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Design of business models for the operation of the charging infrastructure according to the German calibration conformity - development of an automated TCO-tool

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Executive Summary

The calibration law in Germany places extensive requirements on the operation of charging infrastructure. In this paper, the requirements and effects of the calibration law on the current charging infrastructure are examined and profitable business models are developed based on an automated tool.

Keywords: charging, conductive charger, infrastructure, regulation, business model

1 Introduction

The charging infrastructure in Germany is subject to country-specific requirements, which requires a calibration-compliant recording and billing of a charging process. A non-compliant implementation of the charging infrastructure forces the operators to develop new business models based on the billing method. The profitability of these business models, based on the imputed profit over the lifetime of different billing systems, is analyzed in the context of this work and always aligned to the regulatory requirements of the legislator. Based on standard models for the billing of a charging process, the sensitivity of individual parameters with an effect on the calculated profit is simulated. Finally, a recommendation for the design of business models for the operation of the charging infrastructure is given.

2 Today's charging infrastructure

A nationwide charging infrastructure in Germany and other countries is the key to the breakthrough of electric mobility and creates the necessary confidence among drivers that their vehicles can be charged anywhere and at any time. In addition to the quantity of charging infrastructure, the interoperability of the systems and an expansion that corresponds to the ramp-up of electric vehicles are also necessary.

The Nationale Plattform Elektromobilität (NPE)[1] in Germany defines various locations for charging stations and divides them into private, semi-public and public. The demand forecast for semi-public and public charging stations is up to 15% [1].

[1] Nationale Plattform Elektromobilität (in English: The National Platform for Electric Mobility) is an advisory body of the German Federal Government on electric mobility. – Renaming in 2018 into Nationale Plattform Zukunft der Mobilität (in English: The National Platform for Future Mobility)

With currently just over 13,000 publicly accessible charging points in Germany [2], the NPE estimates that up to 170,000 charging points will be needed by 2020 in line with the vehicle ramp-up [3]. To make this construction possible in a brief period, the government has introduced many subsidy programs that promote both the hardware of the charging station and the expansion of a grid connection. However, this expansion must also be an economic undertaking, so that the charging station operators also have an incentive to increase expansion so fast.

3 Regulatory requirements for the charging infrastructure

The legal framework in Germany for the operation of the charging infrastructure is complex and clearly stands out from other EU member states due to the calibration and measurement law. The calibration and measurement law represents the national implementation of the Measuring Instruments Directive (MID) and specifies some requirements regarding the recording, transmission and processing of metrological quantities and other information required during a charging session.

3.1 Legal framework

The legal framework in Germany is diverse. In addition to requirements for the construction of charging infrastructure via the charging station ordinance[2], the calibration and measurement law also defines requirements on the operation of this infrastructure. In addition, the price regulation directive[3] could also play a role in the billing of electricity, greatly limiting the scope for billing models in Germany.

The charging station ordinance in Germany regulates the construction of charging infrastructure in (semi-)public spaces and requires, among other things, the use of Type 2 and/or CCS2 connectors. The charging station must also be barrier-free and offer ad hoc authentication and payment options. However, the exact form of implementation is left to the operator. The legal framework in Germany includes, in addition to the charging station ordinance, the act and decree on the placing on the market and provision of measuring instruments (MessEG and MessEV), which represent the focus of calibration and measurement law. The calibration and measurement law in Germany is a synonym for these two regulations and places a variety of requirements on the operation of charging stations, which the current infrastructure is not yet able to fulfil.

Next to the calibration-conform measurement of electrical energy the reliable data transmission and authenticity testing of the measurement data must also be guaranteed. Unique requirements have been published for the field of electromobility in Germany, which will be described in more detail in the next chapter.

In addition, the price regulation directive regulates the indication of prices for the sale of electricity. In Germany, this information must be given and billed in kilowatt hours (kWh). However, as it is not possible to draw a connection with the charging infrastructure today, various committees are discussing the application of this regulation. However, it is not only foreseeable from a legal perspective that billing should be based on kWh, but the comparability and transparency from the customer's point of view is also highest with billing based on kWh.

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[2] Ladesäulenverordnung (in English: Charging station ordinance) defines the essential requirements for the expansion of the charging infrastructure in Germany.

[3] Preisangabenverordnung (in English: Price regulation directive) is a legal regulation which regulates the indication of prices for the supply of e.g. electricity.

