Project Wirkketteladen "Customer journey"

Final Report v2.6

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1. Introduction

1.1. Task

Until the 2000s, electric mobility was pioneering and both vehicles and charging possibilities were essentially prototypes; for electric vehicle users, it was therefore common for charging processes to take a long time and not every charging attempt resulted in a charged vehicle.

Today, more and more electric vehicles are being mass-produced and adequate charging infrastructures are being built with great public effort. Furthermore, many new products, functions, services (e.g. **Plug and Charge or Vehicle to Grid**) and business models are entering the german market, both from German and foreign market participants. This increases the complexity of the charging process and, based on internal data, results in 10-15% of all cases in a vehicle that is at a charging point not being able to be charged. In addition, the process of charging an electric vehicle will in future affect more and more users who are not innovators or early adopters and are therefore less tech-savvy. It should therefore be examined whether current charging technologies also help these customer groups to have a positive charging experience.

A decisive factor is that many different market participants, such as charge point operators (CPOs), e-mobility providers (EMPs), vehicle manufacturers (OEMs), charging station manufacturers (EVSEs), backend operators and network operators (grids), must form a smooth chain so that vehicles can be reliably charged. The following overview shows the different market participants in a simplified **"big picture" of** an **ECOSYSTEM Charging** and the logical interfaces in principle (source: BMW, modified):

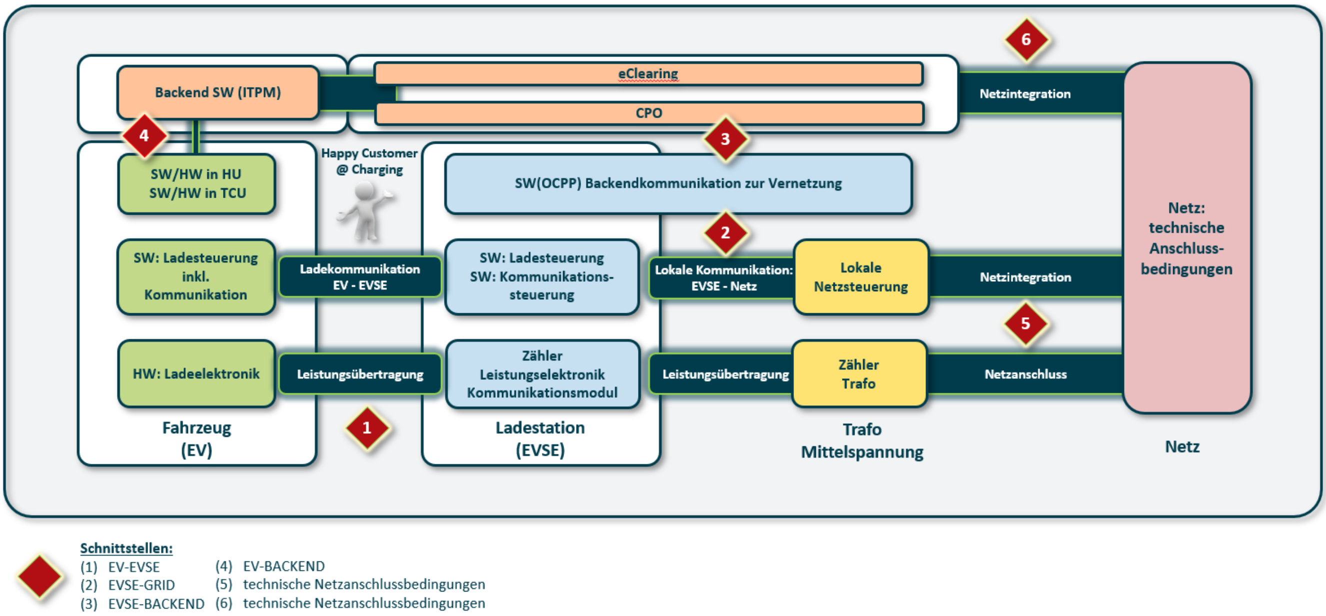

Figure 1 Simplified overview of the charging ecosystem (Source: BMW)

The interoperability of the individual components of a **charging chain** (vehicle, charging station, energy supply, backend, smartphone, etc.) of the different market participants is of crucial importance. The potential interaction of the individual components can only be achieved through a clear definition of the logical interfaces. International standards already exist for the interfaces, which can be used as a basis for product manufacturing. The standards specify not only communication aspects, but also the energy flow, electromagnetic compatibility and safety aspects. When attempting to charge, the customer as end user "plugs in" the system from different suppliers and expects a positive charging experience. In reality, to date many of the standards have broken new ground and the technical specifications have been developed from different angles of consideration. In addition, the charging standards concerned are still "young" overall, have mostly only undergone a few revisions, and their quality is not comparable to those that have been worked on and also harmonized over decades in the standardization committees. Furthermore, there are still no standardized test cases and test systems for many of the interfaces, so that ultimately the products of many different manufacturers have to be tested against each other with considerable effort in order to ensure the smoothest possible functioning in the entire **charging chain. In addition, the** market players involved do not yet have a common overall understanding of which aspects in the **charging chain** most frequently lead to a charging process not being completed as desired; this occurs against the background that the individual participants each work individually on the challenges, but no common view of the problem has yet been developed and is available as a common jumping-off point for necessary further developments.

1.2. Project goals

The overall objective of the project described here is to consider the complete **charging chain of** the market participants involved in the @PUBLIC and @PUBLIC HIGHWAY charging processes with a focus on successful charging of the vehicle (also taking into account the **"Plug and Charge and Vehicle to Grid"** functionality). The approach to solving the described problem consists of presenting errors and error causes according to frequency along the **charging chain on the** basis of data from real charging processes and supporting with findings from the real-lab test. From this overall view, a methodology for describing the maturity of the interfaces involved in the charging process in **the ecosystem charging** was created in order to better understand which interfaces and elements of the charging chain need to be addressed first in order to improve the quality of the charging processes. The overall result of the project will be a catalogue of measures for the market participants involved. In addition, the target image of the **charging chain** will be expanded in a first approach to include future scenarios such as autonomous parking and automated charging.

The aim is to look at different vehicles and charging stations from different manufacturers. Therefore, vehicles of different origins are used in the project:

a) The data analysis will be based on data from vehicles owned by private individuals or companies that use the charging points considered in the project. Based on the number of charging points considered and the average number of charging processes carried out there per day in the 12-month period under consideration, at least 40,000 charging processes are to be analyzed. This corresponds to around 7,000 different vehicles.

b) For the real-lab test with test persons, vehicles of a car rental company are used, which has a wide model cross-section.

1.3. Planning and procedure

The project was divided into several work packages and responsibilities were assigned. **CharIN e.V**. acts as consortium leader and product owner for the CCS charging system and coordinates the project activities.

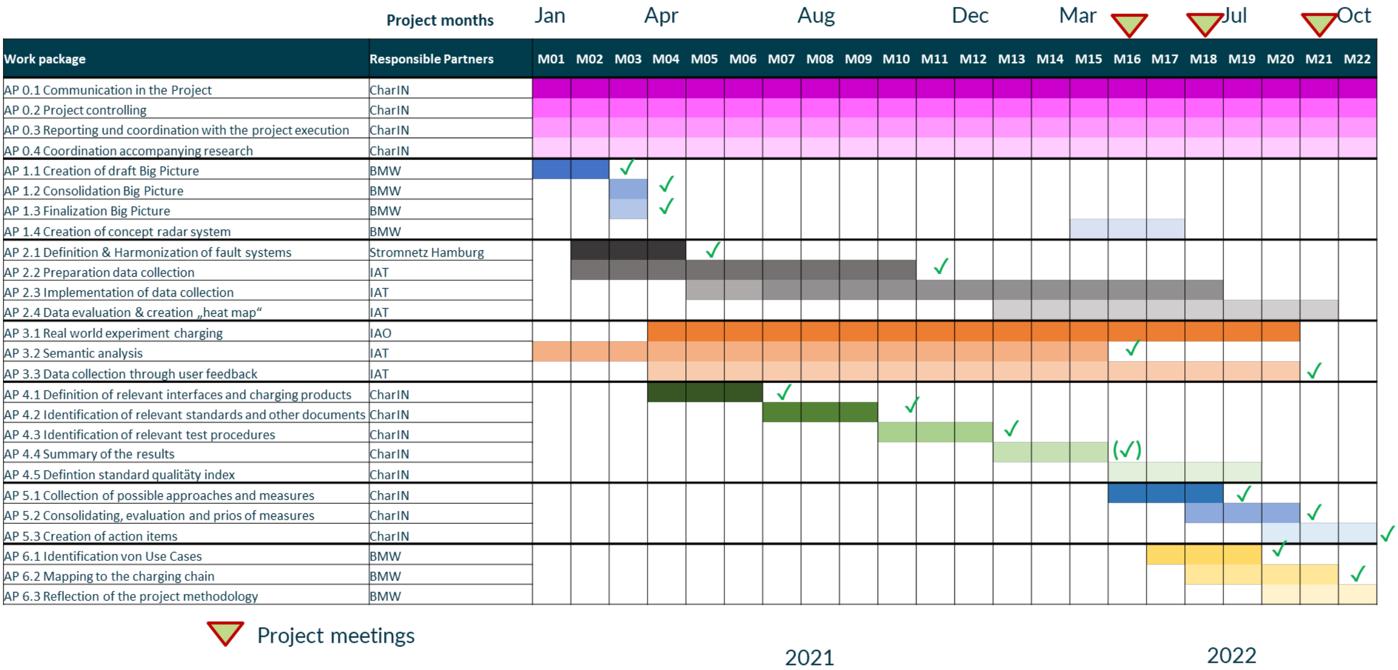

Figure 2 Project plan for the charging chain

AP0

Within the framework of this work package, the project activities are coordinated centrally by **CharIN e.V.**. There is continuous budget and target achievement control, coordination and reporting to the project executing agency. Furthermore, **CharIN e.V.** assumes the role of project-specific contact for the accompanying research of **NOW GmbH**.

Work package	Responsible Partners	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22
AP 0.1 Communication in the Project	CharIN																						
AP 0.2 Project controlling	CharIN																						
AP 0.3 Reporting und coordination with the project execution	CharIN																						
AP 0.4 Coordination accompanying research	CharIN																						

AP1

Coordination of a common **big picture of** an **ECOSYSTEM charging in** an intermodal transport and energy system in 2030, including the key player roles involved in the market, taking into account relevant interfaces and standards specifying the interfaces, e.g. OCPI, ISO 15118 (standardization organization: ISO, SAE, UL, IEEE...) / as well as functions and services based on the standards, such as **Plug and Charge, vehicle to grid** or **charging station reservation**. Development of a common "radar view" (= management view) of the **charging chain** with a view to the current situation today (2020) and the target situation in 2030. This is causally derived from the **Big Picture**.

Work package	Responsible Partners	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22
AP 1.1 Creation of draft Big Picture	BMW																						
AP 1.2 Consolidation Big Picture	BMW																						
AP 1.3 Finalization Big Picture	BMW																						
AP 1.4 Creation of concept radar system	BMW																						

AP2

Over a period of twelve months, data from charging processes will be collected at the locations of the project partners and the unsuccessful charging processes will be analyzed afterwards. On this basis, a **"heat map" will be** developed along the chain of effects through **ECOSYSTEM Charging** (problem hierarchy analysis) and a targeted description/analysis of the causes (where exactly is it "stuck" and what is the reason).

Work package	Responsible Partners	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22
AP 2.1 Definition & Harmonization of fault systems	Stromnetz Hamburg																						
AP 2.2 Preparation data collection	IAT																						
AP 2.3 Implementation of data collection	IAT																						
AP 2.4 Data evaluation & creation „heat map“	IAT																						

AP3

The processing of this part of the project takes place in three approaches:

1. In the **"real-lab experiment charging",** experienced and inexperienced people will carry out charging processes, which will then be examined within the framework of a design thinking approach.
2. Evaluation of user feedback received via the **GoingElectric** platform, which is very well-known among e-vehicle owners.
3. Evaluation of user feedback, which is requested directly at the charging station via a questionnaire.

The objective of the entire work package is to include sources of error in the analysis that may not be exclusively attributable to a faulty technical implementation of the existing standards but should rather be seen in the context of **"usability".** Furthermore, errors can also occur during the charging process that are not even visible in the backend of the charging infrastructure, which is analyzed in WP 2, because the charging process was never started.

Work package	Responsible Partners	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22
AP 3.1 Real world experiment charging	IAO																						
AP 3.2 Semantic analysis	IAT																						
AP 3.3 Data collection through user feedback	IAT																						

AP4

In this work package, a set of interface-specifying documents is to be defined and a standards quality index is to be developed. This will describe the interfaces and charging products along the **charging chain** and their **interoperability.**

Work package	Responsible Partners	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22
AP 4.1 Definition of relevant interfaces and charging products	CharIN																						
AP 4.2 Identification of relevant standards and other documents	CharIN																						
AP 4.3 Identification of relevant test procedures	CharIN																						
AP 4.4 Summary of the results	CharIN																						
AP 4.5 Defintion standard qualitäty index	CharIN																						

AP5

Work package 5 will consolidate and prioritize the knowledge gained in the previous work packages on problems and errors in the charging process at different interfaces along the chain of effects that has been developed. An **evaluated catalogue of measures** will then be derived from this, which will be incorporated into a roadmap. This roadmap shows to what extent the quality of the interfaces can be continuously improved on the basis of the measures to be implemented. After analyzing the current situation, the target situation at a defined point in time still needs to be worked out and specified. This target situation describes the expected result from the customer's point of view.

Work package	Responsible Partners	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22
AP 5.1 Collection of possible approaches and measures	CharIN																						
AP 5.2 Consolidating, evaluation and prios of measures	CharIN																						
AP 5.3 Creation of action items	CharIN																						

AP6

The content of this work package includes both future use cases and future customer functions (automated charging, convenience charging, PHEV operating strategy support, autonomous parking and autonomous re-parking).

Work package	Responsible Partners	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22
AP 6.1 Identification von Use Cases	BMW																						
AP 6.2 Mapping to the charging chain	BMW																						
AP 6.3 Reflection of the project methodology	BMW																						

1.4. Scientific and technical status

Scientific status

Research on charging infrastructure focuses on technical-economic aspects and the preferences of potential users (Globisch, Plötz, Dütschke & Wietschel 2019 : 55). Philipsen, Brell, Brost, Eickels and Ziefle (2018) divide the current research on electric vehicle (BEV) charging into two main topic areas: **User requirements for charging infrastructure** and **decision-making processes in the choice of charging station on the** one hand, and the handling of battery technology and **range from a psychological perspective on** the other (Philipsen et al. 2018 : 476). Sun, Yamamoto and Morikawa (2016) note that there is little research on users' perceptions and preferences for BEV charging. Globisch et al. (2019) highlight that this is surprising as the **need for charging is** one of the main differences with conventionally powered vehicles (Globisch et al. 2019: 54). This shows that there is research interest in the charging of electric vehicles.

