EVS30 Symposium
Stuttgart, Germany, October 9 - 11, 2017

The influence of investment expenditures on the development of fast charging infrastructure

Denis Horn[1], Axel Bauer[2], Alexander Schmidt[3], Olga Udovenko[4]

[1]*University of Stuttgart, IAT, Nobelstr. 12, 70569 Stuttgart, denis.horn@iat.uni-stuttgart.de*

[2]*University of Stuttgart, IAT*

[3,4]*Fraunhofer Institute for Industrial Engineering IAO*

Summary

To get the market of electromobility up and running, increased efforts are made to establish fast-charging stations all over Germany. It is well-known that high-performance charging infrastructure is expensive and the biggest part of its price belongs to the investment expenditure. The present paper illustrates a cost analysis of fast-charging infrastructure and its implication on strategic investment decisions. Data is collected from locations that have been built via the Project SLAM. Based on the obtained results, a critical assessment on the nationwide expansion will be provided.

1 Motivation

The absence of a nationwide charging network is in addition to the high purchase price and the low range of electric vehicles one of the most frequently cited barriers for the breakthrough of electric mobility [1]. In principle, any private company in Germany, regardless of size or sector, is allowed to build charging infrastructure. Fast-charging points are particularly needed at locations between starting- and destination points, namely at motorway axes and federal highways near those axes [2]. Since fast-charging stations are usually used for intermediate charging between trip ends, it is necessary to keep the charging time at about 20 minutes [3]. However, fast-charging infrastructure which meets this requirement is generally expensive. The biggest part of the total cost of operating fast-charging infrastructure belongs to the initial investment. Therefore those costs should be analysed because for example the cost variations depending on locations could influence investment decisions.

2 Approach

In this paper investment expenditures, from now on referred to as capital expenditures, for the establishment of fast-charging infrastructure are examined for 15 locations on German motorway axes to define their impact on amortization and thereby on competitiveness as well as the overall expansion of a fast-charging network. The analysis is based on insights from the research project SLAM (Schnellladen an Achsen und Metropolen) [4].

2.1 Project SLAM

The project SLAM was initialised to face the challenges which electromobility, especially the subject of fast-charging of electric vehicles, originates. A bottom-up approach is applied for systematic research: a nationwide fast-charging network is established with the help of private investors; in the course of the project, insights are feedbacked to the investors and therefore effects can be closely monitored.

To gain financial subsidies, investors had to apply with outright information about their plan of building-up fast-charging infrastructure in Germany. After evaluating the investors' propositions, more precisely, the information about location, building setup, cost estimation and a planned business model, the selection committee decides on the applications. Finally, 12 investors out of more than 100 interested parties, obtained the approval to built-up fast-charging infrastructure within the SLAM-network.

2.2 Database

Since DC-fast-charging stations are to build in axes, 15 locations at off-motorway service areas, which were built-up by one investor, are selected as a database. These locations are quite similar in structure and size, as well as the building setup of the fast-charging infrastructure. This allows for meaningful comparison, considering costs and business model related topics.

2.2.1 Location & building setup

All charging stations are located on off-motorway service areas. 9 out of these 15 locations are in the south of Germany, namely in Baden-Wuerttemberg and Bavaria. Comparability is ensured because off-motorway stations have to meet specific criteria to get their classification [5]:

- the off-motorway station must not be more than 1 Km away from the next junction
- the infrastructure is designed to be used for heavy traffic
- a certain amount of parking lots for trucks is available
- the off-motorway service area is opened 24/7 and all year round and fuelling is possible at any time
- a big variety of food is offered at least from eleven a.m. to ten p.m.

The setup for the planned fast-charging infrastructure has the same characteristics on all 15 locations. 4 fast-charging stations each with 50 KW DC and 22 KW AC power output. The power output of 50 KW for the DC outlet is the minimum requirement defined in the project SLAM. To keep up with the growing demand of faster charging and the evolution of batteries for electric vehicles, investors have the option to prepare the location for super-fast charging on the grid side; in doing so each station can be provided with about 200 KW (150 KW DC + >22 KW AC), which makes 800 KW in total for each location. By a simple upgrade of a station super-fast-charging can be offered to customers, as soon as the advanced hardware is available. Nevertheless, this setup means payment in advance because the increased power source can't be utilized at first. Since super-fast-charging or even ultra-fast charging (up to 350 KW) is seen to be the future for charging on motorways, one should give a closer look at this case.

2.2.2 Capital expenditures

It is often observed that by calculation of capital expenditures for charging infrastructure only the charging station and the power cord leading to the station are taken into consideration. With increasing performance this assumption is frequently wrong: to provide the required energy grid infrastructure, as well civil engineering works, is becoming more sophisticated, thus more expensive. For this purpose cables, connections and transformers have to be correctly dimensioned.