[4] Regelermittlungsausschuss (in English: Committee of Inquiry) is appointed by the Federal Ministry of Economics and Energy (BMWi) for three years and determines rules, findings and technical specifications for measuring instruments, for conformity assessment procedures and for persons using measuring instruments or measured values based on the framework conditions under calibration law and the state of the art.

3.2 The field of electromobility

For measuring instruments that have been specially developed for the field of electromobility and the supply of electricity, the Regelermittlungsausschuss[4] (REA) has formulated concrete requirements based on the MessEG and the MessEV. For the REA, different interest groups work together with specialized working groups to formulate a uniform procedure for the conformity assessment of measuring instruments and additional equipment in conformity with calibration law.

The requirements for the operation of the charging infrastructure can be divided into essential core areas:

- Calibrated measurement of the charging process
- Completeness of the measurement data record
- Permanent storage of measurement data
- Protection against changes in measurement data
- Secure transmission of measurement data
- Proof of authenticity and verification of measurement data
- Display of legally relevant content
- Updating the software

All these areas and requirements should be considered and implemented by the operators of charging infrastructure as well as, under certain circumstances, by other mobility service providers. As there are by end of 2018 no compliant meters available, operators should calculate with a retrofit and additional costs. In addition, processes and interfaces of the backend must be checked regarding to the requirements and appropriate changes must be made. All this can lead to significant changes in the business model and, in addition to additional costs, also to increased competition in Germany.

Currently most of the AC charging stations are already equipped with a MID meter, which is a basis for calibration and measurement law compliant invoicing but still requires a positive compliance check. As a temporary solution for DC charging, AC is measured right before the conversion into DC (~20 % discount for the customer). As of 1 April 2019, this solution is not allowed anymore, at least a conversion plan must be submitted by the charging point operator. A compliant meter can cost between 300-500€ and must be retrofitted in the charging station [4].

Since, in addition to the pure meter, a backend, can also fall within the scope of legal consideration, there are five implementation proposals in Germany, some of which have different levels of backend integration for the operation of charging infrastructure. If the backend calculates or recalculates meter values in any way, it must always be included in the legal consideration. The first form of implementation is protected by a patent and is called "innogy-solution". This includes the entire backend in the legal consideration and is known as a special form. The second form of implementation is called a "cheap solution" and includes the backend in a lesser form in the legal consideration, since certain requirements are implemented on site at the charging station. For example, a local storage facility in the charging station can be used to ensure that a storage facility in the backend, that is conform to legal requirements, is not necessary any more. A third variant is the complete implementation of the legal requirements within the charging station on site, so that the backend can be excluded from any consideration. However, this implies that e.g. intelligent billing functions cannot be implemented in the backend. The fourth form of implementation is not further specified and leaves room for alternative solutions. The fifth implementation form represents a kind of protection of the existing system and cannot be implemented for future charging stations. The analysis is based on the assumption that the "cheap solution" will be used and that some changes will be made to both the hardware and the backend.

4 Design of business models

The requirements of measurement and verification law mean that the billing of a metrological quantity can only be implemented in Germany compliant to the calibration law. The current charging infrastructure has largely not been implemented conform and has not been equipped with appropriate measuring systems. Since, however, from the consumer's point of view, billing according to energy quantity is sometimes the only comparable and fair way of billing, operators should attempt to make this billing possible. Different charging powers, battery sizes and charging states of vehicles have a direct influence on the duration and average charging performance of a charging process.

4.1 Profitability of business models

The development of business models was developed with a Total Cost of Ownership (TCO) view with the help of the imputed profit (G_k). Based on this analysis, a good prediction can be made about the profitability of a business model. In the analysis, the investment costs (Capex) and operating costs (Opex) were superimposed with the average expected profits (Revenue) for each charging system and the parameters were selected based on current market values.

$$G_k\,[€] = -Capex + \left(\frac{1}{1+S_M} * Revenue - Opex - S_G * Max\{0, Revenue - Opex - A\}\right) \qquad (1)$$

$$* \frac{1}{1+Z/(1-S_G)} * \frac{1-\left(\frac{1}{1+Z/(1-S_G)}\right)^n}{1-\left(\frac{1}{1+Z/(1-S_G)}\right)} \qquad [5]$$

with

S_M/S_G : Value added tax / taxes on the profit of a company

A : Straight-line depreciation of investment costs per year

Z : Interest rate of investors after taxes

n : Observed year

4.2 Development of calibration-compliant business models

The TCO tool can take over 100 parameters into account, which can be set individually for each operator to obtain the best possible forecast of the profitability of the current and alternative business models. Figure 1 shows a small extract of the parameters.