Since the charging infrastructure in Germany is organized in a decentralized manner, a differentiation is made between different charging **use cases.** Everyday charging" in private spaces is categorized as charging at home, at one's own home or apartment building, and at work (Nationale Leitstelle Ladeinfrastruktur 2020 : 9). "In-between charging" takes place during another activity in semi-public or public space: for example, in the customer car park during a shopping trip or in the street space when the BEV is parked during an appointment. **"Fast charging"**, on the other hand, is an independent journey purpose for which a fast-charging hub is approached within a town or on a traffic axis (ibid.).

Technical status

In 2013, the decision was made at the political level to make the CCS charging system with a CCS Type2, Combo2 plug mandatory throughout Europe as standard equipment for public charging infrastructure and to use this CCS charging system on the trans-European corridors. In order to ensure the compatibility of vehicles from different manufacturers with charging points, **interoperability tests** were first carried out. Up to now, these have required OEM-specific, bilateral coordination with the charging station manufacturers and caused enormous time and cost expenditure, as both different vehicles and different charging stations have to be physically kept available or are made available at a few times a year within the framework of **"Testivals"**[1]. The findings are based on laboratory conditions. The findings tend to be low due to the laboratory conditions and random tests. Reliable robustness tests can also hardly be derived due to the above-mentioned test conditions.

A solution to simulate interoperability tests of vehicles from different manufacturers for the CCS charging system in a standardized and reproducible manner with the help of a **"Golden Test Device" was** advanced by the BMWI-funded **SLAM project** (Fast Charging Network for Axes and Metropolises, http://www.slam-projekt.de/). The partners **BMW, IAO** and **IAT were also** involved in the project and also play a central role in the consortium **"Wirkkette Laden"** described here. A **"CharIN CCS Test Device" (CCTS) is** currently being developed based on the **SLAM project.** For reasons of complexity, the focus is currently exclusively on the charging interface between EV and EVSE.

[1] The so-called "Testivals" are international test events, organised and hosted by CharIN, with the purpose of creating a platform where stakeholders from the entire value chain in the field of e-mobility can conduct interoperability tests, especially at the EV-EVSE interface. (https://www.charin.global/events/global-testivals/)

Other issues in the **charging chain** in the consumer's customer journey, such as access and charging, are also seen as potential barriers to the potential success of electric mobility. According to various market studies by the companies involved in SLAM, a variety of access and billing systems were tested by different companies and initiatives at the time. Here, too, the need to optimize the situation in the market in favor of customer-friendly solutions and to make a determination for the CCS charging system for customer-friendly charging became clear.

Franke & Krems (2013) concluded that a large proportion of users consider charging an electric vehicle to be easy, with the handling of the charging cable being the most common difficulty. In the **fast-E project** (http://www.fast-e.eu; 2017), a user survey determined that the potential causes for **unsuccessful (fast) charging** include a lack of price transparency, charging points blocked by other electric cars and the non-acceptance of some charging cards.

In the EU-funded project **"evRoaming4EU"** (https://www.evroaming4.eu/), the interface between platforms, EMPs and CPOs via Open Charge Point Interface is being further developed, but here the interface to the vehicle is not considered separately. In the context of the project **"Wirkkette Laden" (effective charging chain)** outlined here, cooperation with the **Open Charge Alliance**[2] **(OCA) is being** sought.

1.5. Cooperation

Cooperation in the project

The cooperation in the **project "Wirkkette Laden"** took place in 2-3 month project meetings, in which the respective status of the different work packages was synchronized and further procedures were discussed. These project meetings took place virtually as well as on site at different consortium partners. They also included guest lectures on various topics. **NOW GmbH** was also involved in the synchronization, as was the **Federal Ministry of Digital Affairs and Transport (BMDV)**. They accompanied the project throughout its entire duration and perceived the necessary measures and will utilize them accordingly.

Cooperation with third parties

Associated partners were also involved in the project, such as Porsche Engineering Group GmbH and Autobahn Tank & Rast GmbH. They provided data for certain work packages, took part in project meetings and actively participated in discussions.

A **diary study** was also conducted. For this, experienced electric vehicle users were asked about the charging processes over a certain period of time and the experience values were evaluated. For further details see **section 2.1.3 WP3 Investigation of the "User Experience Charging under "Diary study"**.

In addition, a **real-lab test** was conducted in which inexperienced people were observed charging the electric vehicle. The insights gained from this were incorporated into the evaluation of the user experience and help to understand where hurdles can occur during charging. These are discussed in **section 2.1.3 WP3 Investigation of the "User Experience Charging under "Real-lab** test".

[2] https://www.openchargealliance.org/

2. Project

2.1. Scientific and technical result achieved

Project results

With the ultimate goal of customer-friendly charging and the associated maximum customer satisfaction, the consortium has pursued the goal of identifying the challenges in the charging process/charging experience and developing solutions.

The aim of the project is to develop and establish a uniform and binding and, above all, transparent **Big Picture of** the **ecosystem charging** across industries and sectors for the first time. The **Big Picture** was developed in the project and is available to the public on the website of NOW as one of the core results of this funding project. This resulted in a cross-sectoral harmonization of the different perspectives and a definition of the components, subsystems and interfaces involved in the charging chain in a common architectural picture. An "archetype" for the envisaged functional developments in the charging ecosystem.

Objective 1: Creation of a **"heat map" of** the most frequently occurring problems that lead to an unsuccessful charging process on the basis of the chain of effects outlined in the figure; this is based on an analysis carried out in the project with charging points that have already been installed and are in operation as well as real customer vehicles. In advance, a common understanding of the **charging chain is** developed with the project partners. In addition to purely technical topics, aspects of user behavior will also be included in the **"heat map" in order** to make these sources of error more transparent.

Objective 2: Description of the quality or **"maturity level" of** the respective interfaces in **ecosystem charging on the** basis of the available specifications and standards. This description should continue beyond the end of the project and be centrally maintained and tracked for the market participants by the project coordinator **CharIN e. V.** For this purpose, cooperation with the National Platform Mobility (NPM) is envisaged.

Objective 3: Derive concrete measures to improve the quality of the interfaces (e.g. development of test methods, standardization harmonization, usability aspects from the user's point of view).

Goal 4: Further development of the target image of the **"charging chain"** in a joint **ecosystem charging** to include aspects of future mobility requirements (automated conductive charging, automated parking, etc.); this also takes into account the risks that may arise from these new technologies with regard to a successful charging process.

2.1.1. WP1 Coordination of a common Big Picture of an ecosystem charging

As part of the 3 sub-work packages in WP1, a **Big Picture Ecosystem Charging** in an intermodal transport and energy system 2030 with all core participants and their roles as well as with all relevant interfaces was developed in "Version 1" and published as a cross-industry template.

For the graphically elaborated **Big Picture Ecosystem Charging 2030,** a document with the three congruent reporting levels was created and made available on the **CharIN e.V.** homepage as the first concrete work result with the cooperation of the **National Charging Infrastructure Control Centre. The Big Picture**

Ecosystem Charging 2030 was presented to the general public at the International Electric Vehicle Symposium & Exhibition (**EVS35**) from 11-15 June 2022 in Oslo and at the conference on charging infrastructure of the **Federal Ministry of Digital Affairs and Transport on** 29 June 2022 in Berlin. Many intensive discussions at the stand of the **National Charging Infrastructure Control Centre** showed the need for such a common basis and therefore the definition of such a universal master meter for an intermodal transport system was expressed appreciatively several times.

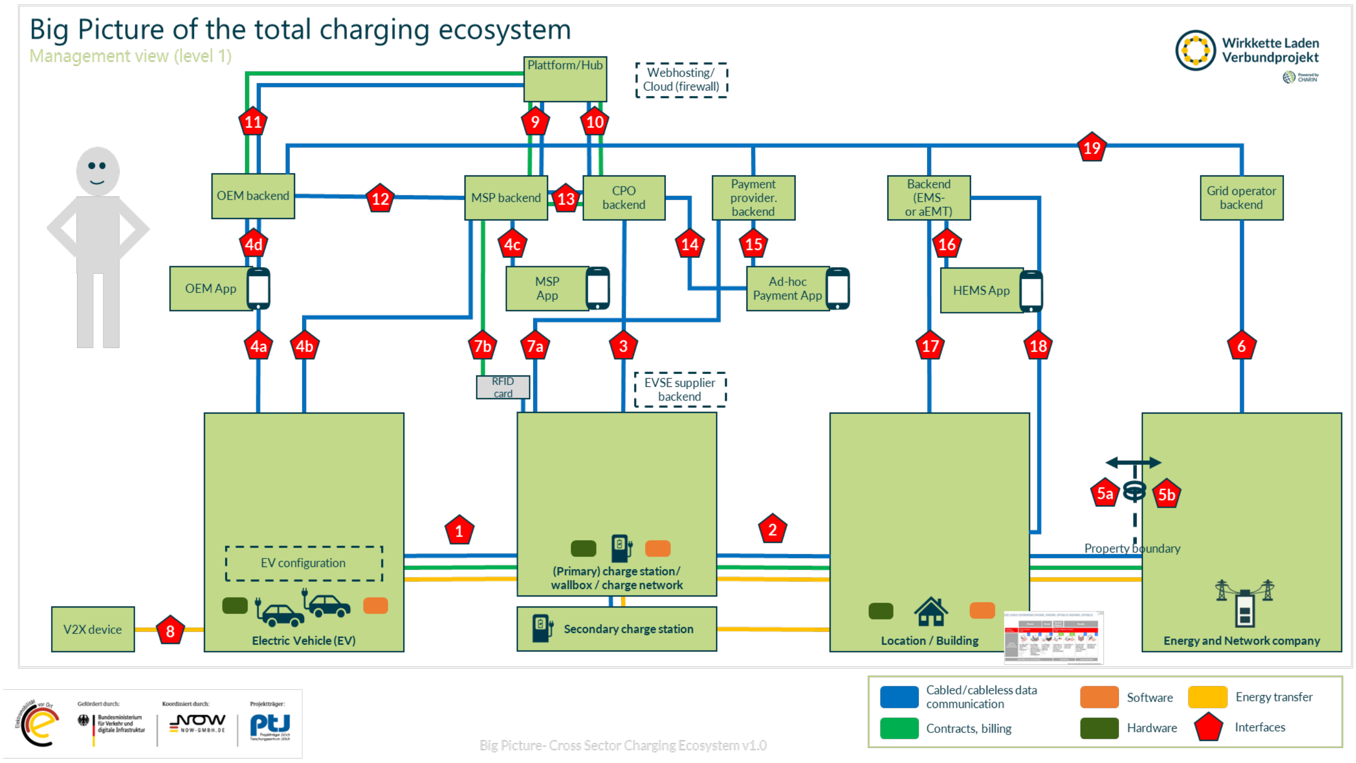

Figure 3 Big Picture Ecosystem Charging 1.0 - Management View

Concept of a **dashboard/radar display of** the status of relevant standards and specifications along the **charging chain**.

Step 1: Design of a "radar system" based on the charging chain as a quick overview tool for recording the status of the relevant standards in the form of a "dashboard" with color coding (green - yellow - red) and subsequent coordination of the framework with the partners. The National Charging Infrastructure Control Centre will also be involved in the creation of the radar system.

Step 2: The radar system will then be filled with the results from WP 4. The radar system will cover all components in ecosystem charging (software/hardware/EV/EVSE/network/backend). For the appropriate level of detail, a common expression of the consideration has to be found and defined. This can be done, for example, with the help of expertise from the area of quality management or Six Sigma.

Step 3: Application of the radar system for the current situation today and a joint forecast for an expected situation in 2030.

Result: joint assessment of a 2030 target and definition of the area of tension between current and targeted as a basis for further measures. The proposed solutions are a joint initiative of the market participants involved to support the market ramp-up of battery electric mobility.

The concept of a **"radar system"** based on the **charging chain** as a quick overview tool for recording the charging customer functions around the relevant standards of the affected interfaces were developed and is available as a starting point. The basis for this is the CCS step model of the charging customer functions, which was agreed and defined with the 220 members of **CharIN** at the time. The matrix of the quantity structure of the CCS charging customer functions spanned over the interfaces of the big picture charging ecosystem results in the effective chain radar charging customer functions. In an initial proof of concept, the funding project **Wirkkette Laden** focused on the CCS basic functions (**CCS step model** Step 1 >> **CCS Basic**).

The approach outlined here in the project gives an idea of the possibilities for supporting the ramp-up of battery-electric mobility. With the help of such a common radar, the respective customer functions in the **charging chain can be** gone through in sequence, chain link by chain link, interface by interface, and it can be discussed whether the interface is defined and sufficiently specified in total. If needs for action are identified, they can be specifically addressed, coordinated and defined with the various standardization organizations on the basis of the numbering and definition of the interfaces defined across all industries in the **BigPicture ecosystem charging.** In the course of processing the different views on the CCS charging functions, further synchronization and harmonization with existing charging function descriptions was started within the framework of this **project "customer journey".** Without this harmonization of the view, there is no possibility of understanding each other industry-wide.

In the following Figures, it can be seen that the view of the integration levels for the customer function Bidirectional Charging has been incorporated and a uniform and harmonized overview as well as a uniform quantity framework of the CCS charging functions has been developed.

