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A Customer-Based Proposal for a Unified Access to Charging Stations for Electric Vehicles

Günter Hofbauer
Professor, Technical University Ingolstadt, Esplanade 10, 85049 Ingolstadt, Germany, guenter.hofbauer@thi.de

Anton Vylegzanin
Technical University Ingolstadt, Esplanade 10, 85049 Ingolstadt, Germany

Abstract

The purpose of this article is to introduce a proposal for a unified activation process for charging stations of electric cars. Currently, many providers are searching for feasible applications and implementation of new charging technologies. Due to the fact that there is no unified standard for the activation process, various technologies, methods, processes and applications are offered. These problems are getting worse as more electric cars are used for long distances and as diversity increases. The underlying thesis of this paper is that there are too many different technologies and proprietary dependencies. This diversity leads to frustration and disappointment of customers, who are in search of electricity.
The methodology is empirical, theoretical, analytical and conceptual. The proposal is based on the results of an empirical primary research, which was carried out with an internet-based questionnaire. Selective literature research on existing technologies serves to a solid substantiation for the proposition. The requirements of the customers were analysed and matched with the features of the available technologies. Plug & Charge turned out to be a far superior technology. The conceptual part provides a two-stage solution to close the gap until the critical mass of Plug & Charge capable vehicles is reached.

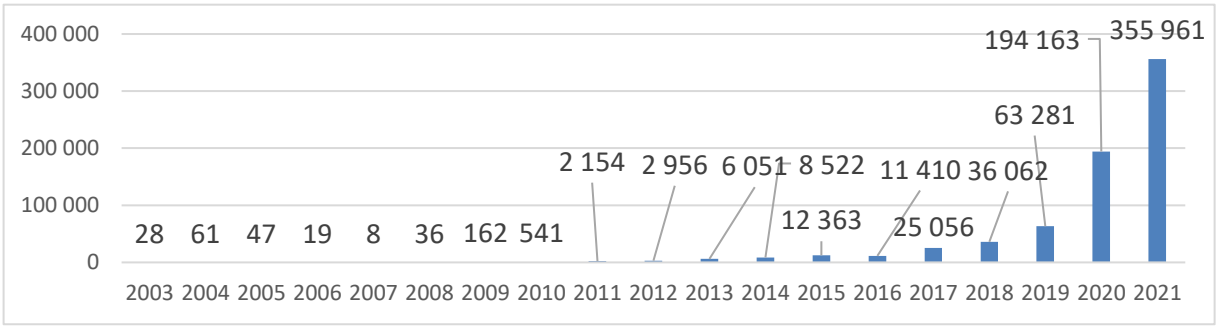
Keywords: activation; electrification; electric cars; charging stations; charging technologies

1. Introduction

The European Commission wants to ban cars with an internal combustion engine by 2035. This is intended to reduce CO2 emission and thus to protect the environment. To achieve this goal, the introduction of new taxes and other levies (Norddeutscher Rundfunk 2021) is planned. Further incentives should convince potential buyers of electric cars. In Germany, for example, there are monetary subsidies of up to 9,000 euros for the purchase of pure electric vehicles, called battery-electric vehicles (BEV) or plug-in hybrid electric vehicles (PHEV). The subsidies are provided from both, the government and the manufacturer (Presse- und Informationsamt der Bundesregierung 2021a; Allgemeiner Deutscher Automobil-Club 2021a;

Deutsche Energie-Agentur no date). In addition to this subsidy, which is initially limited until 2025, owners of electric cars can also enjoy other advantages compared to owners of vehicles with pure combustion engines. For example, tax benefits and waived vehicle insurance premiums are additional monetary benefits (Finke 2020a; Finke 2020b; E-Autos.de Deutschland 2020). These advantages are reflected in the increasing demand of electric vehicles. During the last few years, the number of new registrations of BEVs increased from a few vehicles into a six-digit range, as can be seen in Figure 1. While in total around 300,000 less passenger cars were registered in Germany in 2021 compared to the previous year, the number of registered electric vehicles increased to 355,961 new units in 2021 (Kraftfahrt-Bundesamt 2021; Kraftfahrt-Bundesamt 2022). As can be seen in Figure 1, the registration numbers of electric cars (BEV and PHEV) have risen sharply over the past few years.

