on private or semi-public charge stations (e.g. car parking centres such as Q-Park). Due to an attractive subsidy scheme, several thousands of private charge stations have been installed, a reasonable percentage of which will

have been installed in the region of Amsterdam (likely several hundreds). These charge points are not included in the database (as they are exploited by third parties).

Several contextual factors for the region of Amsterdam are worth mentioning, as they may explain particular results of this case study. For one, the municipality of Amsterdam has a strong subsidy scheme in place, as well as supporting policies to stimulate the purchase of electric vehicles (e.g. priority in getting scarce parking permits). Secondly, locations for new charge points are largely selected based on individual demands from electric vehicle owners: inhabitants of Amsterdam who buy an electric vehicle with a range of over 45 kilometres on a single charge can apply for a public charge station near their home. With this policy the municipality hopes to reduce the chicken-egg dilemma for potential buyers of electric vehicles and in parallel expect that this demand-driven-placement improves the effectiveness of the charge infrastructure compared to municipalities that place charge points at random.

Also typical for the case of Amsterdam is the availability of a car sharing system called Car2Go: a car sharing scheme with electric Smart cars developed by Daimler and exploited under the Car2Go brand. In total 282 electric Smarts are currently operational in the region of Amsterdam; with a gradual increase between April 2012 and April 2013 (230 to 282). In early 2013 the program had over 11.000 registered users, that were able to use any of these electric Smart cars that are available at any preferred time. The Car2Go data can be filtered in the database and analysed separately from the rest of the data.

Lastly the actual use of a charge infrastructure also depends heavily on the availability of electric vehicles in the region. Apart from the 282 Car2Go vehicles, subsidy schemes for electric vehicles have been favourable in the Netherlands and in the municipality of Amsterdam in particular. In the database unique users can be identified; over the period of April 2012 to April 2013 more than 2000 unique (semi)electric vehicles have used the public charge infrastructure in the region of Amsterdam.

3 Results

The logged data of the public charge points charts are plotted to get insight in the real-time usage patterns of the current infrastructure, as well as evaluate the efficiency of public charge points. In

this chapter the trends in the actual (amount of sessions, energy charged) usage of the charge infrastructure are presented, taking into account the growth of the infrastructure throughout the period of analysis. Also figures will be presented that give an indication of the efficiency of the charge infrastructure (amongst others capacity utilization). Lastly usage patterns of the Car2Go vehicles will be presented, in order to evaluate the effect of an electric car sharing scheme on the use of charge infrastructure.

3.1 Application data of the charge infrastructure

3.1.1 Amount of charge sessions

Between April 2012 and April 2013 the *number of charge stations* in the municipality of Amsterdam has more than doubled, from 121 to 260 charge stations in total (or 520 charge points) (see figure 1). Given the policy objective to have 1000 charge points operational by end of 2014 the growth of infrastructure is well underway. The amount of *charge sessions* per month within the focus period more than doubled from 6327 (April 2012) to 13774 (April 2013) over the region of Amsterdam; an increase of 117%. This translates to a growth of approximately 210 to 450 charge sessions per day carried out within the region. Per charge station an average of 1,62 charge sessions were carried out on a daily basis. This figure has remained more or less stable over the course of this period, varying between 1,4 and 1,8 sessions per charge station per day.

Figure 1 and 2 show the growth in amount of charge points and charge sessions in the focus period. Indicative for the dominance of the *four main districts* in Amsterdam (Central, South, East, West), is that 83% of all charge stations are located in these districts, while more than 91% of all charge sessions took place at charge stations in these districts. The share of charge points in the other 3 districts is slowly increasing (from 10% to 17% over the course of the focus year). All in all the amount of charge stations and charge sessions show significant growth.