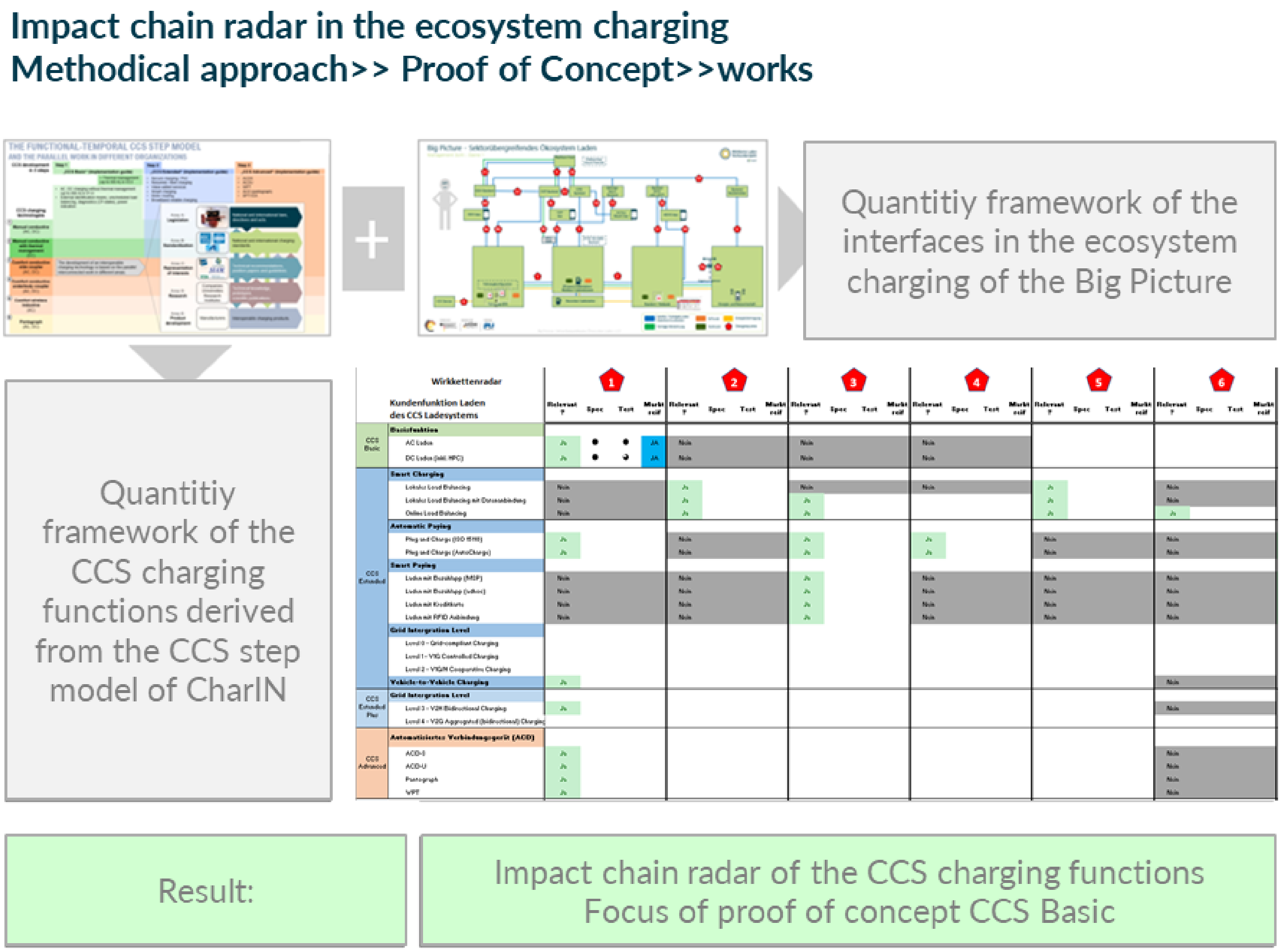

Figure 4 Derivation of CCS quantity structure

A basic methodology and procedure for an **impact chain radar of the ecosystem charging** was developed in the project and is available as a draft. From the point of view and opinion of the consortium partners, it is recommended to consider and pilot the basically described interface radar in a **follow-up project.**

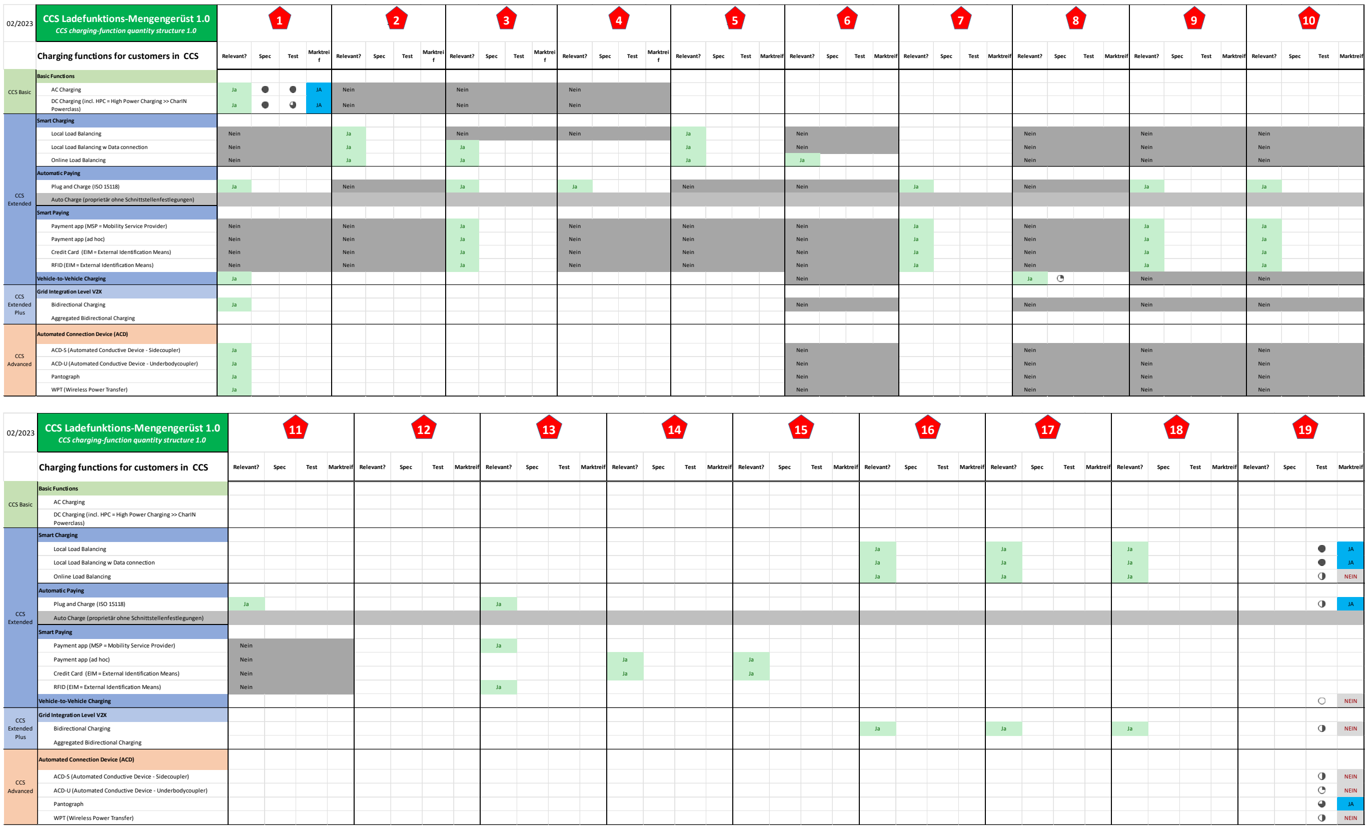

Figure 5 Active chain radar

The impulses of the consortium partners made it possible to understand the need for a common "charging function view". As a result, a **CCS quantity framework of charging functions** was developed and defined as a proposal for industry-wide coordination by pulling together and sorting out different terms and descriptions. This **CCS framework of charging functions** with the explicit focus on customer-friendly charging was then aligned with the existing 7 charging use cases and subjected to a proof of concept. The core question was: Is it possible to assign the charging functions from the defined quantity structure of the CCS charging functions to the existing charging use cases? A proposal was submitted to the consortium to explain this possibility in principle and to discuss and further develop it as an idea together with the consortium partners. During the discussions with the consortium partners, it became clear that the attempt to assign faults in the charging chain requires a common understanding of the different charging functions and also a common understanding of different charging use cases. A further development of the current reference image of the **7 NPM charging use cases** was initiated. The result of the various views and considerations of different charging use cases was summarized in a **draft charging use case for the charging chain and** is thus available for the first time in this funding project as a harmonized basic document for the partners and participants in industry in **ecosystem charging as a** reference. See WP 6.

With this work in the funding project **Wirkkette Laden**, the current views and thoughts in the context of the market ramp-up of e-mobility were further consolidated. They provide the urgently needed basis to be able to discuss and avoid the errors in the charging chain in a targeted and comprehensible way. In the project discussions, the interface definitions in the **Big Picture Ecosystem Charging**, the expansion of the **NPM charging use cases** and the definition of a **CCS charging function quantity framework** were identified as the three important pillars to be able to specifically locate the questions of the error patterns in the **charging chain.** The localization in a **"heat map",** mapped to the big picture of the charging ecosystem, has already brought initial clarity to the project. What was important here was the common basic understanding not to engage in "fingerpointing" when the charging does not work. All participants in the consortium recognized the need to use the jointly created transparency to identify where exactly in the **charging chain the** error occurs. Only when the partners involved knowing exactly where the error exists can the cause of the error be sought in a neutral and non-judgemental manner. The discussions in the consortium have shown that this possibility has now been well prepared and used within the framework of the WKL funding project.

2.1.2. WP2 Data collection of exemplary charging processes and mapping of the occurring problem areas to an existing current situation

The aim of **WP2** was to gain a better understanding of the problem areas during charging by examining exemplary charging processes. To this end, a charging station manufacturer-independent **error classification** was first developed. For this purpose, the manufacturer-specific **(OCPP) error codes of** five different charging station manufacturers as well as the **general error codes** specified in OCPP 1.6 were assigned to the individual elements of the **Big Picture** developed in **WP1**, whereby the majority (58%) were naturally assigned to the charging station - after all, these are error messages of the charging station. It was found that the charging station manufacturers do not transmit faults within the framework of the OCPP (standard) fault codes, but predominantly use **their own manufacturer fault codes,** which are neither uniform nor generally valid. In the second step, a **coordinated data set** was developed for the exports from the participating charging station operators (CPO - IONITY, Stromnetz Hamburg) and traction current providers (EMSP - Digital Charging Solutions). As a basic reference, the CPO used the so-called Charge Detail Records, data records that contain billing-relevant data on individual charging processes. These were enriched with OCPP error messages that are temporally related to the respective charging process (start time CDR to 5 minutes after end time CDR). On the EMSP side, data sets on authorization requests were also collected; both RFID authorizations and remote authorizations were considered. In total, data from the period 01.01.2021 to 30.09.2022 was included in the project, but for various reasons only a part of it could be meaningfully evaluated (see below).

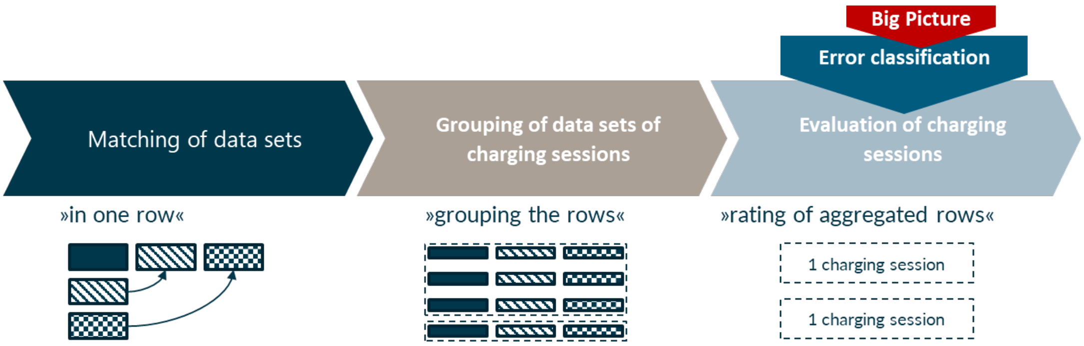

Figure 6Procedure for data evaluation in WP2

All data sets (CDR with error information from the CPO and CDR and authorization messages from the EMSP) were, if possible, processed according to the procedure described in **Figure 6** shown in Figure 6. The biggest challenges were in steps 1 and 2, so the following section will focus on the insights gained there. Only in step 3 does the actual evaluation of the success or non-success of the loading event and a mapping for error classification come into play.

The challenges in steps 1 and 2 can be summarized as follows:

A clear assignment of authorization messages (start/stop) to CDR was not possible, at least for the DCS-SNH consideration, as the version of OCPI implemented at the relevant time does not provide for a unique process **ID** for all process steps of a loading process. Therefore, step 1 of the process described in Figure 6 and the grouping (step 2) was carried out on the basis of different message types.

- **RFID authorization requests** from the CPO to the EMP do not contain an EVSE ID of the charging point because not all roaming protocols contain corresponding fields for the ID of the station, location and plug. In OICP, for example, only the EVSE ID field can be used to transmit a reference to the location in the authorization request - due to a plausibility check on the part of Hubject, however, only a complete and existing EVSE ID (and thus a specific charging point) can be transmitted here. Furthermore, OCPP does not provide for an identification of the charging point in the authorization request, but only the ID of the charging station (charge box ID). Thus, the EVSE ID in the authorization request could not be used for the unambiguous assignment to the respective CDR.

- The CPOs only provided data (CDR + error messages) from a **subset of** all charging stations in Germany, but the EMP provided data (authorization requests + CDR) for all charging stations of the respective CPO in Germany. This was a self-generated challenge in the processing of all data, as it was thus not possible to distinguish on the EMP side between non-potentially erroneous operations and data that were not included in the CPO sample at all.
- If a CPO works with an **(offline) whitelist procedure**, the EMP does not receive any data on the authorization process. Only in the online authorization procedure does the EMP receive data. Thus, it happened in the evaluation that for many data records on one side, no data were clearly assignable or available on the other side.

In summary, it can be said that the large number of **IT systems** involved (CPO backend, EMP backend, platform/hub,...) and possible framework conditions or parameters (charging station type, authorization type, as well as ongoing development work on the systems involved,...) alone made the **data preparation** enormously difficult. The actual evaluation also posed various challenges:

- There are a large number of charging stations in use, each of which **behaves differently** (due to manufacturer-specific individual implementations of OCPP or due to the specific configuration of the charging station), i.e. the "good case" cannot be determined so clearly. For example, for the combination of RFID authorization and Mennekes charging station, it was determined through an experiment that a faultless charging process includes three to four authorization messages and one CDR. The number of authorization messages depends on whether the charging process was terminated by presenting the card again or by the vehicle.
- It was/is not possible to clearly determine whether an **error message** associated with the charging process **actually** led to a **problem** (this may lead to "false negatives"). It could help if the field "Reason" in the Stop.Transaction message of the charging station could be used to specify what the reason for the end of the charging process was, e.g. an error or an action of the user or the vehicle.
- Threshold values for the amount of energy or charging time above which a charging process is considered successful cannot be **reliably** and objectively defined (possibly leading to "**false positives"**).
- There was **no clear definition of** a successful charging process, as the following possibilities cannot be clearly distinguished:
    - Time needed to switch to another charging station vs. normal pause/drive time between two successful charging processes.
    - Change of authorization method (different app, change of app to RFID or the other way round) vs. two successful charging processes by different people (RFID and remote generate different tokens for one and the same customer account).