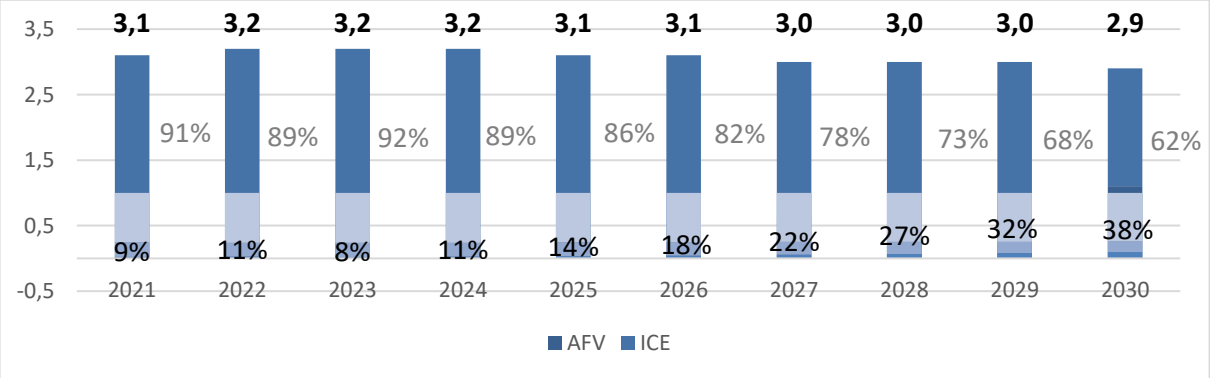
Figure 1: first registrations of electric cars per year



Source: Kords 2022.

This development is expected to continue in the future, so that the number of newly registered cars with alternative drives, especially BEVs, will increase rapidly. The increase in new registrations of electric vehicles with alternative drive systems, often called alternative fuel vehicle (AFV), is expected to continue in the coming years. Figure 2 shows that this increase is expected to be accompanied by a decrease in registrations of cars with internal combustion engines (ICE).

Figure 2: registered passenger cars in total per year



Source: Deloitte 2022.

2. Problem formulation and question of research

Regardless of the rising number of electric cars, many disadvantages of electric vehicles emerge and cause reasons to reject such a car. Despite the subsidies there are relative high purchase costs for electric cars. In addition to that, many respondents in Germany criticize the low battery range, the low number of charging stations available as well as a variety of systems to get access to the charging stations. Once the charging station is reached, 15 % of respondents criticize the difficulty of operating it. Another 14 % criticize the lack of uniform payment systems of different the charging stations (Deutsche Akademie der Technikwissenschaften 2020). It can be assumed that the problem will get worse, when the number of electric cars is increasing and concurrently the growth rate of the number of charging stations does not keep up. Another problematic reason for an increase of criticism will appear as soon as the lengths of run will increase and the drivers need to search a charging station in unknown places instead of their own wall box at home.

The activation of charging stations and the payment for charging are often linked and cannot be defined independently of each other. Some charging stations cannot be used if not activated by a specificly defined mean. For example, some charging stations located in parking garages must be activated with the parking ticket. The fees for parking and charging must be paid together when the car driver wants to leave the parking garage (Weemaes no date a). The lack of a uniform and compatible standard of the systems and the difficulty to easily use them could arise harsh criticism. Increasing numbers of users in search of power and an increasing variety of activation options will accelerate discontent. In addition to the mentioned parking tickets for activating a charging station, customers also have the possibility of using a variety of other options. A large number charging stations must be activated before they can be used for charging. This is often done by an authentication of the car driver as a valid user (Hilchenbach 2021). Currently, there are different types of activating solutions, which are used with varying frequency (Weemaes no date a). In the following section, these activation solutions are presented and their functional principles are briefly described.

All these findings lead to the working hypothesis that there are too many different technologies and proprietary dependencies provided for the time being. Currently it is a matter of fact that there is no unified standard for the activation process. Various different technologies, methods, processes and applications are offered. Providers are searching for feasible applications and implementation of new charging technologies. No one has asked customers and potential users yet about their needs and wants to charge their electric cars. Customers are used to quick and easy refuelling at the gas station. This expectation in combination with the diversity of applications leads to low acceptance as well as frustration of disappointed customers, who are in search of electricity for their cars. These problems are getting worse as more electric cars are used for long distances and as diversity increases. At the same time the expansion of the charging infrastructure is lagging behind plans. This makes the search for a suitable charging station even more difficult.

With reference to this situation, the question of research can be formulated as follows: Is there a preferred technology for users to activate the charging process? In order to answer this fundamental question, the main requirements from the customers' point of view have to be considered for the sought technology.

These questions will be answered on the basis of the judgements of the respondents surveyed in an internet-based questionnaire. Substantiated on the answers to these questions, proposals for all stakeholders can be derived. The range extends from public administration on all levels, from municipality to the EU commission, but also to the management of providers and car

manufacturers. The basic principle should be to create high acceptance and to avoid high variety. A comparable example for a misdirection was the lack of standardisation of charging devices for mobile phones, when they came up. The corresponding EU directive was launched in 2021.

3. Literature research on technologies

There are a lot of different technological solutions currently available. In addition to that, new technologies are in sight for future applications. Table 1 shows the types of technologies, grouping them into existing and future technologies.

Table 1: Types of charging point access (neues Format)

Existing technologies		Future technologies
• RFID charging card	• Hotline	• Biometry
• RFID key fob	• Bank card	• Login method
• Smartphone application	• Park ticket	• Other RFID/NFC wearables
• Website	• Plug & Charge	• Biohacking
• SMS		• Code scanner

Source: Author.