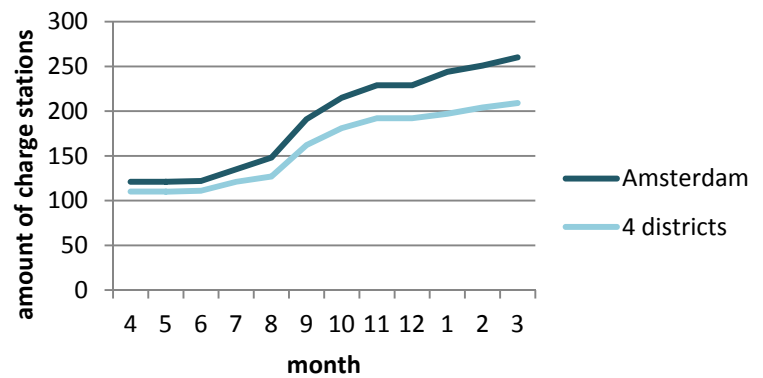


Figure 1: Number of charge points in Amsterdam and four districts

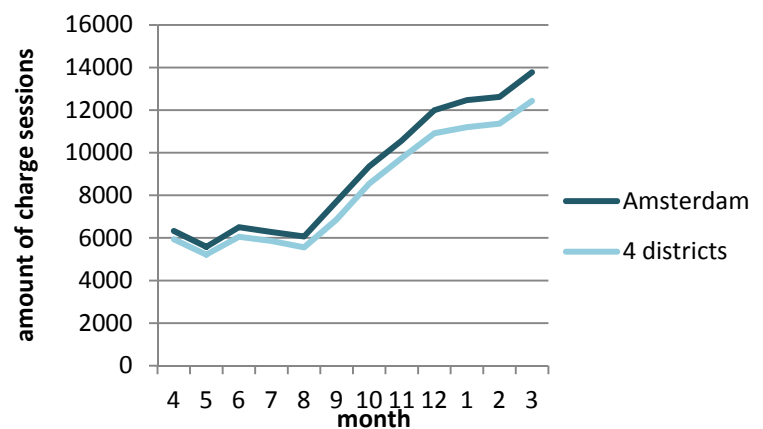


Figure 2: Number of charge sessions in Amsterdam (blue) and four districts (red)

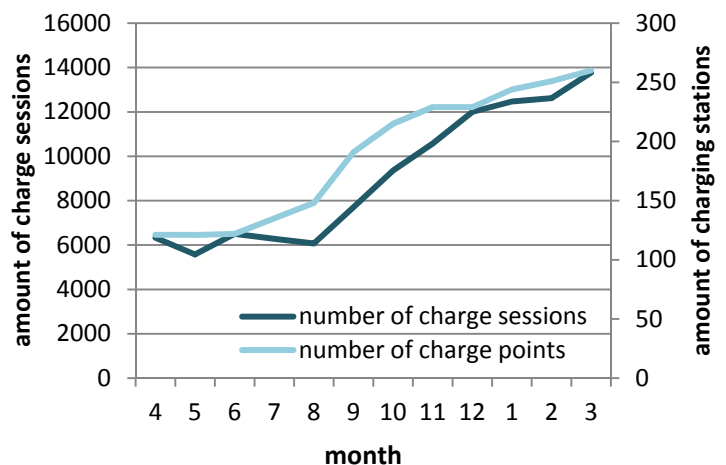


Figure 3: Number of charge sessions and change stations

3.1.2 Amount of unique users

The database shows more than 2100 unique users (RFID), of which close to 300 are Car2Go cars. In other words, more than 2100 (plug-in) electric vehicles have been using the public infrastructure in Amsterdam throughout April 2012 and April 2013. These include both inhabitants of Amsterdam as well as 'guest users' (from outside of Amsterdam). An analysis of users (frequency of charging, charge patterns, variance in charge stations used) will be carried out and presented in the future.

3.1.3 Amount of charged energy

The total amount of charged energy in this one-year period accumulated to 894 MWh. The amount of energy charged per month nearly doubled from 55 MWh (April 2012) tot 109 MWh in March 2013 (see figure 4). Particular growth was made after the summer months, starting from September 2012. This can partly be explained by a significant growth in Car2Go users. Assuming an average 'consumption' of electric vehicles of 5,5 km/kWh, 894 MWh represents over 4,9 million kilometres driven electric and without thus emissions by electric vehicles.