Investors who applied for financial subsidies had to request a cost estimation for each location in advance. This cost estimation is, after being approved by the committee, also the upper cost limit on which subsidies can be granted. In any case the final subsidy is paid on the basis of the submitted invoices[1]. These invoices are the database for the presented paper and illustrate the difference between the locations from a financial point of view.

[1] Invoices were issued in 2015 and 2016

2.3 Methodology

In the present paper it will be speculated whether the development of fast-charging infrastructure can be a worthwhile investment. So far, the cost aspect has been and is going to be determined by the capital expenditure. The question is which costs are the driving factors and which are the greatest uncertainties in planning. Certain locations are then analysed in detail to provide recommendations about the financial feasibility. The invoices as a data base enable a quantitative approach in the evaluation of the investment expenditures. At the end, the differences in capital expenditures are used to highlight their impacts on the establishment of fast-charging infrastructure in Germany.

3. Results

In the following, existing knowledge is matched with data from the project SLAM. Due to great difference in cost, each location is examined in detail. In addition, a comparison between the locations, referring to investment expenditures, is drawn. For illustration purposes, the minimum number of charging processes for the amortisation of such investments are worked out. Therefore assumptions are made with regard to customers' willingness to pay and electricity cost per kWh today and in the future. Further numbers, such as transferred energy per charging process are available in the projects database. Finally, the results are discussed, regarding their feasibility and their impact on the expansion of a nationwide fast-charging network in Germany.

3.1 Classification into categories

In 2015 the NPE (National Platform Electromobility) published the total costs of fast charging stations based on their researches. They divided the capital expenditure for fast charging stations into 4 categories and estimated the value of each category. The categories and their estimated capital expenditure are listed in the following table.

NPE Categories			
Nb. 1 Hardware, incl. Communication and "smart meter"	Nb. 2 Grid connection costs	Nb.3 Grid Authorization / Planning / Location search	Nb. 4 Installation / Construction costs / Signage
25,000 EUR	5,000 EUR	1,500 EUR	3,500 EUR

Table 1: Capital expenditure divided into categories by NPE [6]

According to the NPE the cost of one fast charging station with 50 kW amounts to 35,000 Euro. It was noted, however, that "*the first cost estimations for a grid connection of 3x150kW and corresponding 630kVA including transformer investment amount to 150,000 Euro*"[6]. For a fast charging station with a grid side power supply for higher charging capacities (150 kW per DC connection) the capital expenditure amounts to a total of 85,000 Euro, according to the NPE.

However, the locations built up within the SLAM network demonstrated that in order to better analyse capital expenditure in terms of cost driving factors further categories should be introduced. Further we will refer to the categories listed in the Table 2.

SLAM Categories					
Nb. 1 Charging stations	Nb. 2 Grid connections	Nb. 3 Building cost subsidy	Nb. 4 Compact station	Nb. 5 Planning & Development	Nb. 6 Civil engineering

Table 2: Further divided categories following the division by NPE [6]

The original second category was further subdivided into *power supply* and *building cost subsidy*. *Grid connection* includes the information about the material and works needed to establish an electrical connection between the general supply network and the charging locations and their elements. Depending on the distance between these objects, the required cable length and thus its cost varies.

The building cost subsidy applies when more than 30 kW are used which is naturally the case for all fast-charging locations. Thus, the fee set by the distribution system operator must be paid and is used to expand the general network. The fee is approved by a regulatory body and based on the estimated future investment costs of the grid operator. Due to German *Energiewende*[2], the needed grid investments have spiked and in many occasions which translates into increased expenditures for building cost subsidies in fast charging locations. When planning the project in 2012, an average fee of ca. 50 EUR/kW was used for calculations – reality has shown fees exceeding 100 EUR/kW in recent years. Depending on the location and distribution network operators the building cost subsidy amount can vary a lot. An additional difference between subcontractors is that either the apparent power or the active power is taken into consideration. In order to make the building cost subsidy, which is a large part of the investment expenditure, comparable it was assigned a separate category.

SLAM Category 6 *Civil engineering* corresponds to the NPE Category 4. It covers all works related to the design, safety and marking of all relevant components of a charging location. One subcontractor for example subdivided the *civil engineering* category into site facilities (traffic safety, auxiliary crossings), civil engineering works (excavations, cable trenches, fundaments) and road construction. Other subcontractors were not so detailed in the works listing, but the works performed are basically the same.

It is common for a subcontractor to handle several categories (1: n). For example, a power supply company is often responsible for the grid connection and the building cost subsidy. However, in the data record considered here, it is never appeared that a few subcontractors process together on one category (n: 1).