Some existing activation solutions are based on RFID technology. Such RFID chips store the data relevant to the charging station and can be read with the help of readers attached to the charging station. Charging cards are often used for this purpose. These are similar in size and shape to ordinary credit cards or fitness cards. As soon as the cards are contacted to the reader, the charging process will be started and the necessary data can be read (Hille energiesysteme 2018; Rankl & Effing 2018). This process is similar to contactless payment at the supermarket. For this reason, ordinary bank or credit cards are also frequently used for charging purposes (Ackermann 2016). RFID chips are also often integrated in key fobs in order to enable charging in the same way as charging cards. The only difference is the shape of the activation object, but not the technology behind it or the data stored on the chip (Metriax 2021). A similar technology called near field communication (NFC) is often used in wearables. They contain also chip, which can be coded. This is often used by smartwatches to replace traditional bank cards (Gildemeister 2021; Spehr 2018a). It is not known that smartwatches are used for charging stations activation, they can be theoretically used as such.

There are also smartphone apps that can be used to activate the charging function. For example, a code can be scanned at the charging station, which signalises the charging request at the charging station (Degner 2019). It is also theoretically possible to use the NFC chip in the smartphone to activate the charging station in the same way as the RFID card, including the identification and transaction process (Presse- und Informationsamt der Bundesregierung 2021b; Visa Europe Services 2021). The traditional use of the SMS and telephone function can also be used to activate the charging station. To do this, the user writes an SMS or calls a number noted on the charging station. In response, the user receives a code that must be entered at the charging station, which then unlocks the charging station (Weemaes no data a).

Web sites are also sometimes offered for the activation of charging stations. The handling is only slightly different from the apps, with the difference that the respective web page of the provider has to be opened manually in the web browser (Weemaes no data a).

Plug & Charge relies on a control unit installed in the vehicle to activate charging stations. The only thing drivers have to do is to connect the car to the charging station with a charging cable. The vehicle then sends the necessary data to the charging station itself. Additional confirmation or other steps as with other methods are normally not necessary (Weemaes no data a). The ISO 15118 was created as a standard for the communication between the car and the charging station. It unifies the data protocol and ensures data safety (Spanheimer 2020). The requested data are stored in the car when the customers registrate themselves at a charging station operator (HUSS VERLAG 2021).

The problem for customers with this high number of activation methods is that these methods often do not work across different providers. With the increasing number of RFID cards and apps for charging station activation in use of individual customers, customer confusion can increase, because they have to look for the right charging card for the charging station they are standing in front of, or they have to adapt to a new activation process (Allgemeiner Deutscher Automobil-Club 2021b).

In addition, there are other potential authentication methods, which are not yet used for charging stations, but are used in other contexts. They can be possibly adapted to the usage for charging stations. However, the advantages and disadvantages of the following methods must be evaluated.

For example, there is the possibility of a definite personal identification with biometric features. These can include fingerprints, facial features or the retina of the eye (Buchholz 2014). For this purpose, a respective scanner has to be installed at the charging station.

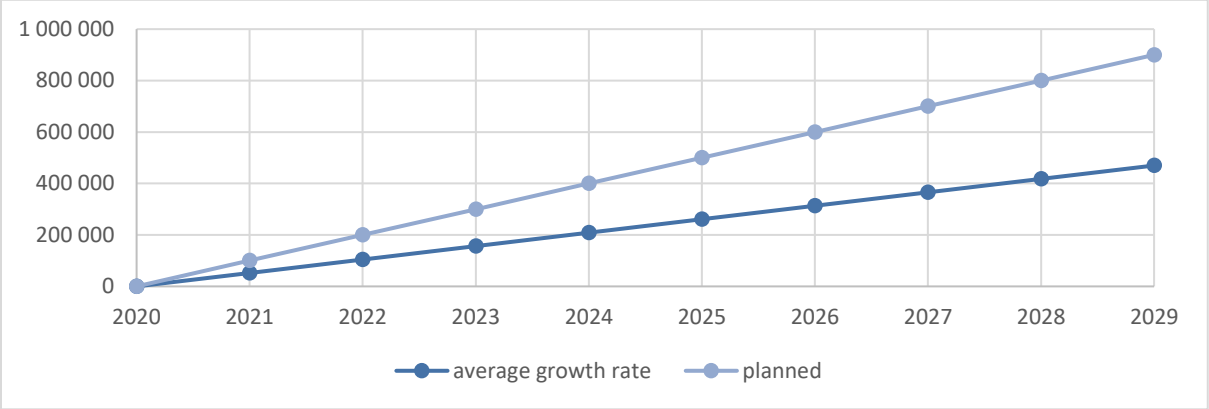
Biohacking would be another alternative. This involves placing a microchip under the skin, e. g. in the hand. Today, many people use such chips to pay at the cash register or to unlock and lock their homes. Since it is also an RFID chip, there is no technical objection to using it in the same way as charging cards and similar solutions for charging authorization (Kramer 2015; Spehr 2018; Koerber 2021).