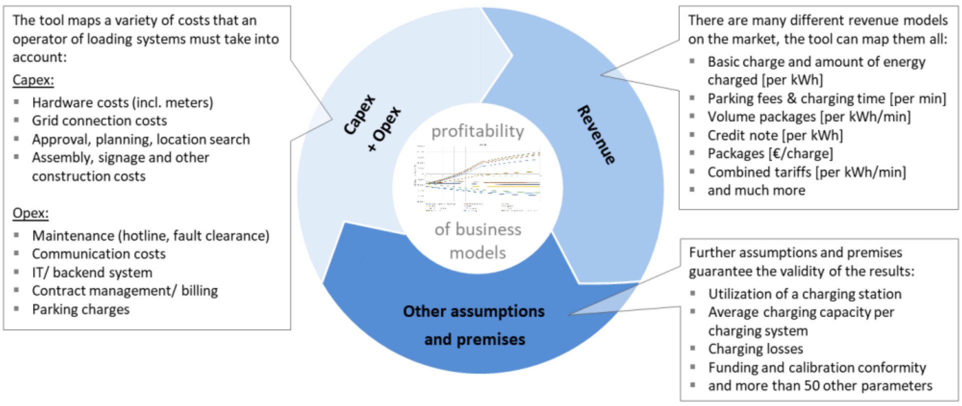

Figure1: Overview of the input parameters of the TCO-Tool

In addition to the billing model based on kilowatt hours, billing based on time is also currently common in Germany. Fixed amounts per charging session are also not uncommon, as these have been decided as a transitional solution to the required calibration-compliant billing. In other countries, combined billing variants are also possible, so that the amount of charged energy and the time required for parking are correlated. Package offers containing a certain amount of electricity for a fixed price are also available on the market as a billing option. In most cases, the billing and underlying business models are differentiated according to the type of charging system, since, for example, significantly more electricity can be delivered in a short period of time with a powerful system.

In the model for Germany special costs for the installation of calibrate-compliant hardware must be taken into account when implementing the systems. In total the tool can map all charging systems available on the market today, from AC charging systems with a charging capacity of between 3.7 and 22 kW to ultra-fast charging stations with a charging capacity of up to 350 kW.

Even though in Germany it might only be possible to bill by kilowatt hours in the future, today's business models are very different. Therefore, the analysis should not only consider the variation of the billing models, but also a sensitivity of the cost points. The costs are divided into one-off investment costs (capex) and recurring annual costs (Opex). The essential costs are broken down to a charging system, so that for example the costs of a grid connection of a charging park with six 150 kW charging systems have been broken down to a single charging system.

4.3 Electric vehicle ramp-up and charging performance

The vehicle ramp-up in the coming years is the basis for the development and profitability assessment of charging infrastructure. The coming vehicle generations will have specific charging capacities and will use the charging infrastructure in Germany in the (semi-)public area with a corresponding distribution. An average increase in charging capacity over the next few years can be assumed for both AC and DC charging processes, as the larger vehicles with higher charging speeds were announced by the German automotive manufacturers by 2018/2019.