3.2 Evaluation

On the basis of the above-mentioned invoices of 15 already built fast charging locations, the categories described in 3.1 are evaluated. Table 2 shows the costs for each category based on information from 3 locations. The displayed total costs are the net prices.

		Capital expenditures					
		Nb. 1 Planning & Development	Nb. 2 Building cost subsidy	Nb. 3 Grid Connection	Nb. 4 Compact station	Nb. 5 Charging station(s)	Nb. 6 Civil engineering
Location	A	7.440 EUR	73.632 EUR	10.650 EUR	62.905 EUR	56.209 EUR	118.198 EUR
	B	7.440 EUR	78.240 EUR	13.389 EUR	62.905 EUR	55.743 EUR	59.072 EUR
	C	7.440 EUR	80.832 EUR	8.876 EUR	55.870 EUR	55.867 EUR	58.817 EUR
	…	…	…	…	…	…	…

Table 3: Examples of prices of capital expenditures separated in categories [illustration of University Stuttgart based on data of the project SLAM]

Table 3 shows that capital expenditure may vary within categories. Its level differs because the locations lay all over Germany and therefore different subcontractors were assigned. In addition, location-specific, unplanned circumstances, as well as envisaged decisions and regulations of investors and subcontractors, can also drive costs up.

An envisaged decision of the investor was to equip 5 locations with a grid connection of 1250 kVA in order to be able to upgrade the stations for ultra-fast charging of more than 150 kW. This decision was taken when the total cost for a location with 4 fast charging stations was still unclear. The resulting higher costs are particularly calculated per kVA or kW in the category *building cost subsidy*. The other 10 locations were

[2] the nation-wide change from nuclear and fossil fuel dependant electricity generation towards renewables

planned with only 800 kVA, which has reduced the building cost subsidy amount. Nevertheless, the lower capacity is sufficient to provide enough power for all 4 fast charging stations. However, in the case of an upgrade to more than 150 kVA per fast charging station, the building cost subsidy has to be reconsidered.

In order to keep the option of a future upgrade available, all compact stations can provide power of 1250 kVA. These compact stations still vary in price as they have to possess specific features such as accessibility or special safety measures depending on the requirements of the location specific network operators.

With the help of a boxplot diagram the categories and the differences between them can be visualized. 15 locations with 4 fast charging stations are considered (as described in 2.2.1).