The authentication data could also be entered manually using a login at the charging station. However, the login data must first be assigned by the charging station operator.

It is also possible to use a code scanner for authentication (Casper 2021). This could involve requesting an individual code from the charging station operator. This code would then have to be scanned with a code scanner at the charging station. The user's individual code would uniquely authenticate the user at the respective charging station.

Germany plans to install one million public charging points available by 2030. Currently, there are just about 52,000 charging points. Regardless of whether the expansion of the charging point infrastructure proceeds at the current average rate or as planned by the German government, the number of charging points will increase rapidly (Springer Fachmedien München 2022). That is why it is so important to set a standard now in the early development phase. The expected trends can be seen in figure 3.

Figure 3: Number of charging points over time



Source: Springer Fachmedien München 2022.

Due to the large number of different activation methods for charging station, the intention of this work is to design a uniform activation method. This should be oriented to the needs and wants of all the users. The handling should be simple and convenient. At the same time, it must be safe to protect personal data as well as to prevent misuse. This includes a physical durability as well as a security of the stored data. In the context of this work, individual attributes are to be evaluated by the importance to future users.

But not all authentication technologies are suitable for a customer-oriented activation process of charging stations. Before they were evaluated by future users, an overall usability test was done. As a result, biometry and biohacking were not part of the future survey and further conception. The reasons are as followed. It is important to have the possibility to change the authentication method if, e. g. it was stolen or lost. There are a lot of cases in which fingerprints and other biometrical features were copied and successfully used to impersonate the robbed person. As people normally have a limited number of fingerprints and other biometrical treats, they cannot be changed infinite times. This restricts the use of biometrical features (AO Kasperky Lab 2021).

On the other hand, it is important to have the opportunity to transfer the authentication method to other people, e. g. when a person wants to rent an electrical car. Implanted chips can be theoretically lent to other people and could be implanted under the skin of the new car owner, but it is prohibited by German laws to force people to harm themselves in such a way only to make a contract, because the physical intactness has a high priority in Germany (Bundeszentrale für politische Bildung 2015). That is the reason for biohacking methods not to be considered during the remaining part of this work.

4. Empirical research

After screening the authentication technologies for their general usability to activate charging ports, the opinion of potential users was investigated in this regard. Since there are no similar published studies of this kind, primary research was done to collect user data for this purpose. For this reason, the data collection method will be described first. This is followed by the data analysis.

4.1 Methodology

Quantitative research methods were used to obtain an overview of the preferences of potential users of charging stations. In contrast to qualitative methods, these quantitative methods aim to quantify the outcomes and to generalize the results of the sample to the relevant population (Kuß, Wildner & Kreis 2018). The goal here is not to establish cause-effect relationships, but to describe the desires of the particular population. Since it is not possible to observe all desires in this context, a survey is selected as the data collection method. A highly-standardized questionnaire, which follows a fixed survey scheme, served as the survey instrument. It was distributed online to the invited participants. The participants did not have the possibility to skip individual questions without discontinuing the questionnaire.

The population, whose opinion on the activation methods was under research, consists of all citizens of the Federal Republic of Germany with a valid driver's license for passenger cars. The number of these people was about 57.45 million in 2020 (VuMA 2021). Since it is not possible to ask the entire population about their wishes within the scope of this work, a random sample of them was used. The interviewees for this were contacted by random selection. The random selection was limited by the possibilities of the selected person and the available channels. The subjects were contacted online. In this proceeding, the survey was distributed over different channels. This contact method had the advantage that it made it possible to contact a large number of people quickly (Raab, Poost & Eichhorn 2009).

One channel was the poll-pool.com website. Surveys can be shared on this platform. Other users can participate in the shared surveys. The incentives for participating on others surveys is the possibility to have more respondents in one’s own survey (Abel &Burkart 2019). Additionally, the poll is published in the GoingElectric online forum. Main contents of the forum posts are electric vehicles and related topics. Here, answers to the survey are expected from people, who are interested in the topic of future mobility (Weemaes no date b). Likewise, the survey was distributed via the student mailing list of the University of Technology Ingolstadt. Recipients are all students of this university.

The survey contained 17 questions, which were divided thematically into five groups. At the beginning, the possesion of a driver’s license was asked as an admission requirement for the survey. Next the respondents were asked to rate activation methods and the relevance of some features on a scale, as well as a combination of both. Furthermore, the respondents had to choose between different characteristics, which they would prefer more over others. Lastly, questions are asked about the demographics of the subjects. These include age, gender, purchase price and annual mileage of their own vehicle, but also the size of their place of residence.

4.2 Structure of the participants

The survey was published on October 7, 2021 and was closed on November 4, 2021. During this period, a total of 564 people participated in the survey. 412 participants fully completed the questionnaire.

Approximately 61% of the respondents were male and 37% female. About 11% drive an electric vehicle, with 8.25% owning a fully electric car. The average age is slightly above 25 years and the average purchase price of their vehicle is 16,438 Euros. They drive on average about 14,016 km per year with their vehicle.