For these reasons, several assumptions had to be made for the data evaluation, which also differ depending on the CPO-EMSP combination considered.

Data evaluation DCS-IONITY (OICP, Hubject)

Since the authorization messages exported from Hubject each contained a unique session ID, it was possible to assign the start and, if necessary, the stop authorization message to the respective CDR. Furthermore, only charging stations from one manufacturer were used at the IONITY locations considered and, in addition, no re-authentication/authorization is necessary to stop the charging process. Thus, the "good case" in terms of authorization could be defined comparatively clearly and corresponded to the concatenation of a start message, a stop message if applicable and a CDR. The two other dimensions used to assess charging success were the amount of energy charged and OCPP error messages linked to the CDR. If there was a 1:1 relationship of authorization message and CDR, the amount of energy charged was greater than 0 kWh and no error message was included, a **charging event was** categorized **as "flawless"** (dark green in **Figure 7**). If there was no error message but more than one start message and/or CDR, the label "Successful LV with authorization irregularities" was assigned (light green), or the label "LV with irregularities" (also light green) if an OCPP error message had also occurred (but without exact temporal correspondence with the CDR end timestamp). Loading events without CDR were interpreted as loading events with "problems starting" (yellow). Charging events where the sum of the charged energy amount of all assigned CDRs was 0 kWh were categorized as faulty, as were charging events where the CDR end timestamp exactly matched the timestamp of an OCPP error message (both dark red).

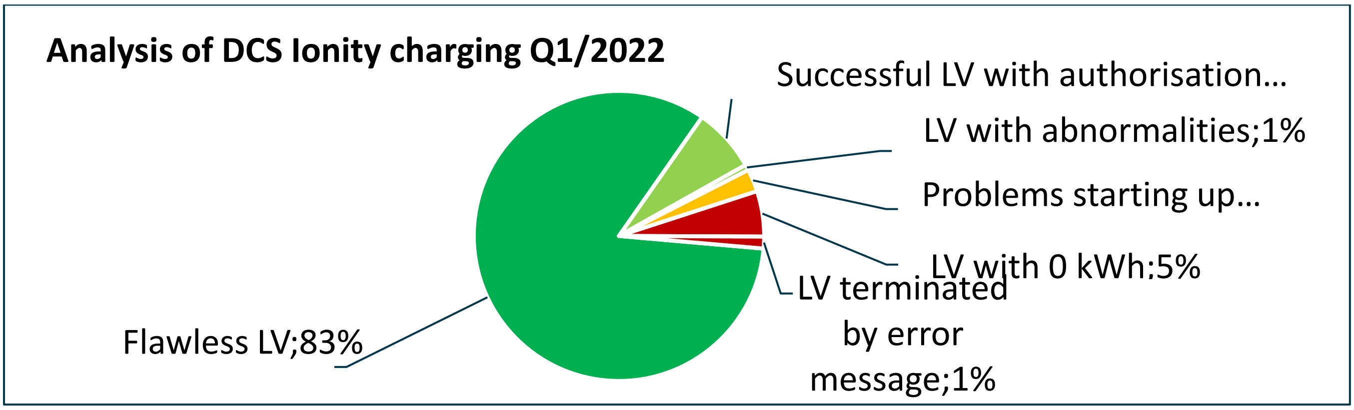

Figure 7Result of the evaluation of 40,939 DCS-IONITY charging processes Q1/2022 (n=78 locations)

If we now look at all processes that have at **least 1 OCPP error message** and assign these faulty processes to the elements of the Big Picture (according to the error classification developed in **WP2.1**), we see that most errors are located at the charging station or at the interface between the charging station and the vehicle (cf. **Figure 8**). This is not surprising, since the error messages are from the charging station.

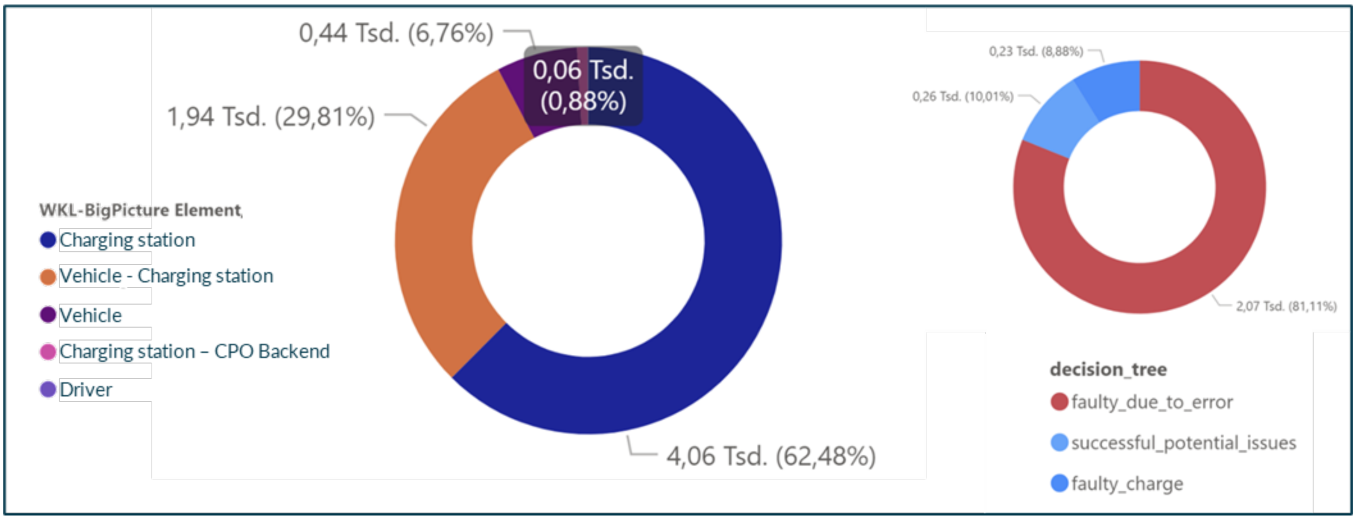

Figure 8Mapping of activities with OCPP error message to Big Picture elements

Data evaluation DCS power grid Hamburg (OCPI, P2P)

Due to the limitations outlined above, only a small sample could be meaningfully evaluated for the charging infrastructure of Stromnetz Hamburg. For the observation period September 2022 and a sample of n=569 charging stations from the same manufacturer, it can be seen that 77% of the 7,000 charging processes considered correspond to the pattern of a **"flawless" charging process**.

2.1.3. WP3 Investigation of the "User Experience Charging

Figure 9 summarizes all research methods used in the project to identify weak points in the charging chain. On the far left, statistical data analysis (**WP2**) is the only approach that does not require direct front-end input from the user. In AP3, on the other hand, the focus was on **"user experience charging",** so that front-end observations were always included in the analysis. The interface between semantic analysis and statistical data analysis is to be understood in such a way that a quantitative evaluation approach was pursued in both approaches. In the real-lab experiment and the diary study, the research was mainly qualitative.

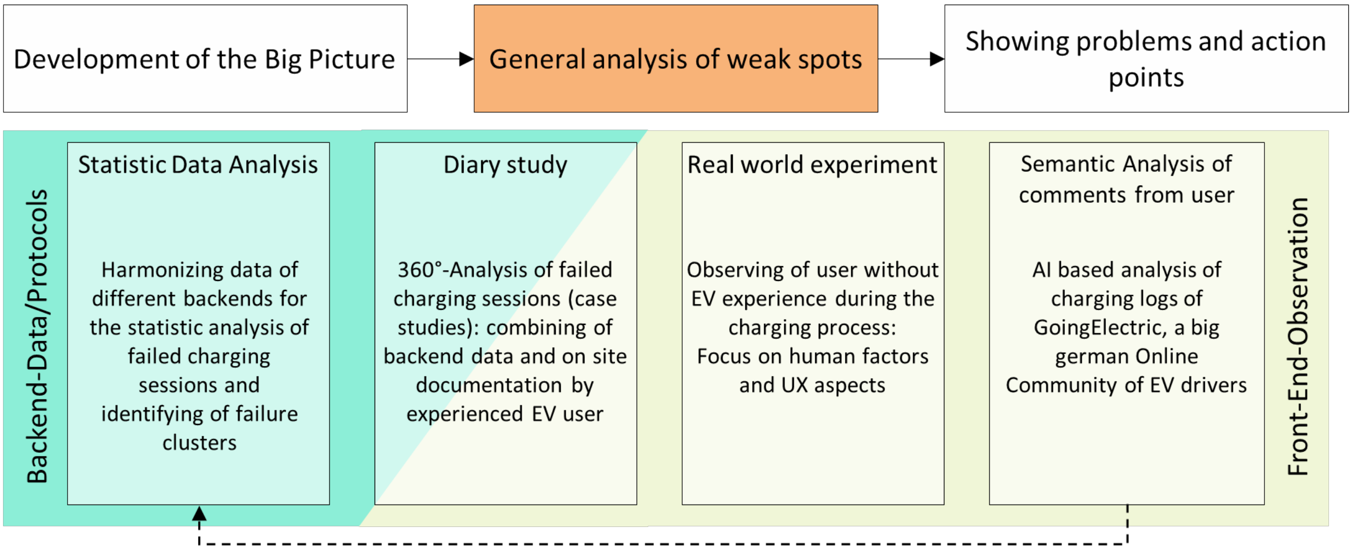

Figure 9: Research methods used in the project

Diary study

While the statistical data analysis conducted in **WP2** left the actual events in front of the charging stations unobserved, the diary study aimed to complement this perspective by including EV users in the **data collection process.** To this end, experienced electric car drivers with their own electric vehicles were recruited to document charging operations at public charging stations that they perform during their daily journeys. It is thus a **self-observation** in the form of an event sample that is systematically documented. Each participant received an individual link to an **online survey with which the** charging processes were documented - through the individualization of the link, it was possible to already store the master data of the participant (in particular the vehicle used) in the questionnaire. However, it was also possible to specify an alternative vehicle for each diary entry. The participants were asked to document both successful and unsuccessful charging processes, whereby more questions were asked in the case of an unsuccessful authentication/authorization or charging process (cf. **Table 1**). An additional data collection channel with a simplified **questionnaire** was implemented via GoingElectric, a large online community and charging station directory for e-drivers in Germany. A link to the survey was added to each directory entry that referred to the charging infrastructure of the project partners. Furthermore, feedback on charging experiences was also collected by BMW from an internal project with BMW iX vehicles for e-mobility experiences.

Q1 On the first attempt, which of the following authentication methods did you use for the charging process? [*Request to specify the provider used in a free text field].	• RFID card / dongle* • EMP App / Traction Current App* • SMS • Web app of the charging station operator (usually QR code on charging station) / Intercharge Direct • Payment terminal with card slot and PIN entry (EC/credit card) • Contactless payment terminal without PIN (EC/credit card, Apple/Google Pay) • Plug & Charge* • Other*	
Q2 What authentication methods did you use for the loading process?	Yes, the process was successful.	No, the following problem has occurred: [free text field]
Q3 Which authentication method did you use after the first attempt failed?	*See above.*	
F5 Was the second authentication method successful?	Yes, the process was successful.	No, the following problem has occurred: [free text field]
Q6 How would you rate the success of the charging process carried out?	The charging process worked without any faults.	The charging process worked poorly.
Q7 Which of the deficiencies listed below applies to your situation? Please explain the occurrences within the free text field as precisely as possible.-	• The charging process is aborted. • There were challenges/problems when starting the loading process. • There were challenges/problems finishing the loading process. • Maximum charging power lower than expected. • Charging power dropped more than expected during the charging process. • Other defects	

Table 1: Main questions to assess the success of the documented charging operations (question numbers for future reference)

Participants were asked to provide the time and date of their charging session as well as additional information that would facilitate later identification of the session. For this purpose, they had the option to upload pictures of the EVSE ID, screenshots from their smartphone showing a charging app and the nameplate of the respective charging station. Alternatively, they could enter the EVSE ID manually. Other questions were related to contextual information about the charging process, such as weather conditions or whether other vehicles were charging at the same time. Finally, some additional questions were asked about the overall satisfaction with the charging process and the condition of the charging station.

At regular intervals, the recorded diary entries were exported from the LimeSurvey system, which was used as the host for the questionnaire. After the data had been checked and cleaned by Fraunhofer IAO, it was made available to the EVSE manufacturers, CPO and EMSP involved in the project so that they could locate the relevant processes in their systems and thus carry out a **joint error analysis** within the project consortium. In addition to charging station protocols (OCPP protocols), authentication message protocols and charging detail protocols, support tickets were also taken into account (cf. **Figure 10**). As an incentive for the targeted use of the project partners' products, i.e. a specific charging app and a specific charging infrastructure, participants were offered free charging for a limited period of time if these products were used.