On average 8,31 kWh was charged per charge session, thereby enabling 45 emission-free kilometres to be driven per charge session, or replacing 45 kilometres of a (polluting) combustion engine cars. Figure 4 shows a slight decrease in the amount of energy charged per charge session throughout the year, from around 9kWh per session early 2012 to 8kWh and less in 2013. This may be explained by a number of factors. Weather conditions may influence charging demand both in a positive way (in hot weather air conditioning is likely to increase energy demand) as well as negative (higher efficiency of batteries occurring at higher temperatures). Also holiday periods will likely influence driving patterns and energy demand. Similarly the portfolio of electric vehicles on the market shifts continuously, which given differences in energy demand (kWh/km) will likely lead to a shift in average energy demand. Another impacting factor is the share of Car2Go vehicles used in Amsterdam, vehicles that tend to make shorter trips and thus require less energy; thereby reducing the average energy demand per vehicle.

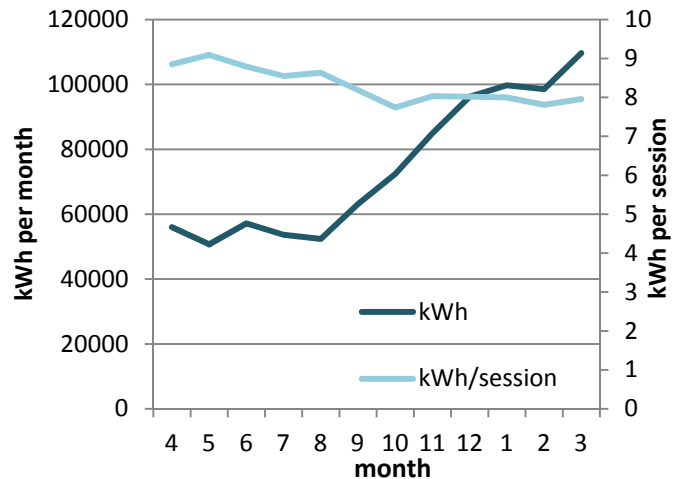


Figure 4: Charged energy and average charged energy per session

Seasonal effects and other contextual factors explaining trends in charge patterns will be considered in future research.

3.2 Capacity utilization and Charge utilization

A relevant question is the degree to which charge stations are used in practice, both for policy makers (effectiveness of policy measures) and exploiters of charge stations (determination of business case). For this purpose the *capacity utilization* for charge stations was calculated, defined as: *the amount of time an electric vehicle is connected to a charge station divided by the total available time per month*. Capacity utilization therefore provides an indicator for effectiveness of the charge infrastructure: a high percentage suggests that a relatively large portion of the time charge stations are 'used'. Note that 'used' in this definition means 'connected' and not necessarily relates to actual 'charging' of the car (see next section). Capacity utilization is a relevant indicator to consider as it also marks the degree to which charge points are accessible for other electric vehicles to charge their electric vehicle: a high percentage suggests that EV-owners will have a harder time finding free charge points. For policy makers a high capacity utilization degree is an indicator whether a certain neighbourhood may require new charge points. Capacity utilization was measured for each charge station. A capacity utilization of 100% implies that a particular charge point was continually connected to an electric vehicle (whether it was charging or not).

Figure 5 shows the results of the capacity utilization of the charge infrastructure, measured per month for each of the *four main districts* in Amsterdam. The average capacity utilization degree for these districts was around 39% over the course of one year. This implies that on average more than one third of the total available time electric vehicles were connected to available charge stations in these districts.

Significant differences can be seen between district Zuid ('South') with an average capacity utilization of 51% and district Oost ('East') (average capacity utilization of 28%). A capacity utilization for a certain neighbourhood of 50% implies that the charge points in this neighbourhood were occupied by electric vehicles for exactly half of the total time available that month (e.g. 15 days fulltime).