To make the survey results representative, a confidence interval of 95% and a sampling error of 5% are assumed. This leads to a necessary sample size of at least 385 subjects (Raab, Poost & Eichhorn 2009). The number of valid questionnaires in the survey conducted as part

of this work exceeds this value. Thus, the responses can be considered representative in this aspect.

4.3 Analysis of the survey

After the successful conduction of the survey, the data can be analysed. First, it has to be examined how the individual activation methods were evaluated among the respondents. The respondents were directly asked to evaluate all methods on a scale between "1" and "10" according to general criteria. The higher number, the better the evaluation. For the evaluation in the context of this work, the respective mean score was used. The mean scores given can be taken from Table 2.

In addition, the responses of individual subject groups were considered to determine differences, if any. This includes subdividing the subjects according to the drive type of their vehicles, their corresponding mileage and purchase price. As Table 2 shows, Plug & Charge was rated the best among other activation methods overall groups. It is followed by the charging cards, key fobs, smartphone apps and bank cards. Hotline, SMS and website were rated the worst.

Table 2: Evaluation of the activation methods

Activations Technologies	Overall Ranking	Vehicle dependent rating			Mileage dependent rating		Purchase price dependent rating	
		ICE	BEV/PHEV	No car	Below avg.	Above avg.	Below avg.	Above avg.
Charging card	7,238	7,127	7,333	7,768	7,368	6,970	7,260	7,080
RFID key fob	7,121	7,049	7,063	7,571	7,347	6,659	7,177	6,720
Wearable	6,075	6,019	5,646	6,750	6,116	5,993	6,033	6,380
Bank card	6,308	6,305	6,042	6,554	6,336	6,252	6,273	6,560
Smartphone application	7,148	7,276	6,125	7,321	7,260	6,919	7,224	6,600
Website	3,867	3,906	3,271	4,161	3,953	3,689	3,917	3,500
SMS	3,648	3,659	2,875	4,250	3,888	3,156	3,680	3,420
Hotline	2,374	2,477	2,104	2,036	2,484	2,148	2,395	2,220
Park ticket	4,752	4,893	4,396	4,286	4,852	4,548	4,840	4,120
Plug & Charge	8,325	8,240	8,563	8,589	8,238	8,504	8,285	8,620
Login	5,352	5,601	3,604	5,482	5,556	4,933	5,539	4,000
Code scanner	5,862	6,058	4,604	5,857	6,022	5,533	5,970	5,080

Source: Author.

Since there appears to be a similarity in scores between the groups, the scores within the groups were tested for correlation between the expressions. The Pearson correlation coefficient can be seen in Table 3. This coefficient is above 0.9 in all cases shown, indicating a strong dependence between the various expressions. This means that the respondents' opinions are independent of their vehicle's drive type, mileage and purchase price. Here it is particularly important to note that the opinions of drivers of vehicles with an internal combustion engine and an electric car hardly differ. Thus, the increased statements of ICE drivers can also be transferred to the result of this work.

Table 3: Correlation of the evaluations of customer groups on activation methods

ICE-Electric Vehicle	ICE-no car	Mileage	Purchase price
0,942914	0,977415	0,989227	0,958322

Source: Author.

In the next step, some properties were presented to the respondents and they had to rate the respective importance on the same scale as before. It was explained to the respondents that these properties belong to a possible activation solution. Table 4 shows he mean ratings.

Table 4: Evaluation of the importance of attributes

Activations Technologies	Overall Ranking	Vehicle dependent rating			Mileage dependent rating		Purchase price dependent rating	
		ICE	BEV/PHEV	No car	Below avg.	Above avg.	Below avg.	Above avg.
Simplicity of handling	9,153	9,039	9,667	9,339	9,148	9,163	9,157	9,120
Fast activation (in terms of time)	9,175	9,068	9,542	9,446	9,162	9,200	9,193	9,040
Same handling at all charging stations	8,604	8,536	8,563	9,018	8,588	8,637	8,641	8,340
Ergonomics	6,869	6,740	7,063	7,411	6,715	7,185	6,826	7,180
Physical durability from wear and tear, etc.	7,381	7,292	7,479	7,786	7,300	7,548	7,370	7,460
Security against data misuse	8,600	8,552	8,688	8,786	8,603	8,593	8,655	8,200
Security against theft	8,699	8,669	8,375	9,143	8,744	8,607	8,798	7,980

Source: Author.

The handling simplicity and the fast activation were rated above average by the respondents. The respondents placed the least value on ergonomics and physical durability. The data show that there is also only a little difference between the ratings of different respondent groups. Table 5 shows that the Pearson correlation coefficient is above 0.9 between all investigated groups of ratings. That means, that there is no difference between the opinions of the individual groups as well.

Table 5: Correlation of the evaluations of individual customer groups on attributes

ICE-Electric Vehicle	ICE-no car	Mileage	Purchase price
0,949872	0,99319	0,99313	0,915974

Source: Author.