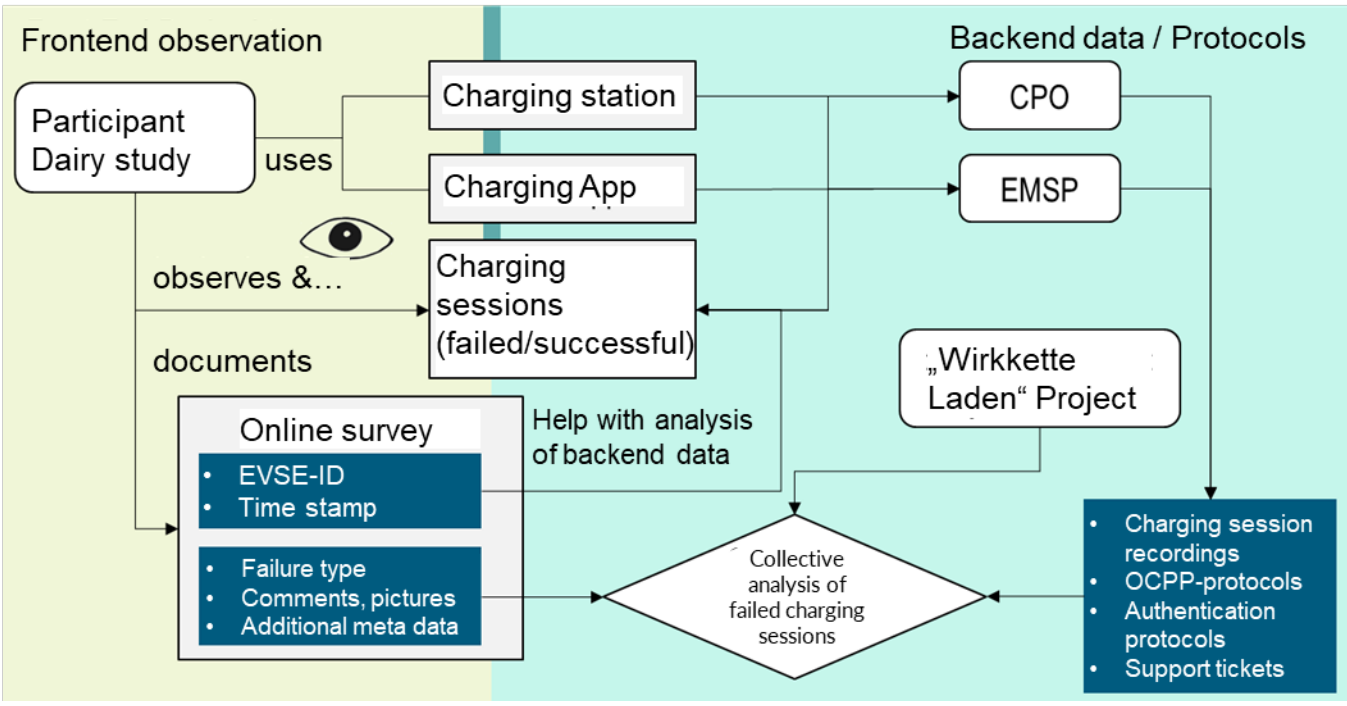

Figure 10: Methodological approach of the diary study (n=42 charging events were analysed according to this scheme).

Finally, **61 people** were invited to participate in the diary study. A total of **312 charging processes** (63 via GoingElectric and 249 by registered participants) were fully documented between 1 January and 30 June 2022. Of these, 88 charging processes were assessed as faulty, 203 were faultless, as were 21 others in the context of which, however, criticism was expressed elsewhere. For 46 of the 88 faulty charging processes, the cause of the fault could not be traced. The causes of the errors in the remaining 42 charging processes were included in **WP 5 in** qualitative and quantitative form. The project partners were involved in 41 of the 88 charging processes with errors (see underlined value in **Table 2**).

Table 2: Success of the documented charging processes taking into account the project partners

	Project partners involved	Project partner not involved	**Total**
Flawless charging	145	58	**203**
Successful charging process, but critical comment by the person using it	14	7	**21**
Faulty charging process	<u>41</u>	47	**88**
Total	**200**	**112**	**312**

Findings from the collaborative, qualitative analysis of the faulty charging processes in the project consortium are briefly summarized below.

QR codes not standardized

In several cases, the electric vehicle users were not able to scan the **QR code** attached to the charging station. The reason for this was found within the consortium. The e-mobility service provider searches the URL for the string "evseid=" followed by the EVSE ID of the respective charging station in the format specified by BDEW:

<EVSEID> = <country code> <S> <EVSE operator ID> <S> <ID type> <socket ID>.

However, one of the charging station operators in the project uses a different format for its charging stations. The EMSP app was therefore not able to read the QR code. If the URL stored in the QR code always contained a standardized character string, e.g. because this is required by **national or international charging infrastructure regulations**, this problem could be improved.

POI data inaccurate

In the results of the diary study, a true classic in electric vehicle charging research and a likely regular experience of e-car drivers emerges **inaccurate POI data,** i.e. metadata of charging stations. This was the case in at least one documented event in the diary study. The EMSP app used showed a particular charging station as being open 24/7. In reality, however, the car park where the charging station was located was closed at night, so the driver of the electric car documenting the charging process parked his car outside the car park, thus blocking the pavement and parts of the roadway next to it (cf. **Figure 11**). The analysis of this problem in the consortium revealed that the (restricted) opening hours were properly entered in the backend, but the attribute "24/7" was not set correctly.

Figure 11: Result of POI data not properly maintained

Swapped charging cables at the charging station go unnoticed

In one case, it was even the man-machine interface that caused problems for the EV user. The charging station used had two CCS plugs right next to each other. When the person participating in the diary study wanted to use the station, they selected one of the two available plugs and started the charging process with the app, which worked without any problems. The socket of the selected plug lit up to indicate that this cable should be used. However, the charging process did not start. The reason was that the two **plugs were reversed**, i.e. plug 1 was plugged into socket 2 and plug 2 into socket 1 - so the colored marking did not help as only the socket was illuminated and not the plug itself. The EV driver(s) eventually noticed this themselves, but it had extended the charging pause from 30 to 40 minutes.

Real-lab experiment

Within this work package, two real-lab tests were carried out in Munich and Hamburg, partly still using a complex corona protection concept. In the real-lab test, possible challenges in the human-machine interaction that could lead to faulty charging processes were investigated. For this purpose, a total of 25 people with no previous experience in charging electric vehicles were observed carrying out several charging processes at different charging stations (DC-HPC, AC) with different authentication methods (app, direct payment, RFID card, SMS). The differentiation from the diary study is made by the level of experience of the people involved: People who had **experience in** charging electric vehicles took part in the diary study; this would have been an **exclusion criterion in** the real-lab trials.

A real-lab experiment is a scientific undertaking that is located in the participants' lifeworld and is not carried out continuously over a longer period of time. The advantage of this method is that the participants are in a free test situation in which they only receive basic information, and their actions are not guided more than necessary. Any difficulties that arise can be identified and verbalized immediately. The focus of the real-lab tests is on three essential objects of the charging chain: **Charging station, vehicle and app**. The participants were observed during the charging process and their feedback and reactions were continuously reflected upon and collected via an accompanying guideline-based survey. For some of the participants, the real-lab experiment was documented with the help of **eye-tracking glasses that** closely tracked their gaze in order to identify, for example, inadequacies in the information displayed on the screens of the charging stations. Permanently installed cameras were used on all participants to record facial expressions and gestures as well as general behavior. In order to facilitate the documentation of such key factors, relevant observation points were determined in advance (e.g. entrance to the car park, plug attachment). The accompanying interview was based on guiding questions that focused on the following:

- missing or misleading information;
- general challenges in the operation of charging stations;
- the discussion of the (lack of) requirements from the non-beneficiary perspective.

The evaluation of the data was done according to the procedure of a **qualitative content analysis**. First, the information gained from the interviews and observation was bundled and reflected upon. In a second step, the generalization into universal challenges (of many participants) and individual mentions (of individual participants) followed.

The demographic composition of the sample is shown in **Figure 12** and **Figure 13**, respectively. The majority of participants in the real-lab trials were men and all age groups were represented, with the largest group being 26-35 year olds.

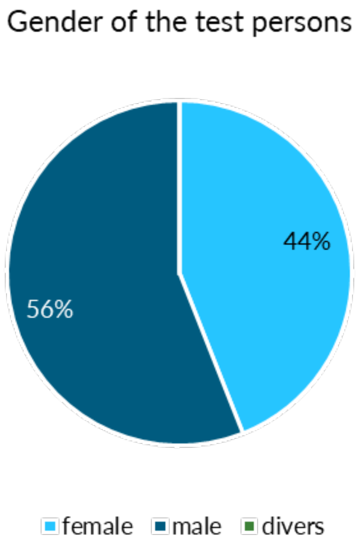

Figure 12Biological sex of the participants in the two real-lab experiments (n=25)

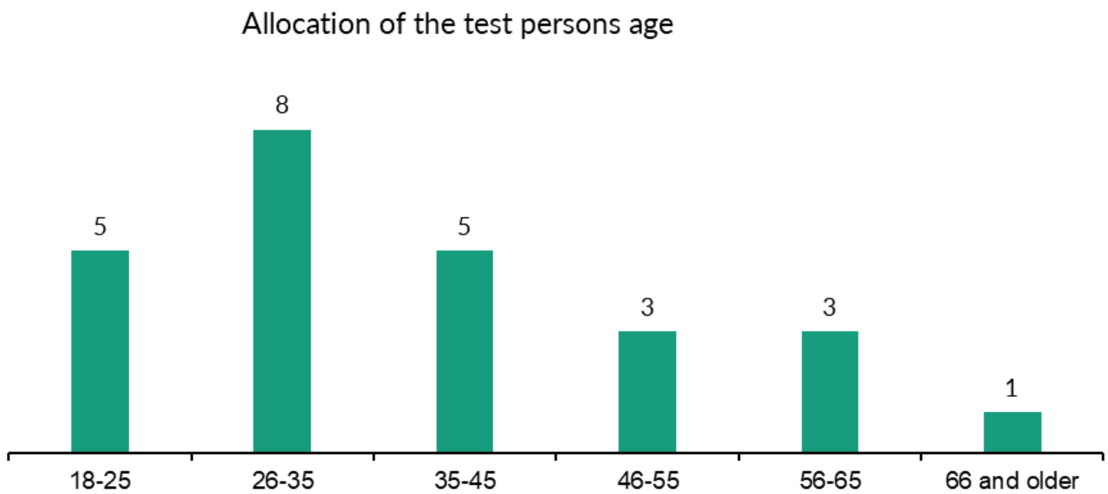

Figure 13Age of the participants in the two real-lab trials in years (n=25)

Conducting the real-lab tests showed that there are only a few hurdles that cause a charging process to fail, but this does not mean that there is nothing to improve about the charging experience from the subjects' point of view. In general, it can be stated that the majority of the test persons initially compare charging with **refuelling** a conventionally powered vehicle and use this process as a **reference.** This mental reference is gradually replaced by the **charging experience.** By the third or fourth charging process at the latest, a certain routine has set in. Nevertheless, the real-lab tests revealed some shortcomings that can more or less impair the user experience or even lead to a failure when charging an electric vehicle.

Reasons for unsuccessful loading

When authenticating with smartphone or web app, it happened that a timeout occurred on the vehicle side because the plug was first inserted into the vehicle and the authentication (e.g. due to the entry of credit card data) took longer than expected.

In addition, some test persons experienced insufficient feedback from the charging station: especially when paying directly via a web app, they were "lost" because neither the charging station nor the (web) app told them what was happening and what the next step was.

Usability issues

Participants found it very helpful when clear step-by-step instructions or clear instructions on the successive steps were given, e.g. step **1-2-3 explanations** at the charging station.

Even if it does not lead to an unsuccessful charging process, it has been shown that unclear feedback leads to dissatisfaction among participants. Each successful step, e.g. plugging in the vehicle, authentication, starting the charging process, finishing the charging process or hanging the charging cable back to the charging station, should be confirmed by the charging station, ideally through a combination of acoustic and visual feedback. In addition, the status and progress of the charging process should be visible at all times (see the following points).

A "sound" during charging implies to the participants that the charging process is running successfully. In addition, an audio signal when starting or ending the charging process is considered helpful. Key tones are also evaluated as positive.

Due to the influence of refueling conventionally powered vehicles, the test persons also expect **immediate price information at the** charging station. This means both a quantity price in €/kWh at the beginning of the charging process as well as the total costs after the end of the charging process. One person even asked whether it would be possible to set a final price (e.g. €20) for charging - which may sound surprising to experienced electric vehicle users.

Almost all respondents would like to be informed about how long it would take to fully charge their vehicle or how long it would take to reach the desired SoC (state of charge) for their planned trip. At this point, it should be noted that some charging stations display the remaining charging time up to 80% SoC. The majority of charging stations tested in the real-lab trials only displayed the current SoC in % and the elapsed charging time.

In addition, it is relevant for the waiting person to be shown how far it is possible to drive with the current or targeted state of charge.

Additional technical information shown on the display of the charging station (such as current and voltage) does not offer any significant added value for most participants. In addition, technical abbreviations such as "A" for ampere or "V" for volt cause **confusion**.

Some participants noticed the **discrepancy** between the SoC displayed in the smartphone or web app and the SoC display on the charging station display and were irritated by this.

Finding the **QR code scanner** in the smartphone and the QR code at the charging station, as well as scanning the QR code with the smartphone, generally seemed to be significantly more difficult than using an RFID card for authentication. Furthermore, it even seemed more natural to swipe the smartphone over the card reader, as is known from NFC-enabled credit cards or mobile payment systems (e.g. Apple Pay).

The evaluation of the findings with regard to potential sources of error as well as the improvement of the charging experience have already been incorporated into the day-to-day business (operation/technology) of the participating project partners during the active project work. The technical problems identified in the real-lab test were analyzed and evaluated by the project partners involved. For this purpose, the **video recordings of** the real-lab test as well as backend data are used, and the findings are made available .

<u>Semantic analysis</u>

With the help of the semantic analysis of user comments on the GoingElectric platform, a further component could be taken into account. In contrast to the diary study and the real-lab test, direct interaction with users could be dispensed with here. By **systematically analyzing** the **user comments, it was** possible to determine further causes of errors and the relative frequencies of their occurrence.

In order to be able to evaluate the users' information, a separate **data processing process** was developed: After importing the information from the platform, all comments were divided into positive and negative comments using a trained **classifier. The language model** based on defined **error categories** was then applied to the negative comments and was able to reliably assign the comments to the defined error categories due to the high **F-score.** The aim of the process was to find clues to new, previously unknown, perceived causes of errors in the unassigned comments and thus complete the overall picture.