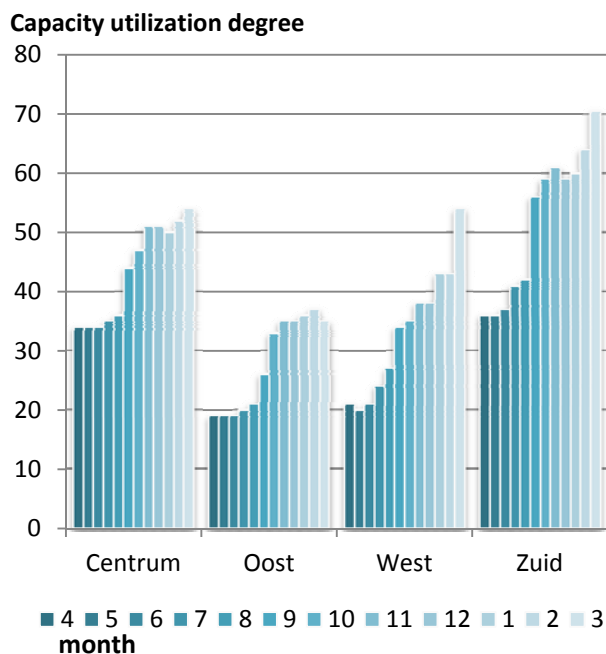


Figure 5: Average capacity utilization degree of four districts per month (4=April 2012, 3=March 2013)

The graphs show steady increase in the capacity utilization in all four districts, growing between 50% to 75% over the course of the focus year. Several factors may contribute to this growth, for instance the growth in popularity of Car2Go, a growing amount of electric vehicles in the region (compared to the amount of charge points) or familiarity of EV-owners with new charge points. For instance, it requires learning for EV-owners to know where new charge points are located, particularly given the large amount of new charge locations added in recent years. This learning process is likely to cause a ramp-up

pattern of capacity utilization for any new charge station. Details in capacity utilization will be studied more in-depth in the near future.

It may be concluded that the capacity utilization for the charge infrastructure in Amsterdam is moderate to high. More than half of the charge points are occupied at least one third of the time; in certain districts a capacity utilization is reached of close to 60% on average. Particularly these districts are likely candidates for extending the current charge infrastructure, so that EV-owners in these districts can profit from more available charge stations. A possible explanation for relative high levels of capacity utilization may lie in the demand-driven policy for placing charge stations. Also the availability of an extensive car sharing scheme will likely have increased the utilization of the charge infrastructure. Comparisons with other cities with respect to capacity utilization will enable further analysis of factors that may increase or decrease capacity utilization, and will be carried out in the near future.

3.3 Connection time vs. Charging time

The connection time per session of electric vehicles (used to calculate capacity utilization) will be higher than the actual charging time per session. The question is which percentage of the connection time is used for actual charging; which is an important indicator of effectiveness of the charge infrastructure. The database provides limited measurements for actual charging time for electric vehicles per session. Charging times were not logged in 2012, and for 2013 only charging data were available for February and March, from one infra provider only. More detailed data will be provided by the infra providers in the future; until now these data will have to be handled with care, given its limitations.

Figure 6 shows the average charging time measurements for the available months in 2013 in comparison to the connection time of the electric vehicles. Based on the database it was found that the average *connection time* of electric vehicles per session is 7:25hours (this includes all districts). Average connection times varies per month, between just under 7 hours a day up to 8 hours a day. Currently no upward or downward trend can be observed for the connection time.

The average *charging time* per session was just over 1 hour, with 1:03hours charged in January 2013 and 0:59hours in February 2013. And thus only 12 to 18% of the average connection time was

actually used for actual charging. Compared to the available hours per day, only 4 to 5% of the time is used for charging. In other words, charge points theoretically have the capacity to be able to provide a factor of 20 more electricity than currently provided.

These figures point to limitations in the effectiveness of charging infrastructure: only a small portion of the connected time is actually used to fulfil the basic function: charging electric vehicles. Given the forecasted growth of electric vehicles in the market, and the high costs of developing charge infrastructure, increasing the charging time per day or per charge station forms an attractive option for policy makers to optimize the current and future infrastructure. Possible solutions may lie in providing services that move electric vehicles once fully charged or incentivize EV-owners to move their cars once fully loaded. Based on this research it is recommended to further investigate opportunities to optimize the actual charging capacity of current infrastructure.