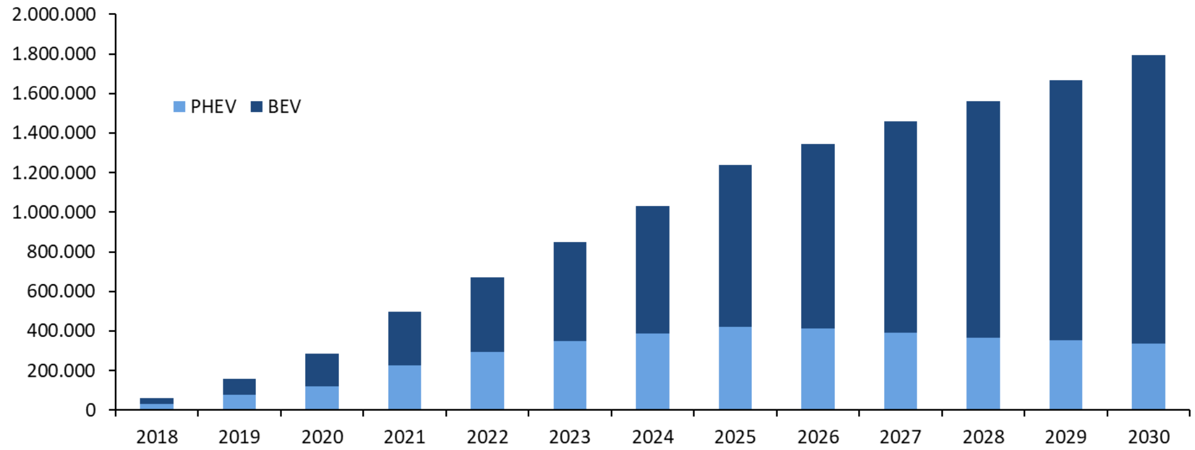

Figure2: New registration xEVs in Germany based on P3 CO_2 compliance tool

The figure shows the underlying vehicle ramp-up in the coming years for Germany, which has been extracted from the P3 CO_2 compliance tool. The P3 CO_2 compliance tool has the purpose to model OEM fleet emissions and targets. Input data for the tool is a vehicle sales database. Within the tool car segmentations (diesel/ gasoline), weight factors and a formula make car segments and different powertrains comparable. Output data is a report about fleet emissions and fleet mix per OEM and region, which can be altered iteratively to be CO_2 compliant. In this way, the proportion of the fleet to be electrified can be determined and superimposed with the vehicle announcements. Specific characteristics, such as battery size and charging speed, can be extrapolated to the next few years. Based on this vehicle ramp-up, specific charging capacities were assumed for each charging system on an annual basis, which can be found in the following illustration.

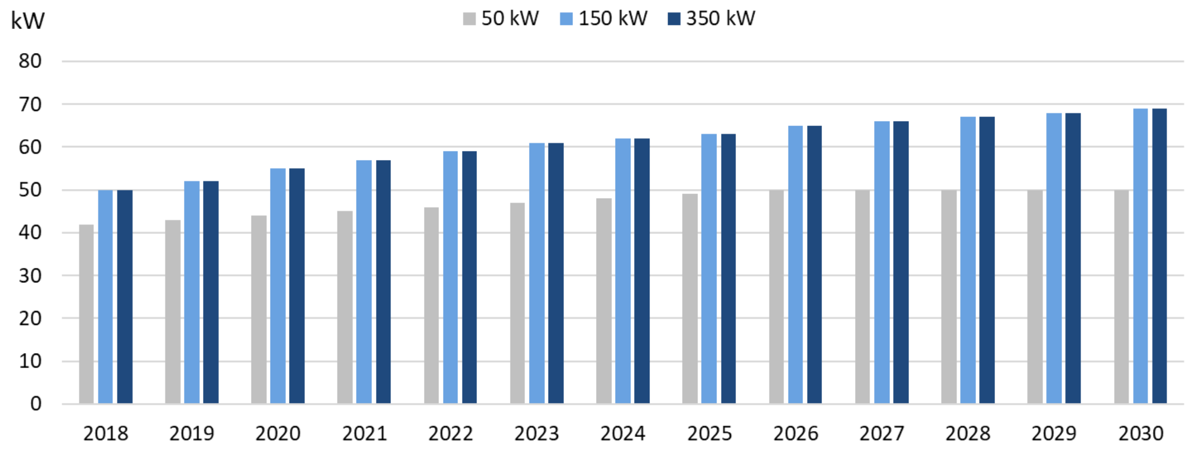

Figure3: Average charging power over the next years per charging system

The charging capacities for 150 and 350 kW charging systems in are highly dependent on the charging performance of future generations of vehicles, which also have correspondingly high charging speeds. Extensive knowledge about the charging performance of vehicles with a maximum charging capacity of 150 kW has already been generated through various test runs. On the basis of this charging performance and the battery characteristics of vehicles with a charging capacity of over 150 kW, an estimate of the charging performance of the few 350 kW capable vehicles for the next few years has been made in accordance with the following figure.