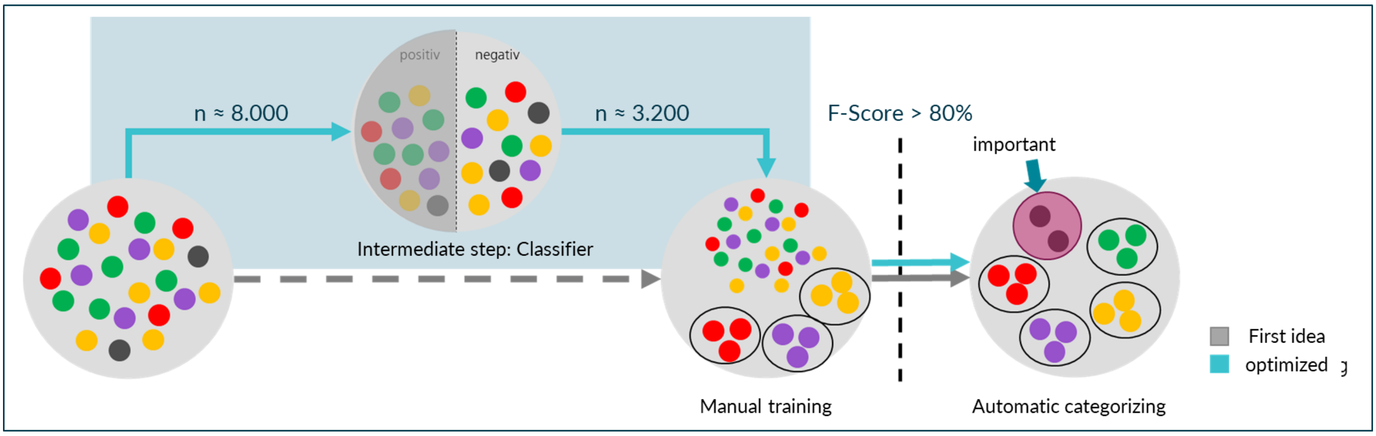

Figure 14 Error classification

It has been found that a **reduced charging performance is the** most frequent error perception on the part of the users. This error perception is followed by **aborted charging processes**, charging **stations blocked by** other charging vehicles and **authentication via RFID**. It is important to emphasize here that the causes for the perceived error categories can be of a very different nature and can lie both on the part of the technical infrastructure and on the part of the users.

Figure 15 shows the location of the defined and occurring error classes as well as the frequency of occurrence on the big picture of the charging ecosystem. It is important to emphasize the subjectivity of the user's assessment. The figure shows the causes of errors from the user's point of view. This does not automatically mean that the actual cause of the error is located at this point in the big picture.

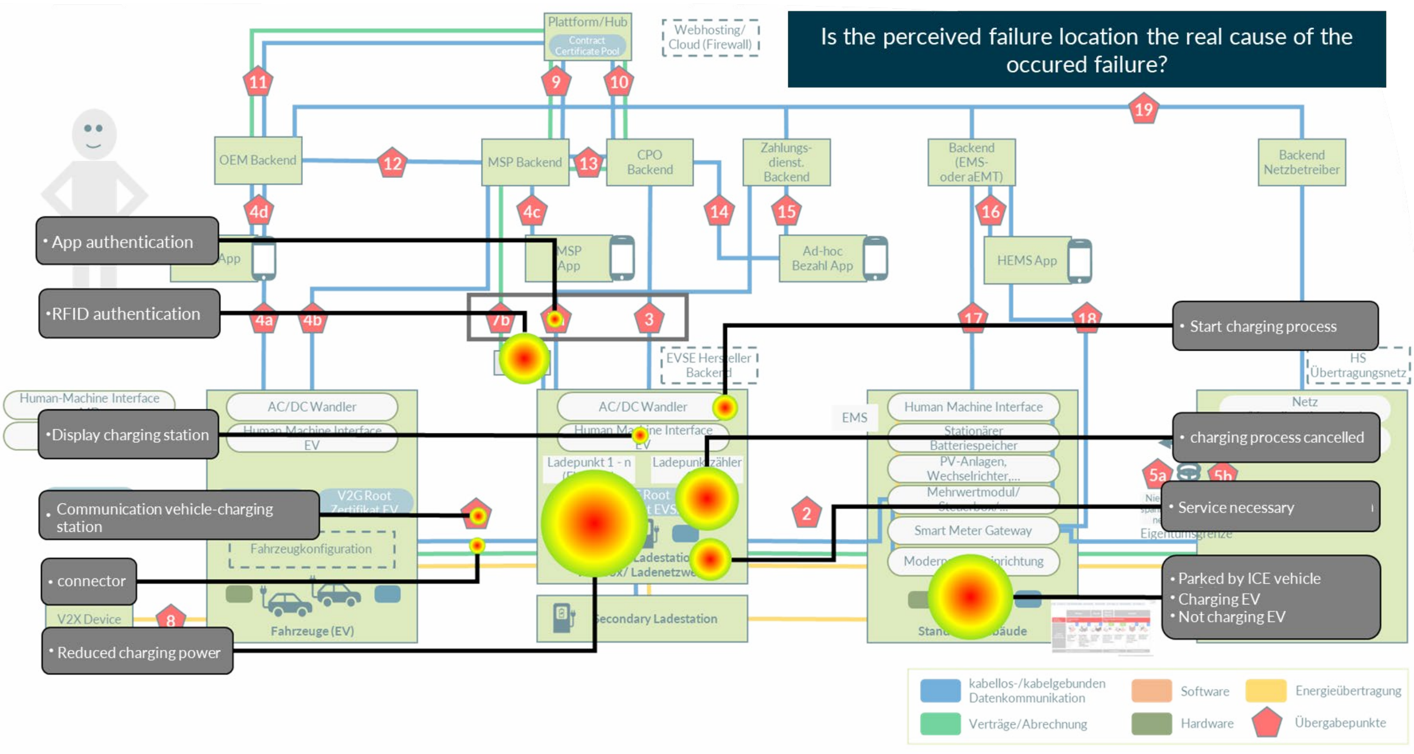

Figure 15 Fault location in the Big Picture

A critical review by the project consortium revealed that some of the actual causes for the perceived faults could also originate on the part of the customer, the vehicle or at the connector (cf. **Figure 16**).

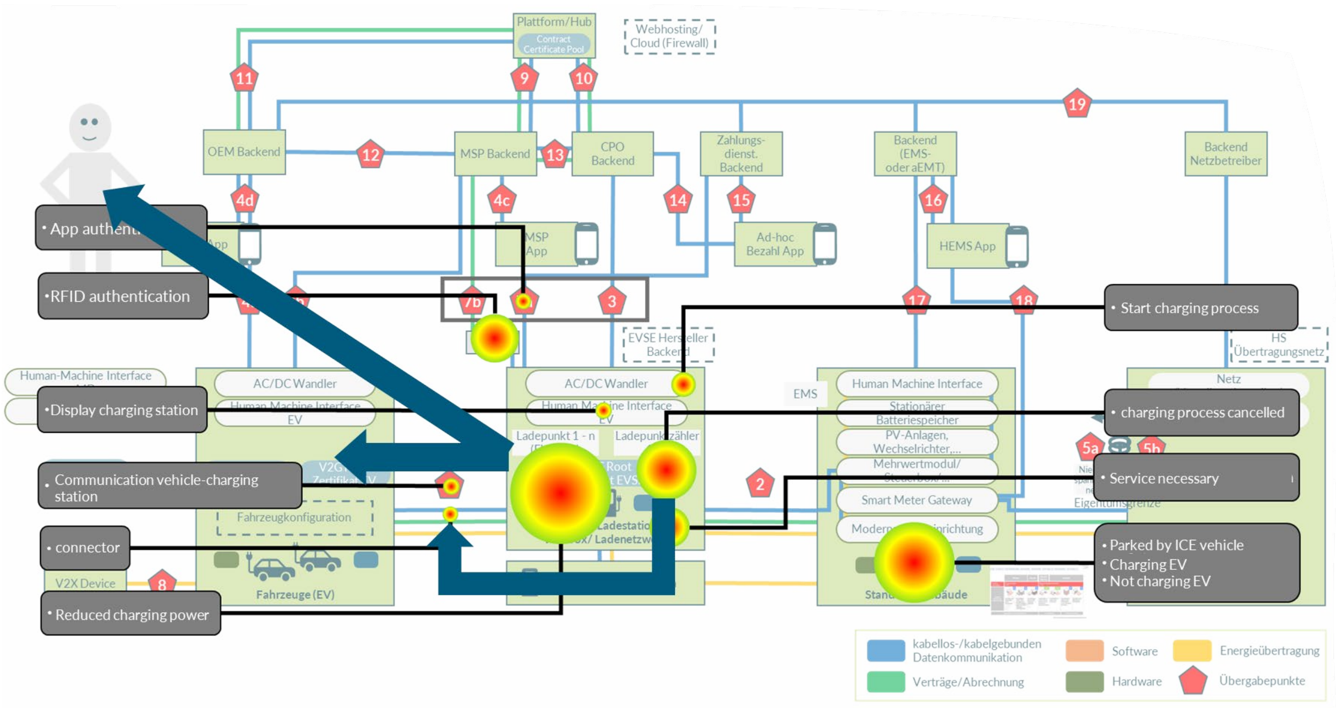

Figure 16 Fault location in the Big Picture according to suspected actual cause

Another exciting statement arises when the cause of the error is mapped in a **process-related view in** the customer journey. From this perspective, it becomes apparent that many of the perceived causes of errors occur before or during loading. If, on the other hand, the charging process itself is positive, the probability that an error will still occur when the charging process is completed, or billing takes place is very low (cf. **Figure 17**).

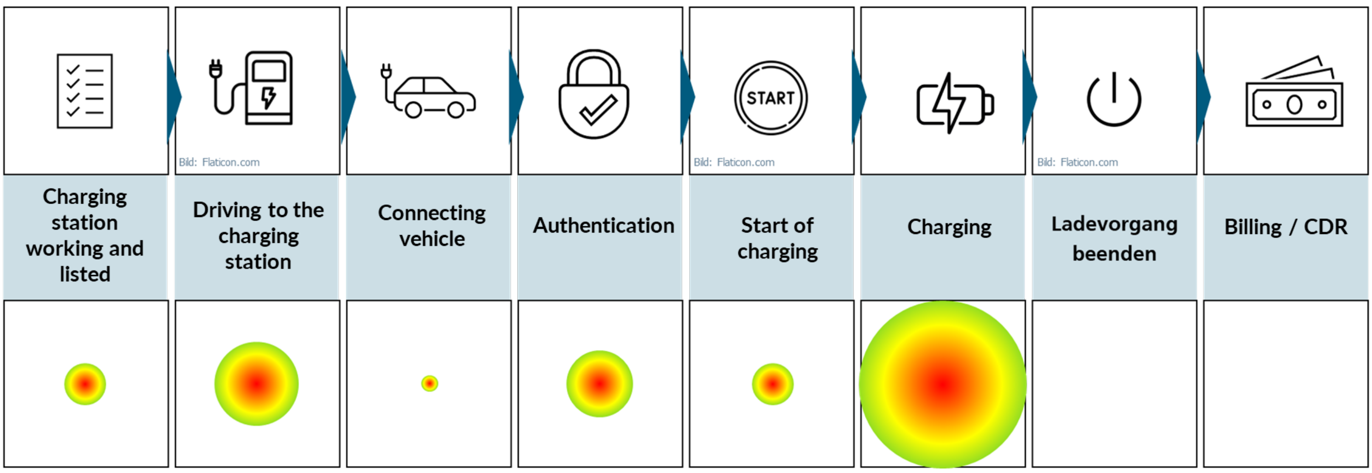

Figure 17 Loading process

In **WP 3.2,** a further optimization of the language model for sorting user comments took place. For this purpose, an additional **"filter" was** added: With the help of the filter, negative and positive user feedback can be separated and sorted in the population of user comments. Through this intermediate step, the **F-score** for measuring quality could be increased to the required order of magnitude of >80%, as envisaged in the funding project. Applied, the results of the semantic analysis show the following error perceptions as the most frequent (related to the totality of all error perceptions): Reduced charging power (25%), charging interruption (15%), charging station blocked by charging e-vehicle (13%), RFID authentication issues (12%) and maintenance/service required (10%). All other error classes occurred in less than 10% of all error perceptions. The period considered was 01.01.2019 to 30.04.2022. SixSigma experts synchronized these distributions with BMW's distribution analyses and carried out a plausibility check with regard to the charging chain.

2.1.4. WP4 Develop a methodology to describe the maturity of the interfaces

- In **WP 4.1, the** challenge is to deal with the definitions of the relevant interfaces and charging products on the basis of the jointly defined **BigPicture.**
- The result should be an opinion on the specific interfaces where there is a need for standardization. From the consortium's point of view, cooperation and harmonization with the various standardization organizations on the basis of a common architecture of the **charging ecosystem is** a major milestone on the road to e-mobility, both battery-electric and fuel cell-electric. In both cases, there is a common jumping-off point not only with the market participants in the different sectors, but also with the different **standardization organizations**. In the consortium, examples of maturity management were discussed and thus the need for a maturity description of the interfaces in PSL was presented. Without a common view on the maturity of the interface, highly divergent views naturally exist in the different sectors and thus prevent targeted measures to increase maturity.
An initial overview of the interface-specifying standards and descriptive documents was compiled in **WP 4.2**. For the interfaces defined in **WP 4.1,** the existing norms and standards as well as other documents were compiled, assigned to the defined interfaces in the ecosystem charging and a distinction was made between compulsory (**technical implementation basis**) and optional (explanatory and **contextual documents**). In the course of the project, it became apparent that this task is a necessary measure to generate a cross-industry and also cross-standardization-organization view. The consortium partners contributed impulses and views of US standards as well as standards from China. The focus on the CCS charging system for Germany and Europe within the framework of the current funding project already shows the dimension of the topic of charging.

In the course of the project, it was confirmed that the originally planned scope of work was not sufficient for a comprehensive and substantive research of the individual interfaces. The quantity of 19 (!) interfaces to be considered could not have been anticipated at the start of the project and shows the potential for a causal follow-up project. Initial previous definitions of interface-specifying standards at interface (1) EV-EVSE were made available. Thus, it could be made aware that specifications also have to be defined at the other 18 interfaces in **the ecosystem charging**. Only in this way are cross-industry sub-functions for interoperable charging in the charging chain representable. This is the only way to ensure complete and functioning customer charging functions and thus satisfactory charging experiences for customers. A detailed examination of the interfaces in the **ecosystem charging** on basis of the valuable specifications and results here in the funding project is recommended for a follow-up project.

The next logical step was to clarify which **test procedures** and test tools would be used to test the interfaces. Within the consortium it was intensively discussed to determine the quantity framework of the necessary test cases for each interface. The example of approx. **300 test cases** and the corresponding test case descriptions at interface (1) EV-EVSE shows the dimension of the necessary specifications. The discussions show the large implementation scope of the individual market participants and the associated error possibilities. This is due to market policy considerations, partly due to ignorance of existing specifications, partly due to non-awareness of the resulting error patterns in the charging chain. Within the framework of the funding project, the discussions were able to raise the awareness for the view of the entire charging chain. A core insight on the way to a **customer-friendly charging** is that successfully sold energy does not automatically result in a customer-friendly charging at the end of the charging chain. Feedback in the charging chain to the chain participants on whether a successful charging experience has actually been generated is a key insight.