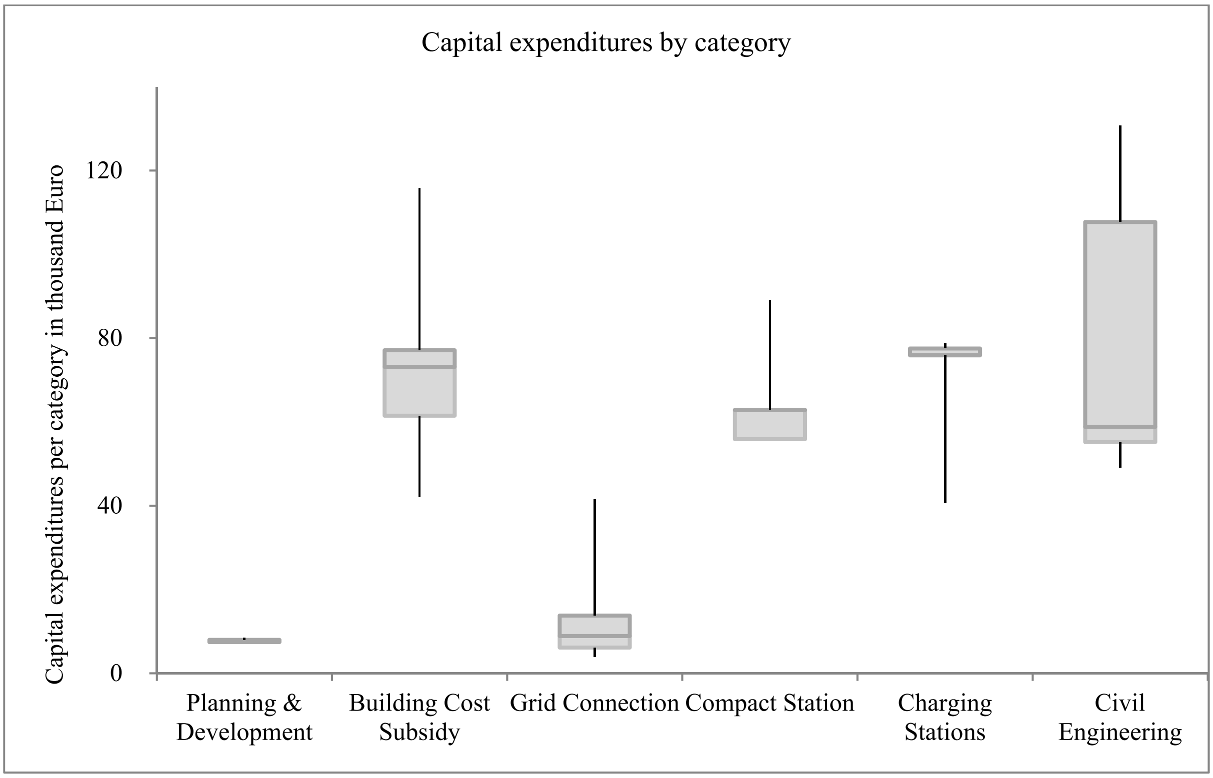

Figure 1: Boxplot diagram of capital expenditures by category [illustration of University Stuttgart based on data of the project SLAM]

The categories *building cost subsidy* and *civil engineering* show a particularly large spread in capital expenditure. Both also form a major part of total investment expenditure.

The value of the *building cost subsidy* category is not entirely dependent on the described above differences in capacity between the first 5 and the other 10 locations. In addition, the fees of the different network operators vary up onto a factor of two.[3]

The minimum value of the category *charging stations* can be explained by the fact that for this location 3 used fast charging stations were purchased. The works of the category *Planning & Development* are carried out by the investor and are relatively constant due to similar work processes.

The reasons for the price fluctuation of the category *civil engineering* are of different nature. Here the cost fluctuates from the first to the third quartile between 55,000 Euro and 108,000 Euro. This is attributable to the different conditions of the locations and requirements of owners and responsible authorities. Thus, for example, special safety measures such as a concrete wall (approx. 50,000 Euro) or additional signposting

[3] Lowest tariff: 52,42 EUR/kVA
Highest tariff: 101,04 EUR/kVA
(As in 2016)

increase the costs. In other locations, longer cable trenches have to be installed and cables relocated to overcome the distance between the compact stations and the fast charging stations. As a result, a larger surface area of the excavated surface must be restored. In addition the type of soil affects the costs of the excavations. Lastly the cost differences depend on the pricing of the various subcontractors.

3.3 Examination of locations

The categories described in 3.1 are independent. At locations with high civil engineering costs, for example, building cost subsidy does not necessarily have to be above average. Based on these different combinations the investment expenditures shown in figure 2 are generated for each location.

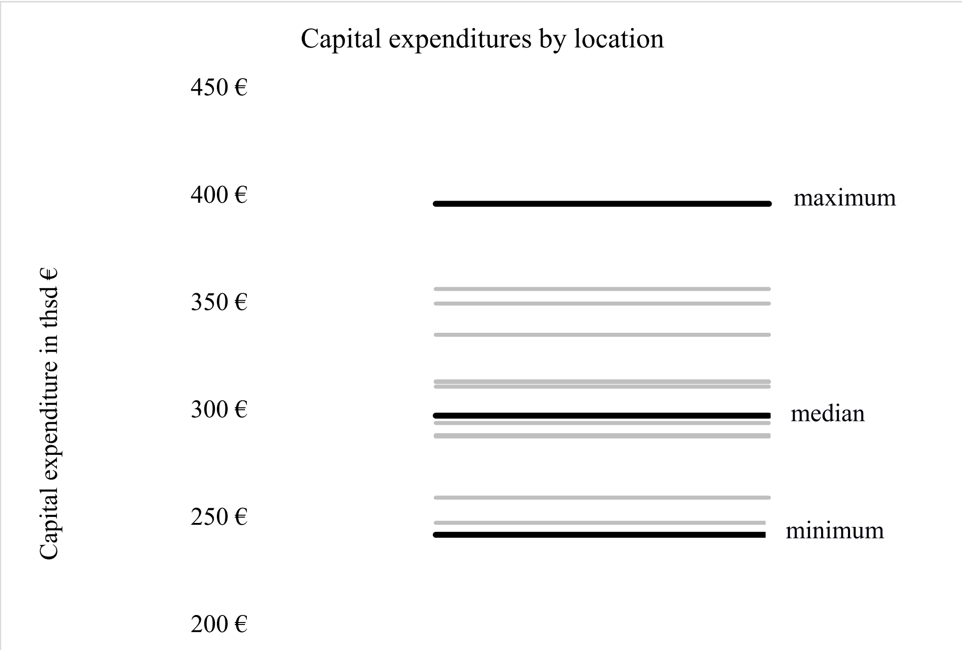

Figure 2: Capital expenditures of the individual sites [illustration of University Stuttgart based on data of the project SLAM]

The bold lines mark the locations with the minimum, median and maximum investment expenditures. The minimum is 241,393.26 Euro, the median is 296,889.03 Euro and the maximum is 395,602.09 Euro. Thus the maximum exceeds the median by 33% and the minimum is 19% below the median and the difference between the extreme values is around 150.000 Euro. The median value for each fast charging station is 74,222.26 Euro. The grey lines represent each charging location.