The same findings apply in the following evaluations of the answers. The respondents were shown the same activation methods and attributes as before. They had to decide which activation method complies the attributes the best. Plug & Charge was selected the most times with a large difference to the second placed for each attribute. Table 6 shows only a selection of the activation method. The selection consists of some of the methods chosen the most by respondents. Furthermore, the respondents answered the questions similarly regardless of their vehicle, mileage and purchase price.

Table 6: Fulfilment of the attributes by the activation methods - Number of votes

	Handling simplicity	Fast activation	Handling equality	Ergonomics	Physical durability	Data security	Theft security
RFID-charging card	54	61	53	49	41	43	24
RFID key fob	48	58	29	48	32	23	18
Bank card	17	14	25	15	12	29	16
Smartphone application	62	38	79	68	77	33	49
Park ticket	13	6	17	11	21	82	39
Plug & Charge	180	190	142	153	151	109	159
Login	7	3	21	8	18	25	36
Code scanner	9	17	20	12	18	20	18

Source: Author.

Furthermore, on the next questions, the respondents had to decide between the best suited stowage form of the activation method. With a majority of 284 answers (69%) the integration in the car was preferred to the card, pendants and similar things, digital storage on

the smartphone and others. In addition, the future customers want to have their own activation methods, which they possess instead of things that are e. g. attached or integrated in the charging station like it would be with a code scanner within the scanning method. The respondents do not want to enter any data, but if it has to be entered, they only want to enter non personal data. Furthermore, they want to do it without any buttons and touch field, but automatically. Additionally, the respondents prefer to use new, even unknown technology instead of old technology.

5. Application of the findings for a common unified concept

After analysing the survey responses, a customer-oriented solution, based on the results of the analysis, was designed. Plug & Charge was rated best by the respondents (Table 2). The features selected by the surveyed persons for the unlocking methods, such as the deactivation form, the novelty of the technology, the ownership and data entry are also met the best by Plug & Charge, as chosen by the respondents. Therefore Plug & Charge served as the basis of the future customer-oriented activation concept. The next step was to check whether Plug & Charge already met the customers' needs. If not, it should be adapted for this purpose.

5.1 Plug & charge as a proposal for the long-term solution

Since Plug & Charge is defined in many aspects by the ISO 15118 standard, this already creates uniform communication options between the charging stations and the vehicles to be charged. Due to the fact that only the plugging in of the charging cable is necessary for successful charging with already completed registration, there are few design options compared to other methods. Due to the necessary registration, a payment method is currently stored at Plug & Charge. However, in the future, registration should not depend on individual companies, to avoid that only their charging stations can be used. Instead, only the driver's general data required for authentication and payment of the charging process will be stored. The only relevant data is the card number of the stored debit card, the card type and its expiration date. No other data need be transmitted (CHECK24 Vergleichsportal Karten & Konten 2019). This ensures that the amount to be paid for the charged electricity is automatically debited from the customer. It is recommended that the amount to be paid has to be debited promptly after the charging process has been stopped.

In the case of no pre-registration, the car driver should be able to enter the mandatory data into the vehicle identification by himself or, if assistance is required, with the help of the car dealer. If data are missing, the charging station will refuse to accept Plug & Charge as an authentication method.

The features (Table 4) rated best by the surveyed respondents can be implemented without restrictions by Plug & Charge. As described above, Plug & Charge activates the charging station by simply connecting the user's own vehicle to the charging point using a charging plug. Compared to other methods, which require additional steps to be performed in addition to plugging in the charging cable, Plug & Charge is therefore the fastest activation method in terms of time. The activation speed cannot be improved anymore, without changing the technical side of Plug & Charge.

Likewise, this method is the easiest to use compared to others. Apart from the initial registration, only the cable has to be connected for each charging process. As previously described, the remaining methods require the completion of additional steps. This also fulfils the desire for uniform operation at all charging stations.

Security against misuse of the data is ensured by using the ISO 15118 standard. As described above, the data sent to the charging station are encrypted (Spanheimer 2020).
Security against theft arises from the lack of additional necessary devices for charging release. The charging cable is already locked during the charging process in some vehicles, for example in some models from the car manufacturer Volvo, and cannot be unlocked and removed from the vehicle by third parties (Volvo Car Corporation 2019).

Other aspects selected by customers will be examined. The most often prioritized form of storage by the respondents is already realised by the nature of Plug & Charge. As showed in section 3, it must be integrated into the car, as its operating principle is based on it.

The subjects' desire to use their own devices instead of devices attached to the charging pole also only slightly affects Plug & Charge. During authentication, only a charging cable is used by the customer. This must also be used for charging with nearly all other activation methods, except inductive charging, in order to transmit the electrical current from the charging station to the car battery. Although a charging cable is already available at some charging points, customers can still satisfy their desire to use their own items and plug in their own charging cable (Babcicky 2021). The type of data input is equally in line with the respondents' wishes. On the one hand, no direct data input by the users is required, and on the other hand, the charging request does not have to be confirmed, as this is signalled to the charging point by the plugged-in charging cable.