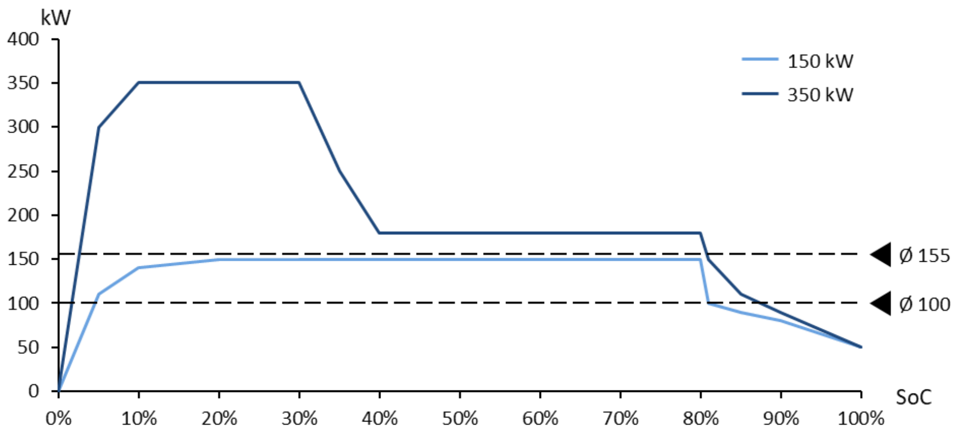

Figure4: Charging curves of a 150 and 350[5] kW vehicle based on test runs of the P3 (simplified)

The average charging capacity of a vehicle with a 150 kW charging system can be up to 100 kW over the entire charging process - even with higher charging capacities, even more energy can be converted. However, taking into account the large proportion of vehicles that can charge more than 50 kW in peak, the average charging capacity of the corresponding charging systems, as described in figure 3, is significantly lower.

In addition to the average charging capacity, assumptions were also made about the future utilisation of the respective charging systems, based on vehicle ramp-up, battery size, average distances travelled in Germany per day and average charging capacity. Thus, the energy requirements of the vehicles can be transferred to the individual charging systems with the distribution of the charging processes in the (semi-)public area.

[5] Extrapolated to 350 kW based on empirical values, as no corresponding vehicle is available yet.

4.4 Comparison of different business models and charging systems

A comparison of the business models per charging system enables a well-founded decision to be made for a specific billing model and charging system for operators. At the same time, it shows the influence of individual parameters through a sensitivity analysis and can thus respond to the individual circumstances of the companies and point out risks and opportunities accordingly.

In the following two results of the analysis are presented in more detail. The first charging system shown is a 22 AC charging station, which is not profitable in any of the billing models considered with today's pricing in the public sector in Germany. This is primarily due to very high operating costs that cannot be covered assuming current capacity utilisation and electricity sales. This leads to a strongly negative business case and is not an attractive business model for operators.

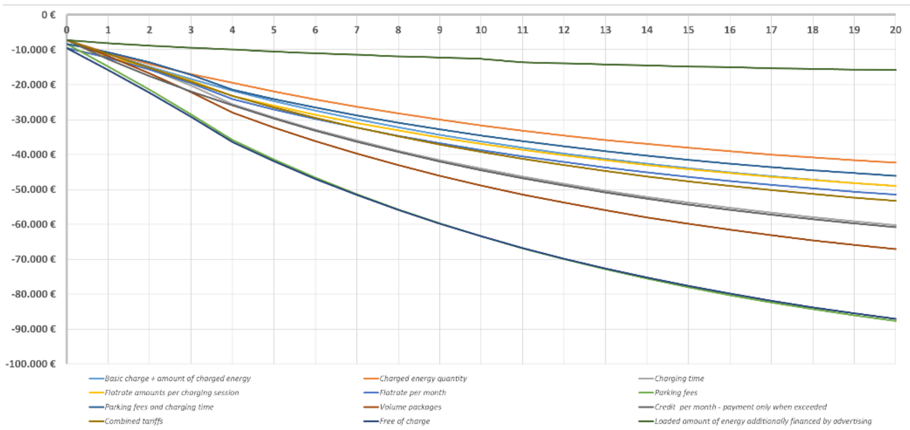

Figure5: Profitability of the business models of a 22 kW AC charging station

Even additional advertising financing can only rudimentarily cover the costs. The small amount of space and attention means that advertising on AC charging systems will be less attractive in the future. Only significantly higher prices for the use of an AC charging station in (semi-) public spaces would cover the operating costs. However, it must then be considered that customers can maybe charge their vehicles at home for a price of approx. 0.30€/kWh.