The minimum, the median and the maximum correspond to the investment expenditure of real locations. Those locations are built as described in 2.2.1. In the following, the minimum is referred to as scenario 1, the median as scenario 2 and the maximum as scenario 3.

3.4 In-depth analysis of CAPEX

This chapter evaluates the impact of these strategic investments. To that end a monthly depreciation for the 3 scenarios – *Minimum*, *Median* and *Maximum* (cf. 3.3) is calculated. A depreciation period of 7 years is assumed, since this is the usual duration of license agreements for off-motorway service areas. These agreements can be extended on a per-period basis, therefore the depreciation is considered over one as well as two periods. Having in mind the technical development of fast charging stations during these periods it is assumed that after each period at every location new fast charging stations will be purchased. [4] When

[4] The fast charging stations that will be purchased have a capacity of 50 KW

considering two periods the price for 4 fast charging stations is added to the total capital expenditure after 7 years.

Thereafter the depreciation rates are analysed. It determines how many charges per month and fast charging location are needed to cover the capital expenditures.

3.4.1 Depreciation rate

To calculate the depreciation rate a dynamic investment process is used [7]. A corresponding method is the equivalent annual cost, which is used to determine the amount of depreciation.

At first the annuity corresponding to the amount of the yearly depreciation of an object is determined. This amount can then be mapped over the desired period. The formula of the annuity is [11]:

$$Ann = KW \cdot \frac{(1+i)^T \cdot i}{(1+i)^T - 1} \qquad \text{(I)}$$

Ann	annuity
KW	capital value
i	required rate of return
T	economic life

The capital value corresponds to the amount of the total investment expenditure per location. The economic life is 7 years and equals the depreciation period. A value of 7% was assumed for the required rate of return, which is quite common for long-term investments, especially in times of low interest rates.

In scenario 1, the annuity for one period is 44,791.30 Euro per year, respectively 3,732.61 Euro per month.

When considering 2 periods the economic life is 14 years and the annuity is calculated for this period, although it is applicable only for the period of 1-7 years. After 7 years 4 fast charging stations are added to the remaining depreciation amount. As a result, the annuity changes and must be recalculated for the period 8-14 years.

It is unclear how the price of the fast charging stations will change within the 7 years period. The NPE, however, forecasted that in 2020, a fast charging station will cost 15,000 Euro [6]. It can be assumed that this price change is not linear. Therefore, no statement can be made about the price of the fast charging stations after expiry of the leasing contract. Therefore it is assumed that after a period the price per a station will be 15,000 Euro that amounts to a total cost of 60,000 Euro per location with four fast charging stations.

The following annuity values are calculated using the above described numbers.

		Annuity per month		
		1 Period	2 Periods (year 1 - 7)	2 Periods (year 8 - 14)
Scenario	1	3,733 EUR	2,300 EUR	3,228 EUR
	2	4,591 EUR	2,829 EUR	3,757 EUR
	3	6,117 EUR	3,770 EUR	4,697 EUR

Table 4: Annuities of Scenario the 3 Scenarios over 1 and 2 periods.

In order to cover the investment expenditures of the fast charging locations monthly profits have to achieve the amount of annuities per month.

3.4.2 Derivation of annuities

In the following, the framework conditions for covering the annuities are determined. To begin with, the definition of profit as a difference between revenue and expenses is taken into account [8].

(II) $$G = U - K$$

G	Profit
U	Revenue
K	Expenses

The expenses for the fast charging stations consist of capital expenditures (CAPEX) and operational expenditures (OPEX).

(III) $$K = CAPEX + OPEX$$

The NPE ascribes to the operational expenditures the following costs: usage, hotline, maintenance, anti-interference costs, communication costs, contract management / billing and IT system [6]. These costs cannot be considered in the paper, as no sufficient data was available. Only CAPEX are subject of investigation.

The revenue corresponds to the earnings from selling charging services. In the frames of the accompanying and effectiveness research of *Schaufenster Elektromobilität,* 590 electric vehicle users and interested parties were interviewed on how much more they are ready to pay for the domestic electricity if they can use charging stations with the capacity up to 50 kW as a return service. The survey showed that the respondents agree to pay 30% on top of the price of the household electricity [9]. In order to calculate the revenue the value of these 30% is multiplied by the cost of electricity, the amount of energy transmitted and the charging sessions per location per month.