Connection time vs. Charge time

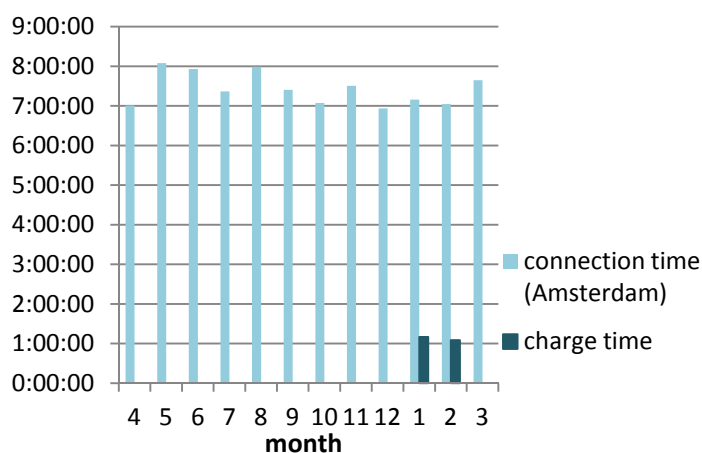


Figure 6: Connection time versus charging time (4=April 2012, 3=March 2013)

3.4 Car2go

A last analysis is spent on the influence of Car2Go on the data collected in the database for the case of electric driving in Amsterdam. At the time Car2Go was presented in the municipality it was hypothesized that the electric Smart cars could increase the use of the charge infrastructure in the municipality. The data collected in the database allowed to differentiate between Car2Go users and 'regular' users of the charge infrastructure, based on RFID data. Some interesting observations were made.

First of all, Car2Go was responsible for 66% of all charge sessions in the period April 2012-April

2013. In total more than 72.000 charge sessions were made by Car2Go users. Divided by the 282 cars available in Amsterdam, every Car2Go vehicle was charged more than 258 times over the whole year. In comparison, the other 2000 unique users of the public charge infrastructure were responsible for the remaining 37.000 charge sessions; translating to 18-20 charge sessions per year; a factor 12-14 lower than Car2Go. Partly this can be explained by charging sessions by guest users; but it also provides evidence of the large contribution of this car sharing scheme to the efficient use of the available charge infrastructure.

The data also show that Car2Go charge sessions are shorter in length than 'regular' charge sessions: 5:50 hours for Car2Go vehicles versus 10:22 hours for regular vehicles. Furthermore, Car2Go vehicles drive all over the city (rather than sticking to more dedicated routes of EV owners). On average Car2Go cars were charged at 77 different locations throughout the year. In comparison other electric cars (non Car2Go) charge on only four different charging locations over the course of one year.

The data provides some evidence that a car sharing concept like Car2Go can provide a significant boost in the use of public charging infrastructure. Because of the large share in the data and the effect in evaluating the use patterns of public charging infrastructure, Car2Go data need to be filtered out to generalize the data and compare with other cities where an electric car sharing scheme is lacking.

4 Reflection of results

The EV-database provides a rich dataset that enables analyzing the use and effectiveness of a relatively mature public charging infrastructure for electric vehicles. The fast growing amount of charge stations in Amsterdam has spurred the actual use of this charge infrastructure, both in terms of amount of sessions as well as in the total amount of energy charged.

The data provide some evidence that the facilitating role of the municipality in developing public charging infrastructure is successful for stimulating electric mobility and enables zero emission kilometres driven. Particularly the demand-driven policy on designating new charge station locations seems effective achieving a relatively high average capacity utilization of the infrastructure.

Despite these positive signs the data also shows some concerns. The long connection times of electric vehicles compared to the relatively short

charge times point to the difficulty of using the charge stations in the most effective way. It may provide opportunities for incentives for users, for moving their car once fully loaded, or for more flexible charge systems, or for stimulating additional services (e.g. moving services of charged cars) to optimize the use of the current and future charge points.

Charge infrastructure and electric vehicles relate to the classic chicken and egg dilemma. The database provides a valuable dataset for evaluating the interplay between the use of charge infrastructure (chicken) and electric vehicles (egg). One may argue that developing a charge infrastructure (as was done by the municipality of Amsterdam) may overcome the first hurdles for electric vehicles. During this period one then would expect gradually increasing levels of capacity utilization, charge utilization and amount of energy charged – as indications that the chicken and egg problem is slowly disappearing. This is one of the reasons for the University of Applied Sciences and the Municipality of Amsterdam to continue carrying out analysis and investigate trends in the database.

Similarly trends in the influence of Car2Go users will have to be evaluated. Car2Go proves to have major influence on the public charging network in Amsterdam. Further analysis should be done regarding behavioural differences between drivers and detailed drive patterns, in order to establish the impact of Car2Go on the effectiveness of the charge infrastructure and ways how this can be improved.