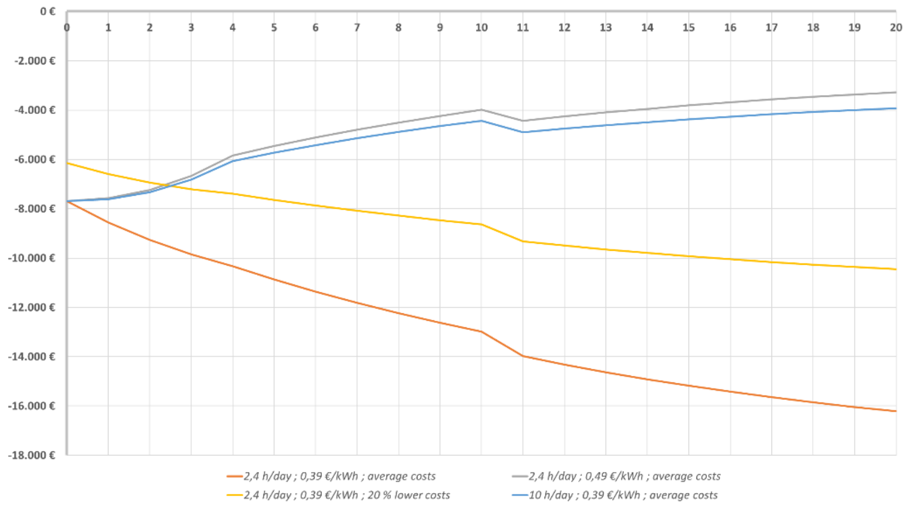

Figure6: Sensitivity of energy-based billing with advertising financing 22 kW AC charging station

If an utilisation of over 10 hours per day is assumed today, there is a scenario in which at least the costs can be covered and the operation of an AC charging station over time would not have a further negative impact on the business model. However, AC charging systems are very limited in their maximum electricity output. Even a full utiliation of a corresponding charging station is not profitable after a depreciation period of 10 years.

Newer DC charging stations with a charging capacity of up to 150 kW are being set up by various operators along the most important sections of the route in Germany. Locations along heavily trafficked long-distance routes are particularly suitable to ensure the utilisation of these systems in the medium term. The first vehicles to arrive will be able to take on high charging capacities. A connection via a transformer to the medium voltage grid is assumed for these charging systems, as a corresponding charging park of approx. six charging stations represents a very large load overall. The resulting variable costs for energy procurement have a major impact on the profitability of this business model. Charging systems with a charging capacity of 150 kW or more and a corresponding capacity utilisation will be highly profitable in the future. With billing based on kilowatt hours and a high margin on electricity sales (due to a medium-voltage connection and high purchase quantities), high profits can be expected within a period of less than 10 years. Figure 7 shows a clearly profitable business case here, as a significantly higher utilisation of the stations was assumed. This is due to the necessity of charging on long-haul routes.

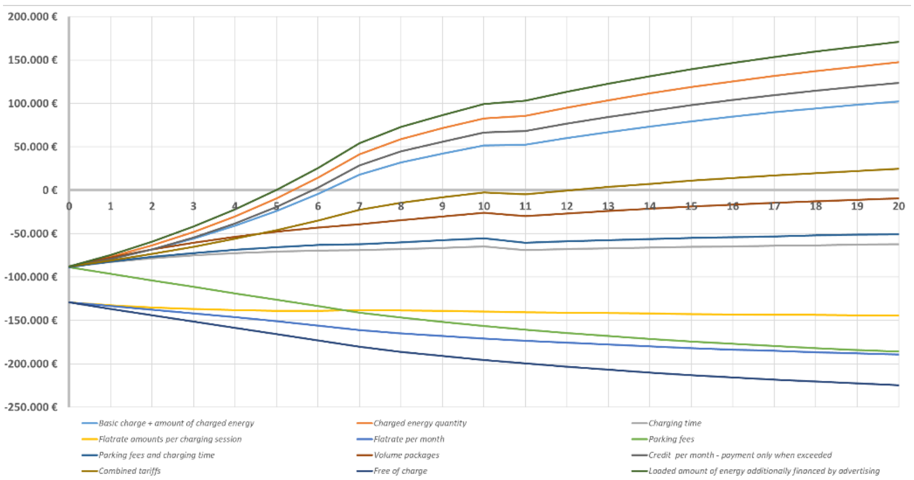

Figure7: Profitability of the business models of a 150 kW DC charging station

Since it is already apparent here that business models based on the billing of the charged energy quantity are to be favored at high power charging systems, a sensitivity analysis should show which lower limit of the respective parameters is enough to be able to record imputed profits within ten years. The consideration of the sensitivity of the business model to the exclusive billing of the charged energy quantity will serve as a basis for the following.