WP 4.5 Definition of a standards quality index

Objective: Standards quality index for the interfaces of ecosystem charging
Definition of an appropriate standards quality index with the help of experts from the CharIN focus groups.

This index can provide information on the public availability, the copyright status and the urgency of updating the document, e.g. due to ambiguities, room for interpretation and the need for harmonization of different views of different standardization organizations.

The consortium partners are developing a common understanding on the topic of **standard quality**. As an orientation the already defined interface 1 (EV-EVSE) by the CCS Baseline V1 is valid. In two years of work in **CharIN e.V.** the **quantity structure of** the specifying different standards (DIN, ISO, IEC, ...) for this one interface was coordinated and defined cross-industry in year 01/2020 for the **CCS charging system.**

A standards quality index is to be developed for all other defined interfaces in the **charging ecosystem in order** to show and evaluate the maturity of the interface. For this will start with a methodical first approach in order to then develop it further with the consortium into a resilient joint evaluation approach. For this purpose, developed the methodical essay for the basic framework of an overview of the charging functions and for the corresponding allocation to the interfaces in the charging chain. The fundamental agreement **with the methodology**, which emerged in the last interim report, was confirmed in the further course of the project and also by the expertise of SixSigma experts. The methodology is very simple and each interface in the supply chain can be clearly and comprehensibly represented and tracked transparently across all industries by collecting and defining the respective specifying documents. As an example, reference is made to the initial definition of the **specification scope of** interface 1 (EV-EVSE). For this interface, 34 different **standards** and 9 supplementary documents had to be coordinated and defined across industries in order to make the energy transmission, communication, electrical safety, the scope for electromagnetic compatibility and noise emissions available as a **reference for** all participants. Only in this way it will be possible to speak of a common perspective on charging across all industries. In the consortium of the funding project, it is also apparent that there is a need for an overarching and clamping body that is not involved in market activities, which neutrally evaluates and demonstrates the maturity of the **customer functions charging of** the CCS charging system in the **ecosystem charging.** Due to the almost threefold increase in the originally assumed interfaces in the ECOSYSTEM Charging, the allocation of the current situation is shown in the approach, but a prolongation for 2030 within the framework of the current project work as originally planned is no longer feasible.

At the **management or control level,** a simple assessment methodology was designed and intensively coordinated with the project partners. The aim is to find an approach for evaluation that is as simple as possible and at the same time effective and comprehensible. Each interface is assigned with three **Harvey Balls**, which show how well the respective interface is developed for a customer function, e.g. Plug&Charge. The ratings are fully specified, fully tested, fully experienceable (life). In the course of the project, the methodology was further developed to interface **relevant (YES/NO)**, interface **specified (**HarveyBall), interface **tested** (HarveyBall), interface **ready for the market (YES/NO)**. With the evaluations of the consortium partners involved, a common assessment can be made of the quality of the interface description.

The fact is that from today's point of view, such a quality index for standards does not yet exist from the point of view of the customer functions of loading. This means that there is currently no causal link between the customer function of loading and the specification or test specification in the corresponding standards of the 19 interfaces concerned in the ecosystem charging. With the help of the funding project Wirkkette Laden, this connection could be recognized and made transparent for the **first time.** The problem is also suitable for a causal **follow-up project** with the participation of the affected standardization organizations, in order to be able to reach further agreements and specifications with the relevant industry partners. For happy customers at charging and happy companies at E-Mobility. A discussion of the findings with the **National Charging Infrastructure Control Centre** appears to be valuable in connection with the implementation of the **MASTERPLAN Charging Infrastructure 2.0** and is recommended by the consortium beyond the scope of the project. Findings from the funding project Wirkkette Laden were already actively provided by the VDA during the project as part of the comments for the MASTERPLAN Charging Infrastructure 2.

Wirkkette Laden Verbundprojekt

In the course of the project, it became apparent that the envisaged standards quality index can be further developed into an effective chain radar in conjunction with the synchronized **CCS charging function quantity framework**. For the first time, the harmonized view of the CCS charging function set framework was superimposed as a matrix over the 19 interfaces from the BigPicture and an initial assessment was made by the consortium partners as to which of the interfaces in the charging functions are affected and whether they are fully specified, testable and ready for the market. The result shows that depending on the charging function, **different interfaces** and partners in the charging chain are affected. This methodical approach - which is available as a project result in the form of the "**active chain radar 1.0**" - offers the potential to specifically address **open specification needs for specific interfaces** with the standardization organizations as well as with industry partners in the **CharIN,** depending on one or the other charging function.

02/2023 — **CCS Ladefunktions-Mengengerüst 1.0** — *CCS charging-function quantity structure 1.0*

02/2023	Charging functions for customers in CCS	1 Relevant?	1 Spec	1 Test	1 Marktreif	2 Relevant?	2 Spec	2 Test	2 Marktreif	3 Relevant?	3 Spec	3 Test	3 Marktreif	4 Relevant?	4 Spec	4 Test	4 Marktreif	5 Relevant?	5 Spec	5 Test	5 Marktreif
CCS Basic	**Basic Functions**																				
	AC Charging	Ja	●	●	JA	Nein				Nein				Nein							
	DC Charging (incl. HPC = High Power Charging >> CharIN Powerclass)	Ja	●	◕	JA	Nein				Nein				Nein							
CCS Extended	**Smart Charging**																				
	Local Load Balancing	Nein				Ja				Nein				Nein				Ja			
	Local Load Balancing w Data connection	Nein				Ja				Ja								Ja			
	Online Load Balancing	Nein				Ja				Ja								Ja			
	Automatic Paying																				
	Plug and Charge (ISO 15118)	Ja				Nein				Ja				Ja				Nein			
	Auto Charge (proprietär ohne Schnittstellenfestlegungen)																				
	Smart Paying																				
	Payment app (MSP = Mobility Service Provider)	Nein				Nein				Ja				Nein				Nein			
	Payment app (ad hoc)	Nein				Nein				Ja				Nein				Nein			
	Credit Card (EIM = External Identification Means)	Nein				Nein				Ja				Nein				Nein			
	RFID (EIM = External Identification Means)	Nein				Nein				Ja				Nein				Nein			
	Vehicle-to-Vehicle Charging	Ja																			
CCS Extended Plus	**Grid Integration Level V2X**																				
	Bidirectional Charging	Ja																			
	Aggregated Bidirectional Charging																				
CCS Advanced	**Automated Connection Device (ACD)**																				
	ACD-S (Automated Conductive Device - Sidecoupler)	Ja																			
	ACD-U (Automated Conductive Device - Underbodycoupler)	Ja																			
	Pantograph	Ja																			
	WPT (Wireless Power Transfer)	Ja																			

02/2023	Charging functions for customers in CCS	6 Relevant?	6 Spec	6 Test	6 Marktreif	7 Relevant?	7 Spec	7 Test	7 Marktreif	8 Relevant?	8 Spec	8 Test	8 Marktreif	9 Relevant?	9 Spec	9 Test	9 Marktreif	10 Relevant?	10 Spec	10 Test	10 Marktreif
CCS Basic	**Basic Functions**																				
	AC Charging																				
	DC Charging (incl. HPC = High Power Charging >> CharIN Powerclass)																				
CCS Extended	**Smart Charging**																				
	Local Load Balancing	Nein								Nein				Nein				Nein			
	Local Load Balancing w Data connection	Nein								Nein				Nein				Nein			
	Online Load Balancing	Ja								Nein				Nein				Nein			
	Automatic Paying																				
	Plug and Charge (ISO 15118)	Nein				Ja				Nein				Ja				Ja			
	Auto Charge (proprietär ohne Schnittstellenfestlegungen)																				
	Smart Paying																				
	Payment app (MSP = Mobility Service Provider)	Nein				Ja				Nein				Ja				Ja			
	Payment app (ad hoc)	Nein				Ja				Nein				Ja				Ja			
	Credit Card (EIM = External Identification Means)	Nein				Ja				Nein				Ja				Ja			
	RFID (EIM = External Identification Means)	Nein				Ja				Nein				Ja				Ja			
	Vehicle-to-Vehicle Charging	Nein								Ja	◔			Nein				Nein			
CCS Extended Plus	**Grid Integration Level V2X**																				
	Bidirectional Charging	Nein								Nein				Nein				Nein			
	Aggregated Bidirectional Charging																				
CCS Advanced	**Automated Connection Device (ACD)**																				
	ACD-S (Automated Conductive Device - Sidecoupler)	Nein								Nein				Nein				Nein			
	ACD-U (Automated Conductive Device - Underbodycoupler)	Nein								Nein				Nein				Nein			
	Pantograph	Nein								Nein				Nein				Nein			
	WPT (Wireless Power Transfer)	Nein								Nein				Nein				Nein			

02/2023 — **CCS Ladefunktions-Mengengerüst 1.0** — *CCS charging-function quantity structure 1.0*

02/2023	Charging functions for customers in CCS	11 Relevant?	11 Spec	11 Test	11 Marktreif	12 Relevant?	12 Spec	12 Test	12 Marktreif	13 Relevant?	13 Spec	13 Test	13 Marktreif	14 Relevant?	14 Spec	14 Test	14 Marktreif	15 Relevant?	15 Spec	15 Test	15 Marktreif
CCS Basic	**Basic Functions**																				
	AC Charging																				
	DC Charging (incl. HPC = High Power Charging >> CharIN Powerclass)																				
CCS Extended	**Smart Charging**																				
	Local Load Balancing																				
	Local Load Balancing w Data connection																				
	Online Load Balancing																				
	Automatic Paying																				
	Plug and Charge (ISO 15118)	Ja								Ja											
	Auto Charge (proprietär ohne Schnittstellenfestlegungen)																				
	Smart Paying																				
	Payment app (MSP = Mobility Service Provider)	Nein								Ja											
	Payment app (ad hoc)	Nein												Ja				Ja			
	Credit Card (EIM = External Identification Means)	Nein												Ja				Ja			
	RFID (EIM = External Identification Means)	Nein								Ja											
	Vehicle-to-Vehicle Charging																				
CCS Extended Plus	**Grid Integration Level V2X**																				
	Bidirectional Charging																				
	Aggregated Bidirectional Charging																				
CCS Advanced	**Automated Connection Device (ACD)**																				
	ACD-S (Automated Conductive Device - Sidecoupler)																				
	ACD-U (Automated Conductive Device - Underbodycoupler)																				
	Pantograph																				
	WPT (Wireless Power Transfer)																				

02/2023	Charging functions for customers in CCS	16 Relevant?	16 Spec	16 Test	16 Marktreif	17 Relevant?	17 Spec	17 Test	17 Marktreif	18 Relevant?	18 Spec	18 Test	18 Marktreif	19 Relevant?	19 Spec	19 Test	19 Marktreif
CCS Basic	**Basic Functions**																
	AC Charging																
	DC Charging (incl. HPC = High Power Charging >> CharIN Powerclass)																
CCS Extended	**Smart Charging**																
	Local Load Balancing	Ja				Ja				Ja						●	JA
	Local Load Balancing w Data connection	Ja				Ja				Ja						●	JA
	Online Load Balancing	Ja				Ja				Ja						◑	NEIN
	Automatic Paying																
	Plug and Charge (ISO 15118)															◑	JA
	Auto Charge (proprietär ohne Schnittstellenfestlegungen)																
	Smart Paying																
	Payment app (MSP = Mobility Service Provider)																
	Payment app (ad hoc)																
	Credit Card (EIM = External Identification Means)																
	RFID (EIM = External Identification Means)																
	Vehicle-to-Vehicle Charging															○	NEIN
CCS Extended Plus	**Grid Integration Level V2X**																
	Bidirectional Charging	Ja				Ja				Ja						◑	NEIN
	Aggregated Bidirectional Charging																
CCS Advanced	**Automated Connection Device (ACD)**																
	ACD-S (Automated Conductive Device - Sidecoupler)															◑	NEIN
	ACD-U (Automated Conductive Device - Underbodycoupler)															◔	NEIN
	Pantograph															◕	JA
	WPT (Wireless Power Transfer)															◑	NEIN

Figure 18 CCS charging functions quantitiy framework

2.1.5. WP5 Derive measures to improve the quality of the interfaces

The consortium will derive a catalogue of measures for error messages and develop a uniform CCS **error catalogue for** charging with the CCS charging system, the charging customer functions and thus for the charging chain.