(IV) $$U = M * S * E * A$$

M	Percentage of willingness to pay extra
S	Electricity costs per kilowatt hour (KWh)
E	Transmitted energy amount in KWh
A	Charging sessions per location per month

Data from the research project SLAM shows that customers usually charge their electric vehicles with 10 kWh per charging session (see figure 3).

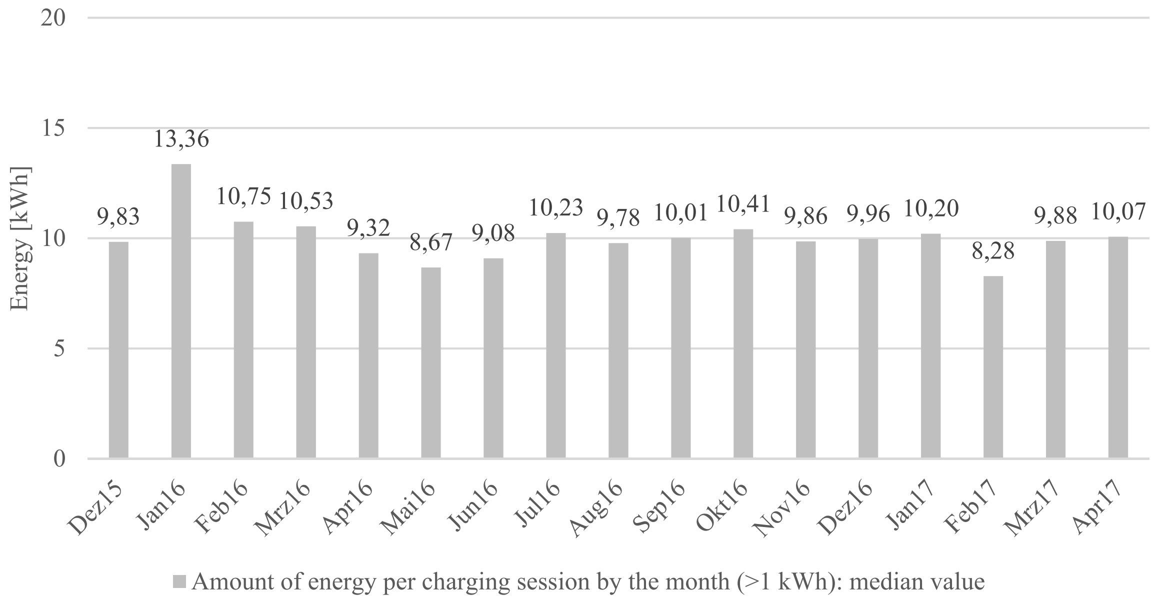

Figure 3: transferred energy per charging session collected from all 15 locations [illustration of University Stuttgart based on data of the project SLAM]

When examining the domestic electricity price in Germany from 1998 to 2017) it can be noted that there was in average 3% increase in the yearly price. In 2016 the price was 28.7 ct. / kWh [10]. Assuming a steady increase, the electricity price in the next 7 years will be around 31.90 ct. / kWh and in the next 14 years - around 35.59 ct. / kWh. The revenue per charging is therefore 0.96 Euro when considering one period and 1.07 Euro in the case of 2.

By transforming and combining the formulas, it is now possible to determine how many charging operations per month and station are needed at least to cover the investment costs of the fast charging locations. Thus, the number of charges is determined for which the gain is equal to zero.

(V) $$A = \frac{CAPEX}{M * S * E}$$

Corresponding to table 4, the number of charging processes per fast-charging location and months necessary for the amortization of the investment costs, is the following:

		Number of charging sessions		
		1 Period	2 Periods (year 1 - 7)	2 Periods (year 8 - 14)
Scenario	1	33	18	26
	2	40	23	30
	3	54	30	37

Table 5: Number of necessary charging processes per fast charging location per day[5]

The number of charging sessions per day and charging station for the scenario 3 for one period is 54. In the most favourable case, 18 charges per day and charging station are needed, only to amortize the capital expenditures. In reality, in order to cover also the ignored operational expenditures, the number of charges per fast charging location should exceed the values from table 5.

[5] The results were rounded to the next whole numbers

4. Discussion

The number of charging locations (n = 15) is too small to draw a valid statistical conclusions about the actual range of total costs for fast-charging infrastructure. However the orders of magnitude provide valuable inside into many assumptions of the Returns on Investment (ROI) into fast charging. As shown it is difficult to derive a reliable value of CAPEX and therefore ROI, since such categories as “building cost subsidy” as well as the “civil engineering” can vary a lot in value. In a good planning, both factors can be pre-calculated reasonably accurate. Nationwide or international investors can minimize the effect through mixed calculation. Smaller and locally bounded investors cannot enjoy this benefit introducing a barrier into a market that is perceived to be fully accessible by all kinds of small private investors. On the other hand large-scale investors will have the opportunity to build charging locations in areas that are by themselves not eligible for investments and therefore close gaps in national and international charging networks. The different kinds of investors will mainly compete on the charging stations with low investments costs and high frequentation of users. Whereas investments into stations needed to create an uninterrupted charging network are mainly provided by large-scale providers.