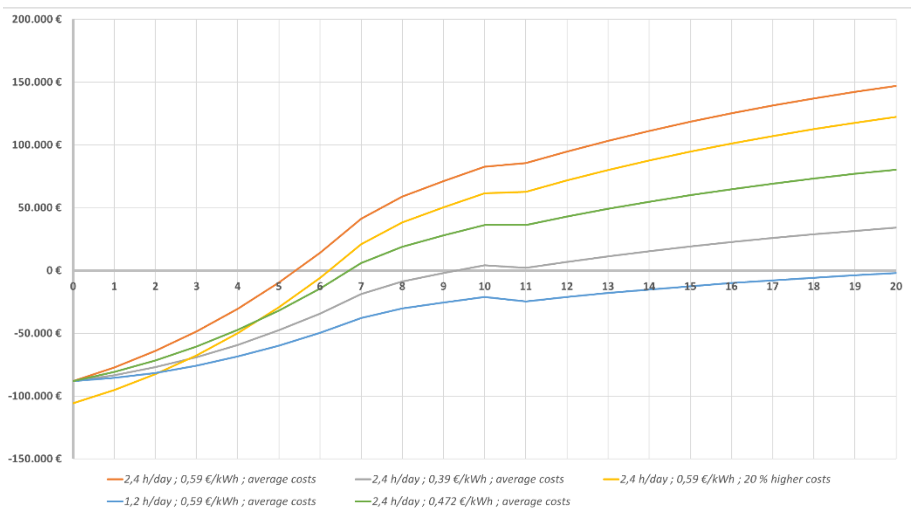

Figure8: Sensitivity of energy-based billing of a 150 kW DC charging station

The influence of the investment and operating costs is rather small compared to the other parameters. Thus 20 % higher costs lead to an approximately 17 % lower imputed profit after 20 years. On the other hand, a 20 % reduction in electricity revenues leads to a reduction of about 45 % after 20 years. The influence of electricity revenues is thus significantly higher than the investment and operating costs of this charging system. Since the usage rate is directly linked to the revenues, further analyses have shown that profitability is more dependent on the usage rate than on the costs of the charging system. If the usage rate is clearly below the assumed usage rate, the profitability of the business model is not given. A further sensitivity analysis of this parameter shows that to reach the profit zone within ten years, it is necessary to have an utilisation about 2 h/day with the average charging capacity.

Further analyses have shown that AC charging systems in public spaces are generally not a profitable business model. The 350 kW charging systems have a similarly high average charging capacity and are significantly more expensive to set up as a higher extension of the grid connection is required. Therefore, the profitability analysis of these charging systems shows a low profitability compared to the 150 kW charging systems used, but this is also a profitable business model in case of higher capacity utilisation. DC charging systems with a charging capacity of 50 kW are a solid business model in operation, but the almost maximum charging capacity has already been reached and scaling is no longer possible. Thus, even vehicles with higher charging speeds must stay longer at these stations and do not generate any additional revenue.

4.5 Analysis of the minimum kilowatt hour prices for DC charging systems

In the medium term, the German market will develop into a market in which billing will take place almost exclusively based on kilowatt hours purchased. It is therefore of great interest to know which lower prices limit is necessary to have a still profitable business model for DC charging systems and to what extent the competition can differentiate itself in price here.