As starting points for a customer-oriented design, the exchange of data during registration and roaming between charging stations of different providers remain. As described in section 3, a contract must be concluded with a provider before Plug & Charge can be used by a customer for the first time. This contract is the prerequisite that the billing data be processed and stored into the charging point operator. Due to the necessary registration, it is recommended that the contract partner offers nationwide roaming so that the customer can use all reachable charging stations.

But Plug & Charge is not supported by many car models for the time being. Even though the companies can upgrade their charging stations to support Plug & Charge, a large amount of car models supporting this system is expected in 2025. That is why a temporary solution was designed for short term use.

5.2 Charging card and smartphone app as interim solutions

In this paragraph Plug & Charge, as presented in section 3 and subsection 5.1, will be compared to other technologies. By using Plug & Charge, the respondents' desire for new technologies is fulfilled. The proposed concept has to fulfil the desires of the customers as best as it can. The activation methods charging card and smartphone app achieved the second and third best average scores, both, in the overall evaluation and in the individual evaluations, with the respective average scores being similar. For this reason, the attributes rated by future users were looked at in more detail.

The two best-rated features, ease of use and fast activation, favour the charging card as an adequate activation method. Due to diverse functions of the charging apps, it can be assumed that multiple steps are often necessary within the app to perform the activation of the charging station. However, the charging card often only needs to be held up to the reader at the charging point. Thus, activation with the charging card can be executed faster.

The same handling at different charging stations can be implemented by both methods. For this, the respective charging card must support roaming from the provider's side. This also applies to the app, depending on its version. If activation is implemented in the app by means

of a charging station search, it is necessary that all charging stations currently in operation can be selected in the app.

The security against theft cannot be compared between a wallet theft and a cell phone theft, since no statistics are available for this matter. It is assumed that because both items are often carried close to the body or in pockets, the chances of theft are roughly the same. Security against data theft is also difficult to assess. Therefore, only the fact whether there is a general possibility of data theft is considered here. No incidents have yet been found in which readers for RFID cards were manipulated invisibly to the user in order to read the card data. Data theft from apps can take place via malware. However, it can be assumed that apps from charging station operators are normally free of such software (Martin 2021).

In addition, the surveyed persons prefer button-free data entry rather than manual data entry, which speaks in favour of the charging card, as it only has to be held against the reader. However, the digital stowage form of the card is clearly more preferred. Likewise, the respondents would like to see the use of new technologies, which speaks in favour of the smartphone apps.

In a comparison of charging cards versus smartphone apps, the cards score slightly higher. At the same time, the two most important features for the respondents, the simplicity and speed of charging approval, score best. With respect to other aspects, the charging card is often on a par with the apps, or in some cases better. For these reasons, the charging card is designed in the following as the method for a short-term implementation. Nevertheless, the smartphone apps have a high rating and possess some advantages over charging cards. Therefore, an attempt was made to design a smartphone app that can supplement or, in some cases, substitute the charging cards.

The design is to be worked through on the basis of the individual properties. The respondents require that the activation should be fast. The charging card offers several design options for this. To authenticate oneself as a customer at the charging station, the charging card can either be held up to an RFID reader or inserted into a card reader. Since holding the charging card up to the reader and the reading process is usually faster than inserting the card into the device, this alternative is chosen for the design. An app can assist in this regard. Many smartphones already support NFC, an app can theoretically store the contents of the charging card on the respective smartphone. Thus, depending on preferences, the user can either hold the charging card or the smartphone to the NFC reader for charging release and have the data read from the chip.

The design of security against theft is limited due to the physical nature of the unlocking method. It is assumed that the charge card will be stored in the owner's wallet along with other cards, since it is the same size as other cards, such as a credit card, as previously described. This is similar with the smartphone. In both cases the user has to take care of the security of his cards and devices.

Security against data misuse cannot be influenced directly via the charging card either. A two-factor authentication, which requires further entries in addition to reading out the chip data, could prevent the consequences of data theft and the theft of the activation items. However, it is not recommended due to the increasing complexity. However, something different is recommended here. The customer should be given the option of temporarily or permanently blocking his charging cards either via the app or via other web applications. Thus, in the event of theft or loss of the activation object, the user can block it from being used by third parties. In addition, it is advisable for the issuers of the charging cards and apps to document all charging processes with the date and location. These can be displayed within the app. If the user notices that vehicles have been charged using his identity but he was not

involved, he can react accordingly and, if necessary, block the use of the charging function of his charging card and app and apply for a replacement card with different authentication data.

The same handling at all charging stations can be influenced indirectly via the charging card. For this purpose, all charging stations must be equipped with a corresponding RFID and NFC reader.

Since registration is unavoidable when using charging cards, it is necessary for the issued charging card to function in a cross-provider roaming network. As described in Chapter, this must at best be extended to all charging stations in operation. In addition, a payment method should be stored as part of the registration process. This will enable automatic payment and avoids unnecessary steps done be the users.