This result allows us to conclude: the diversity of small operators will in the future mainly be presented on operating locations that belong to them or to their companies. And the locations with several charging stations and charging capacities of >> 50 KW (super-fast charging or ultra-fast charging) will be built up and operated by an oligopolistic operator structure. If insufficient benefits towards large-scale investors to fill blanks are provided, the fast charging infrastructure in Germany will remain having "white spots". This can happen above all if the current number of charging sessions will not increase in the future i.e. the number of electric vehicles does not increase significantly. The issue becomes even more pressing with regards to time as nationwide operators of fast-charging infrastructure have only a certain time slot in their disposal to amortise the investments, since the duration of license agreements for motorway and off-motorway service areas is usually less than 10 years. It is obvious that the current number of 1 charging session in 10 days (see figure 4) is far from being enough to amortise the capital expenditures.

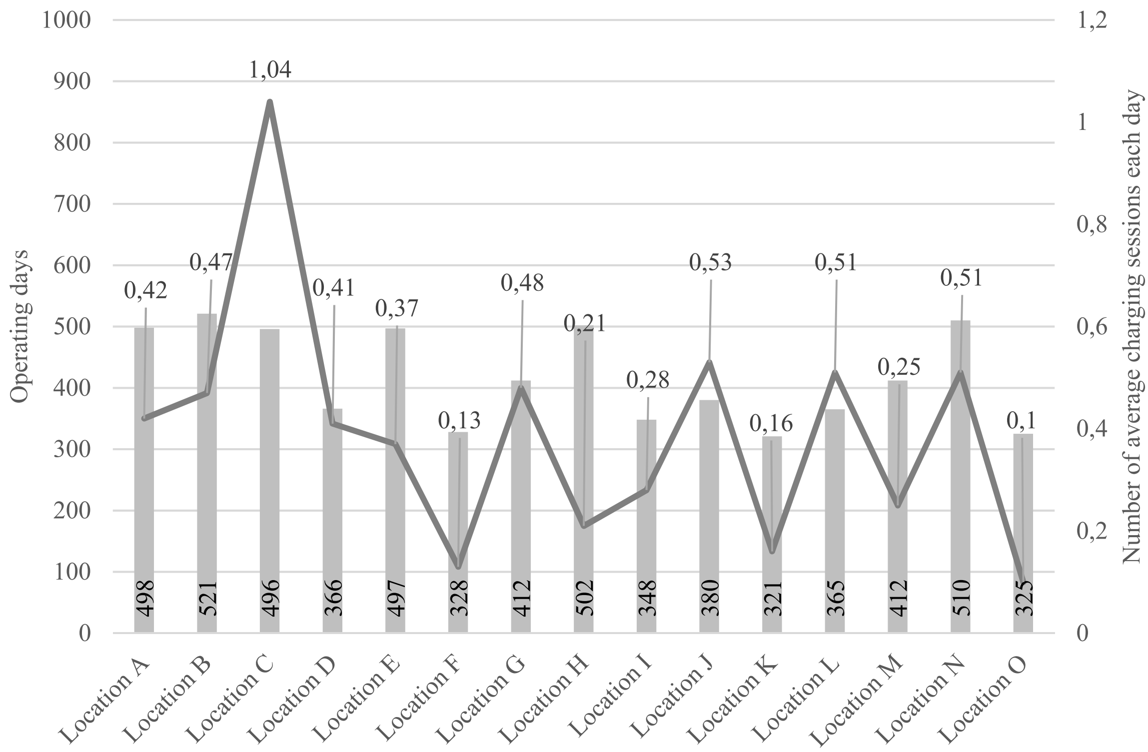

Figure 4: average charging sessions each day of 15 examined locations (with 4 fast-charging stations each) [illustration of University Stuttgart based on data of the project SLAM]

A further factor is the operating costs, which can significantly increase the total amount to be amortized depending on the kind of maintenance agreement, billing systems and offered services. Table 5 (3.4.2) shows that in the worst case 54 charges per station and day (Scenario 3, 1 period) have to be carried out. In the best case, it is 18 (scenario 1, 2 periods (1-7 years). So far, only the amortisation of capital expenditures would have been achieved. On the one hand, this makes it clear that there are large differences per fast charging location and approach. On the other hand, this number of charging sessions is hardly possible in reality. 54 sessions per charging station and day means that a 25-minute charging cycle within 24 hours takes place without interruption. In the end it must be noted that subsidies can significantly reduce capital expenditures. But even with 50% subsidy some locations would have problems to refinance themselves. And with increasing expenditure on network upgrade this problem can be exacerbated in the future. For example, from 2016 to 2017 building cost subsidy has increased by around 20%. And we are just starting to build up charging infrastructure with high charging capacities.