Care should be taken to generalizing the results of this study to other cities; contextual factors (demand driven policy regarding charge points, air quality problems in the municipality) and market factors (amount of electric vehicles on the market, Car2Go availability) play an important role in the success of the current growth in infrastructure and its use by EV-drivers. Comparing the results of this study to other cities would increase the value of this analysis and may lead to results that can also be generalized towards other cities and municipalities with an interest to stimulate electric mobility.

5 Conclusions

Facilitating the development of a public charging infrastructure by the municipality of Amsterdam has had a positive effect on the use the charging infrastructure. In one year the amount of charge stations, amount of charge sessions and amount

of energy charged in electric vehicles has nearly doubled. In one year nearly 5 million zero emission kilometres were enabled by the charge infrastructure. The case of Amsterdam thereby provides some evidence that a facilitating role in developing public charge infrastructure using a demand-driven placement policy in combination with stimulating policy measures can play a positive role in stimulating electric mobility in a city context. The available database points to the major contribution of the Car2Go car sharing scheme in the total amount of charge sessions, and suggest that car sharing schemes may play an important complimentary role in increasing effectiveness of charge infrastructure. The data provide opportunities for policy makers to plan further extensions to the current charge infrastructure based on capacity utilization. Meanwhile the data point to the current low level of actual charge times per day, leading to the recommendation to further investigate incentives and design opportunities to increase the effectiveness of charge stations.

Acknowledgements

This paper builds on the results of two student projects at the University of Applied Sciences, carried out by Bram van der Kraan, BE and Yassine Karimi, BE in assignment of the Municipality of Amsterdam.

References

- [1] *Amsterdam Elektrisch*, <http://www.amsterdam.nl/parkeren-verkeer/amsterdam-elektrisch>, accessed on 10 november 2012,
- [2] *WEVA*, <http://wevaonline.net/>, accessed on 23-20-2012
- [3] *Better Place*, <http://www.betterplace.com/the-company/press-room/Better-Place-Consortium-Delivers-EU-Showcase-in-Amsterdam>, accessed on 30-10-2012
- [4] Car2Go. (2013, Mei) Car2Go. [Online]. <https://www.car2go.com/nl/amsterdam/#pid=45991>, accessed on 30-10-2012
- [5] <http://www.civitas-initiative.org/>, accessed 25-09-2013
- [6] <http://www.elcidis.org>, accessed on 25-09-2013
- [7] Stichting E-Laad. (2012, December) www.e-laad.nl. [Online]. <http://www.e-laad.nl/submenunieuws/375-statistieken-stichting-e-laad-laten-sterkte-groei-elektrisch-laden-op-saat-zien> accessed 25-09-2013, accessed 30-10-2012

Authors

Robert van den Hoed is lector Energy and Innovation at the University of Applied Science Amsterdam (starting in 2011), and as such is one of the coordinators of the CleanTech research program. After his graduation at the faculty of Industrial Design Engineering at the Delft University of Technology he carried out his PhD studying how established industries react to radical technologies, with a case on hydrogen and fuel cells in the automotive industry. After finishing his PhD he worked at Ecofys for 7 years, a large consultancy agency in the field of sustainable energy.



Jurjen Helmus studied Technical Business Administration at the University of Groningen (RUG) and is specialized in the field of Innovation Management. He also completed the University of Groningen in the study Industrial Engineering with specialization in Chemical Engineering. He has worked at the University of Applied Science Amsterdam (HVA) in the Technology Management program as coordinator of the specialization Innovation Management and Business Development. Besides working at the HvA he is engaged in entrepreneurship at the intersection of Technology, Innovation and Design.



Rutger de Vries is a researcher focusing on electric mobility at the research program CleanTech. Since his graduation on electric vehicle infrastructure at the faculty Industrial Design Engineering at the TU Delft, he is specialized in electric mobility. Besides his research on electric mobility in the metropolitan area of Amsterdam, he teaches design methods at the faculty of Engineering, Design & Innovation at the University of Applied Science Amsterdam.



Doede Bardok studied Architectural history at the VU in Amsterdam. He is project manager at the municipality of Amsterdam at the division Infrastructure, traffic and transport. He is involved in the implementation of the charge infrastructure in Amsterdam since the beginning. He is working on the public infrastructure since 2009, at the municipality of Amsterdam.