The smartphone app functionalities described above can be expanded with further functions to improve the charging experience for customers. In order to find a nearby charging station, these can be mapped within the app. This can be designed analogously to Google Maps or other map services (Google Ireland 2021). It is recommended that routes to selected charging stations can be put either within the same app or by forwarding them to the smartphone's own map service. It can also be advantageous for users to be able to view the charging history in the form of charging time, charging location and the charge paid.

5.3 Migration concept

The use of the charging card is to continue until the Plug & Charge technology has become sufficiently supported and established. The mere introduction of Plug & Charge will not be enough to end the use of the charging card. The diffusion process of both technologies in the charging sector must be observed. Only when the charging card is in the decline phase and is thus displaced by Plug & Charge, its use can be terminated (Hofbauer 2018).

As described in section 3, debit cards are similar to charging cards in their functional principle. In the normal case, it can be assumed that charging station operators only expect a monetary payment in return for the service provided. Since, contactless payment using NFC is already possible, and this function can also be transferred to smartphones, the charging card can theoretically be replaced by a debit card. Since a large proportion of Germans own a bank card, and are therefore already registered with a financial institution, there is no need to register additionally for the purpose of charging.

Due to the similarity of usage and functionality, the charging process would be as simple and quick for users as it would be with the help of a charging card. Likewise, due to the physical nature of the debit card, it would be just as secure against theft and misuse by third parties.

However, uniform handling, in the sense of cross-provider roaming, is easier to solve with a debit card in comparison. The common debit cards can be read at all readers designed for this purpose. It is possible that the contents of charge cards are encoded in such a way that they can only be read and interpreted correctly by the systems intended for this purpose. Uniform communication requires a uniform standard similar to the ISO 15118. However, since debit cards can already be read by common readers, roaming in this respect can be implemented quickly from the technical side.

The debit card achieved an average score of around 6.31 points across in the survey, putting it in fifth place. Its score is above average. Despite the many similarities to the charge card, it scored approximately 0.93 points lower than average.

Due to the previously described advantages over the charge card, it is recommended that the debit card can be used as an activation method as a short-term measure. This should be replaced in the use of Plug & Charge due to the wishes of the test persons in this regard.

6. Conclusion

The underlying working hypothesis that there are too many different solutions for the activation procedure of charging stations has been confirmed. Thus, complexity of the activation of charging stations should be avoided in order to increase customer satisfaction. In order to answer the question of research, a comprehensive understanding of the general situation regarding the activation of charging stations was provided first. Existing enabling methods were described in detail. In addition, potentially usable approaches were pointed out.

The subsequent evaluation of all these methods reduced the shortlist. The evaluation was based only on generally objective criteria.

In order to get insight into customers' needs and wants, a questionnaire was the best way to figure out. The survey was answered by a total of 412 respondents, who fully completed the questionnaire. As verified before, this number exceeds the necessary number of respondents for a representative result on a significance level of 95%.

After accurate analysis of the survey results, Plug & Charge was designed as the long-term method for the most preferred customer-oriented deployment. According to the answers of the respondents, it is assumed the safest, most convenient and easiest method to use. However, this technology is not yet supported by enough vehicles for the time being. So, the critical mass has not yet been reached and this technology cannot be used to a large extent. Sufficient penetration of this technology among electric vehicles is not expected before 2025.

For this reason and as a first step, an adequate interim solution has been proposed on the basis of the survey. This is intended to bridge the time until Plug & Charge is sufficiently widespread. Initially designed as a charging card with RFID technology, the solution was transformed into a debit card in the course of work. It fulfils the features and aspects important to the respondents similar to the charging card at a relatively high level. It also facilitates cross-provider roaming and saves the user from additional registration procedures.

For a second interim step, a smartphone app was suggested to support the debit card and also the future Plug & Charge procedure. Among other means, it should also be possible to enable charging, as well as to view the history of past charging processes and to plan routes to nearby charging stations.

To sum up, the central research question "Is there a preferred technology for users to activate the charging process?", postulated in section 2 was answered. A customer-oriented activation solution for charging stations in the form of Plug & Charge was found out. This is both, simple and convenient to use from the respondents' point of view. At the same time, it is secure with regard to theft and data misuse.

In order to bridge the time, until the Plug & Charge technology has become sufficiently supported by the car manufacturers, the debit card as a temporary solution should be established in a first step. Close to that proposal, the charging card includes the requested characteristics and are thus customer-oriented from the respondents' point of view. In a second step, smartphone apps should be introduced.

The limitation of this research may be that the survey took a snapshot of participating respondents' opinions. It is conceivable that the opinions of the subjects regarding the preferences and evaluations of individual solutions, features and aspects may change over time. This is particularly relevant with regard to the delayed introduction of Plug & Charge. For this reason, it makes sense to repeat and reissue the survey at a later time.

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