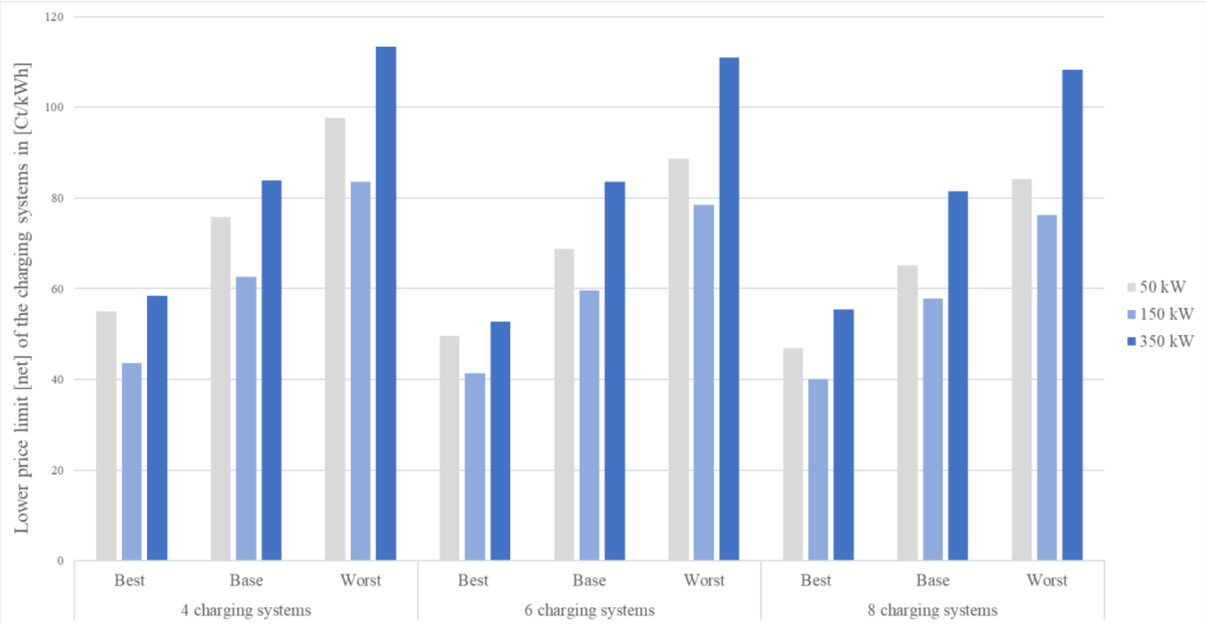

Figure9: Lower price limit (net) for a billing according to kWh at DC charging systems in a scenario analysis with variation of the number of charging points

An average utilisation of 10% leads to an almost constant difference between the individual charging systems in the scenario analysis and across a different number of charging points or stations. Economies of scale due to an increase in the number of charging systems are therefore negligible unless the maximum electricity sale rate is increased by increasing the average charging capacity.

It can clearly be seen that the 150 kW charging system provides the lowest price limit. This is due to the ratio of electricity sales to investment costs. Charging systems with lower charging capacity are much more limited in their energy output and charging systems with 350 kW have much higher investment costs, which must be depreciated over the years. Therefore, charging parks with 150 kW charging systems can already be operated profitably with approx. 0.75 €/kWh (gross). If the capacity utilisation is increased, this lower price limit will again be significantly lowered. It also shows that charging systems with 50 or 350 kW have significantly higher lower price limits. For 350 kW charging systems, this may be an acceptable surcharge for a premium charging experience for a small proportion of corresponding electric vehicle drivers, with 50 kW charging systems, however, it will be much more difficult to explain a corresponding surcharge to a customer.

5 Summary and outlook

The results of the analysis of the legal basis have shown that in Germany a completely calibration-compliant solution and handling is unavoidable for the charging infrastructure in the near future. At the same time, billing by kilowatt hours is the only transparent and fair way to design a business model for customers. If today's prices for charging processes are assumed, it is foreseeable that with a vehicle ramp-up the profit with billing by kilowatt hours will also be significantly higher than the other billing models. The sensitivity analysis of the charging systems with a high charging capacity and connection to the medium voltage has shown that the current revenues represent the greatest control lever for profitability, provided that enough utilisation is available.

The German calibration law can also serve as a model for other markets in Europe. However, the billing methods that have been partly established in other European countries today are much more difficult to calculate regarding to a lower price limit, as e.g. charging time is directly related to the charging speed of the various vehicles and initially has no direct influence on the energy consumed. Therefore, in addition to the adaptation of the German regulations, a kilowatt-hour-based billing variant is the only transparent solution for the customer, but also offers a good basis for calculation for operators. In this case, the results of this analysis can be transferred almost directly to other countries, under the premise that the installation costs do not deviate significantly from the conditions in the German market. The developed TCO-Tool offers German as well as other European operators a basis to check the design of the business models and to further develop them in accordance with the legal framework.

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Before joining P3, he studied industrial engineering with a focus on energy technology at the TU Dortmund and has also gained experience in other consultancies.