The above calculations do not consider the difference in the number of charging stations per location (in all the cases studied above it has been 4), the charging power (charging stations with 150 kW charging power are already available in the market, even 350 kW chargers are now piloted). Also current market prices of up to 12 EUR/charging session show that the market is not bound to the wishes of customers of home electricity price +30%.

The analysis shows that a fully market driven approach considering the current wishes of the customers is not realistic. Either the cost structure of CAPEX or the demands of the users have to change. In addition there is the opportunity to operate the charging station itself in a deficit and profit from image gains, using the station for a cooperate fleet or having other deals related to the location of the charging station, such as advertisements on the station. Even though the authors consider these factors highly important for the market uptake, building the number of ca. 7000 fast-charging stations needed following NPE calculations is unlikely to be reached under these circumstances.

Acknowledgments

This research was supported by a grant from the German Ministry for Economic Affairs and Energy (BMWi) to University of Stuttgart (support code: 01MX13007J).

References

[1] Nationale Plattform Elektromobilität, *Fortschrittsbericht 2014*, Berlin, Dezember 2014, chapter 2
[2] Nationale Plattform Elektromobilität, *Ladeinfrastruktur für Elektrofahrzeuge in Deutschland*, Berlin, November 2015, chapter 2
[3] B.Walzel et al, *Anforderungen an die Tankstelle im Jahr 2025*, 14.Symposium Energieinnovation (2016)
[4] Schnelladenetz für Achsen und Metropolen (SLAM), *Leitfaden*, http://www.slam-projekt.de/, accessed on 2017-02-14
[5] K. Bauer: *Kapitel 43.* In: Kurt Kodal (Hrsg.): *Straßenrecht Handbuch.* ISBN 978-3-406-52567-4, München, Verlag C.H. Beck, 2010
[6] Nationale Plattform Elektromobilität, *Ladeinfrastruktur für Elektrofahrzeuge in Deutschland*, Berlin, November 2015, chapter 3
[7] Gabler Wirtschaftslexikon: keyword: *Investitionsrechnung*. http://wirtschaftslexikon.gabler.de/Archiv/54836/investitionsrechnung-v11.html, accessed on 2017-08-04.
[8] Gabler Wirtschaftslexikon: keyword: *Gewinn*. http://wirtschaftslexikon.gabler.de/Archiv/54078/gewinn-v9.html, accessed on 2017-08-04.
[9] Schaufenster Elektromobilität*, Bedarfsorientierte Ladeinfrastruktur aus Kundensicht*, Frankfurt am Main, März 2017, chapter 3.4.2
[10] Strompreise, https://www.strompreise.de/strompreis-kWh/, accessed on 2017-08-04
[11] Götze, Uwe: *Investitionsrechnung, Modelle und Analysen zur Beurteilung von Investitionsvorhaben*. 3. Aufl. Berlin, Heidelberg: Springer, 2002.

Authors

Denis Horn holds a Diploma in Business Engineering from the University of Applied Science in Kempten as well as a M.Sc. in Innovation Management from the University of Applied Science in Esslingen. In 2010 he began working at Fraunhofer IAO and at University of Stuttgart IAT. His research aims on topics as innovation & technology management, in particular on technology commercialisation. Most of his recent work comprises projects in the area of electromobility and charging infrastructure. As project manager of SLAM, he is in charge of fund management and investor relationship management, as well as of business model development.

Alexander Schmidt is a researcher within the Fraunhofer IAO and University of Stuttgart since 2013. He holds two undergraduate degrees in Environmental Engineering (B.Sc.) and technically oriented Business Administration (B.Sc.) from the University of Stuttgart and a postgraduate degree in Transport Engineering (M.Sc.) from Imperial College London. At present he is a project leader in public as well as direct industry commissioned research projects on fast charging for electric vehicles and other aspects of future mobility.

Axel Bauer is a student of technology management at the University of Stuttgart and is expected to finish his Bachelor degree in 2017. Because of his interests in electric mobility and the energy infrastructure he works at University of Stuttgart IAT since 2015 as a research assistant. Currently he works on the project SLAM and writes his Bachelor thesis about the topic of fast charging infrastructure in Germany.

Olga Udovenko holds a M.A in International Relations and Translation from the national University of Donetsk, Ukraine. In 2015 she began to work in Fraunhofer IAO in project SLAM. Her research interests are in the area of electromobility and charging infrastructure.