					Schwer (Laden ist nicht möglich)					hoch	langfristig (>5 Jahre)	hoch					
					Mittel (Laden ist erschwert)					mittel	kurzfristig (1-2 Jahre)	mittel					
					Leicht (Laden ist möglich)					gering	mittelfristig (3-5 Jahre)	gering					
Quelle der Erkenntnis	**Kurzbeschreibung Problemstellung/Fehler**	**Anzahl/ Häufigkeit**	**EV-Fahrers Fehlerzuordnung zur Schnittstelle/Komponent im Ökosystem**	**Technisch analysierte Zuordnung zur Schnittstelle/Komponent im Ökosystem**	**Schwere des Fehlers (nur info)**	**Problemursache**	**Maßnahme/ Problemlösung A**	**Maßnahme/ Problemlösung B**	**Maßnahmen Stakeholder**	**Aufwand zur Behebung**	**Zeithorizont der Verbesserung**	**Priorität der Maßnahme (gewichtet)**	**Usecase**	**Bereits behoben ?**	**Fehlercluster?**	**Beschreibung Lösungsansatz Detailbetrachtung im Abschluss**	**Maßnahmenkatalog Bewertung**
Reallaborversuch	Authentifizierung SMS		Kunden	Kunden	Schwer (Laden ist nicht möglich)	-Sperre der SMS Bezahlfunktion beim Nutzer -Für Prepaid/ausländische Nutzer ist die Funktion nicht gegeben	-Hinweis per SMS auf alternative Bezahlmöglichkeiten		Kunde	gering	kurzfristig (1-2 Jahre)	gering	öffentlicher Parkraum	Nein			
Tagebuchstudie_qual	Vertauschte Kabel (Stecker-Buchse) werden von der Ladestation nicht bemerkt	einmal	Ladesäule	Ladesäule	Leicht (Laden ist möglich)	-vertausche Kabel in der Buchse	-explizite Kennzeichnung an der Ladesäule		CPO	gering	kurzfristig (1-2 Jahre)	gering	öffentlicher Parkraum	Nein			**3**
Tagebuchstudie_qual	QR-Code nicht standardisiert (QR-Codes können nicht von allen Apps gelesen werden)	5% (3%)		MSP-Backend - CPO-Backend	Mittel (Laden ist erschwert)	-nicht auslesbare EVSE-ID in der URL des QR Codes	standardisierte Formatierung der EVSE-ID in der URL		MSP/CPO	gering	kurzfristig (1-2 Jahre)	gering	öffentlich/privat	Nein			**3**
Tagebuchstudie_qual	POI-Daten sind ungenau bzw. nicht aktuell	3% (2%)	CPO	CPO	Schwer (Laden ist nicht möglich)	-nicht gepflegte POI Daten -MSP hat nicht die aktuellsten Daten	-regelmäßige Überprüfung der Daten (zB bei der Wartung)	-regelmäßiger Abruf der Daten durch MSP	MSP/CPO	gering	kurzfristig (1-2 Jahre)	gering	öffentlich/privat	Nein			**3**
Tagebuchstudie_quant	Ladestation-Backend: Verbindungsproblem	2% (1%)	Ladesäule - CPO-Backend	Ladesäule - CPO-Backend	Schwer (Laden ist nicht möglich)	-Netzabdeckung (Empfangsprobleme) -Verbindungsproblem	-Whitelisting -Notfallladefunktion aktivieren	-sekundärer Sim Modem (redundante Kommunikationkanäle)	CPO	gering	kurzfristig (1-2 Jahre)	gering	öffentlicher Parkraum	Nein			**3**
Tagebuchstudie_quant	Authentifizierung: falsche Reihenfolge	1% (1%)	EV-Fahrer	EV-Fahrer	Leicht (Laden ist möglich)	-Timeout bei der Authentfizierung	-Erweiterung der Timeou	-verbesserte Benutzerführung/ Userinterface	CPO	gering	kurzfristig (1-2 Jahre)	gering	öffentlich/privat	Nein			**3**
Tagebuchstudie_quant	Ladestation: falsche Parameter-Einstellung	1% (1%)	Ladesäule	CPO-Backend	Mittel (Laden ist erschwert)	unvollständig gepflegte Daten, Fehlinterpretation der Schnittstellen	CPO muss sicherstellen, dass die Daten korrekt hinterlegt sind	Roamingprotokolle müssen angepasst werden um die konkrete Ladeleistung am Ladepunkt zu übermitteln	MSP/CPO	gering	kurzfristig (1-2 Jahre)	gering	öffentlicher Parkraum	Nein			**3**
Tagebuchstudie_quant	Ladestation: Stecker vertauscht	1% (1%)	Ladesäule	Ladesäule	Schwer (Laden ist nicht möglich)	Falsche Ablage des Steckers beim Ladevorgang zuvor	Beschriftung/Markierung an der Ladestation/Ladestecker muss eindeutig sein		CPO	gering	kurzfristig (1-2 Jahre)	mittel	öffentlicher Parkraum	Nein		X	**2**
Tagebuchstudie_quant	Ladestation-Fahrzeug: techn. Fehler / unbekannt	1% (2%)	Ladesäule	Ladesäule-Fahrzeug	Schwer (Laden ist nicht möglich)	nicht nachvollziehbare Fehleranzeige	Vereinheitlichung der am häufigsten auftretenden Fehlerzustände -Top20 Fehler in einem standardisierten Fehlerkatalog Ladestation zusammenfassen		Fahrzeug/CPO/MSP	hoch	mittelfristig (3-5 Jahre)	mittel	öffentlicher Parkraum	Nein		X	**4**

Figure 19 Proof of concept agreed in the consortium for a harmonised error catalogue of the CCS charging system (excerpt)

The overall view for a quality improvement of the interfaces in the ECOSYSTEM Charging depends to a large extent on the participating industry partners and standardization organizations actively and value-free dealing with the **BigPicture Ecosystem** Charging and the impact chain radar of the impact chain Charging developed here in the funding project. The **SMART** (S - Specific, M - Measurable, A - Achievable, R - Relevant, T - Timely) approach is an impulse from the SIXSIGMA experts to actively shape the measurability of CCS charging system development in cooperation with the various standardization organizations, and to subsequently be able to track it. During the **final workshop** the possible measures will be discussed, supplemented and next steps for implementation recommended. In the course of the project, one topic came to the fore and was introduced in the consortium and also in the context of the charging infrastructure conference of the **National Charging Infrastructure Control Centre.** In order to clearly identify a charging point and to clearly locate it in the charging ecosystem, there is a need to give each **charging point** a mandatory **EVSE ID**. This makes it possible to discuss the question of who is responsible for doing something to close this gap in the charging chain in the charging ecosystem as quickly as possible or at a defined expected time. See also the **catalogue of measures for the** charging infrastructure.

The following 10 measures were developed. These are divided according to time horizon into short, medium and long term

Short-term measures

1. Improving POI data quality for the user
2. Monitoring of user input and corresponding service measures
3. Automated Resumption of the charging process
4. Correct and clear marking of the charging plug on the charging station
5. Activate emergency charging function for offline operation
6. Creation of transparency regarding charging performance of the charging station, charging curve of the vehicle, ambient conditions/temperature rating, power split, forecasting

Medium-term measures

7. Reliable live status display of the charging station along the charging chain
8. Roaming protocols must transmit the current charging power of a charging process
9. Standardized error codes and determination along the charging chain

Long-term measures

10. Raising awareness about parking bans in loading areas

The details of the measures from the project are discussed below.

1. Improve POI data quality to the user

It turned out that outdated and unreliable POI data can be a problem for loading. This means that information relevant for navigation, among other things, is missing. For example, can be used to check whether POI data such as geolocation is up to date during maintenance operations. Adding access information to the POI data (e.g. geolocation of the access road, floor, etc.) facilitates navigation to the charging station. Feedback from the customer should also be taken into account. Prompt provision through retrieval of the data by the MSPs should be ensured. Activities on mobility data at federal and EU level have already started.

2. Monitoring of user input and corresponding service measures

In some cases, charging will not start due to a non-responsive user interface or charge controller. Environmental influences can also prevent charging from starting. By monitoring the user interaction at the charging infrastructure, repeated unsuccessful charging attempts can be detected and responded to. Monitoring can take place both in the backend and at the charging infrastructure. Based on the monitoring, interaction patterns for known errors can be recorded and application instructions can be provided to the user in order to avoid sources of error.

3. Resuming the charging process

The interruption of the charging process due to short-term technical faults in the charging station or in the vehicle that allow the charging process to continue should be avoided. If this nevertheless happens, an independent resumption of the charging process ("restart") by the charging station is possible as soon as the malfunction is no longer present. Without a new plug-in process and new authorization, the technical charging process must be restarted and it must be ensured that this is only a short-term fault. This can be done by a technical clarification of the restart signaling, e.g. within the framework of a CharIN application note. In addition, it must be clarified in the terms and conditions that a restart falls under the previous authorization. A clarification of the technical restart signaling has already been initiated in the CharIN "field observation group".

4. Correct marking of the charging plug on the charging station

It should be avoided that the charging process cannot be started due to the incomprehensible labeling of the different charging plugs at the charging station. This can be due to the lack of labeling of the charging plug or the failure to process the identifier from the EMP due to a lack of standardization. This can be prevented with best practice charging station foiling and uniform plug labeling on the plug, on the charging station, in the app and in the vehicle. The EVSE ID should be a central identification feature at the charging point.

5. Activate emergency charging function

If a charging station is not accessible from the IT side (e.g. due to failure of the mobile phone/sim card or the CPO backend), an emergency charging function should be activated. an emergency charging function should be activated. This prevents the "stranding" of e-vehicles and billing is also possible afterwards. This can be made possible by "whitelisting", among other things. Alternatively, national roaming can be used and switching to another mobile network, provided the modems support it (redundant communication channel).

6. Creation of transparency regarding charging performance of the charging station, charging curve of the vehicle, ambient conditions/temperature rating, power split, forecasting

By providing more information to the customer, questions are clarified that would otherwise lead to uncertainty afterwards. Like the reduced charging performance, which can have various causes. For this, more data from the vehicles and the charging stations must be collected and made available so that a corresponding improved transparency towards the driver is made possible. This requires a standardization of the provision of the various data from the vehicle and the charging station. An interface is needed to ensure a secure exchange of data. To this end, an activity on the provision of information has been launched in the CharIN focus group on charging infrastructure.

7. Synchronized and reliable status display of the charging station's occupancy status

The customer must receive reliable information about the occupancy status of the charging station in the app and in the vehicle when planning the charging process. In individual cases, there does not seem to be sufficient updating of the statuses and the "age"/time stamp of the status information, which leads to greater uncertainty for the user. A lack of data connectivity at sites exacerbates the situation. It is clear that synchronization of status across all interfaces up to the driver cannot always be guaranteed. An improvement towards a comprehensive and reliable data connection at all locations (including network coverage) is certainly to be strived for. In the short term, an "age" of the status information would already be very helpful for the driver as an indication, as he can then assess the reliability of the information and, if necessary, reschedule at an early stage. In addition, activities and projects for reservation and traffic management at charging locations increase reliability.

8. Roaming protocols must be adapted to transmit the specific charging power at the charging point

It takes standard roaming protocols to extend the actual charging power of the current charging process on the display. The remaining charging time at a charging station is essentially derived from the real charging power during the charging process. This is displayed in the vehicle or partially at the charging station, but as soon as the driver leaves the charging location, this information is no longer available to him. Thus, he cannot estimate how long the charging process will take to reach the intended charging status and when he should be back at the vehicle. For this, the market participants need to agree on how the roaming protocols can be expanded to include data in order to clearly and correctly transmit the current status of the charging process, including the charging power. The expansion of the CPO and EMP apps is necessary to enable the corresponding display of this data.

9. Standardized error code handling

If errors occur during a charging process, their causes should be available in a uniform and standardized way to the vehicle, the CPO, the EMP and thus also the driver. This does not prevent the occurrence of the error but helps to trace it and to rectify it in a later step. For this, all vehicle and charging station manufacturers must agree on a uniform fault code system. These uniform fault codes must be made available in the standardized interfaces for all market participants. The errors should be presented to the driver so that he understands the causes.

10. Raising awareness about parking bans in loading areas

If charging is prevented by internal combustion vehicles (illegal parking) or non-charging vehicles, this must be punished either by appropriate signage or by blocking fees. A long-term measure here would be to educate people as early as in driving school. Uniform regulations must be established for this purpose.

In addition to the 10 measures, additional ideas were collected during the course of the project that would be relevant for an optimal charging station. We have divided these ideas into mandatory and recommended ones and presented them in a diagram (Figure 20).

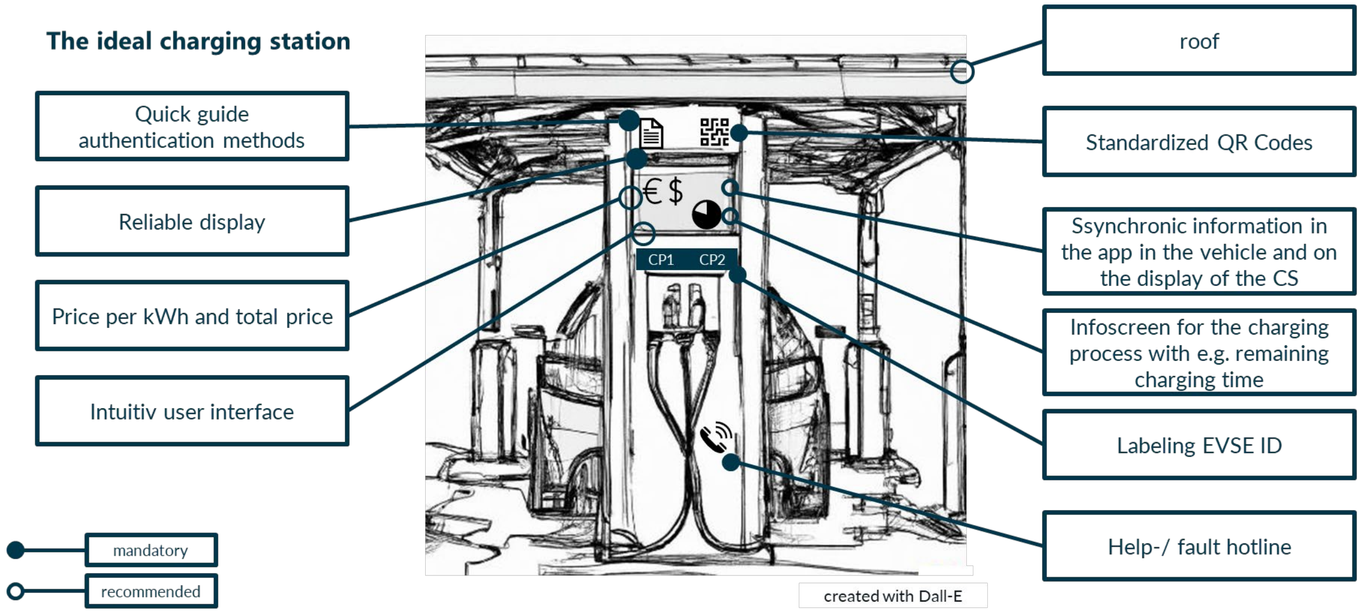

Figure 20 "The Ideal Charging Point

Comprehensively, we have established **12 design premises that are** required for an ideal charging station.

Mandatory

The EVSE ID or a part of the EVSE ID (usually the last digits) is used uniformly to designate the charging connections at the charging station - independent, other IDs, e.g. CPO-internal charging station numbers, should not be found on the charging station. The ID of the electricity meter that complies with the calibration law must be differentiated from the EVSE ID as far as possible.

2. the EVSE ID labeling is placed where it is impossible to mix it up, e.g. on the charging plug itself and not on its socket.

3. operating elements such as touch screens and buttons function reliably in all weather conditions - in the same way, the display is readable in all weather conditions and the RFID reading field is clearly recognizable as such, even in sunlight.

4. the URLs stored in the QR codes attached to the charging station are standardized to such an extent that they can be read by any app and thus enable the charging process to be started - and not just link to general information about charging.

5. for all possible authentication methods, there is at least a brief instruction directly at the charging station.

6. the charging station operator's help hotline or fault hotline (with 24/7 availability) should be clearly visible on the charging station.

Recommended

7. the price per kWh is displayed at the charging station before charging and the total price after charging - also in the case of contract-based charging (requires the cooperation of the traction current provider; technical and organizational feasibility to be checked).

The loading station gives instructions for action steps and feedback on the success or failure of a process step (with assistance if necessary). Assistance is displayed for each process step.

The intuitive usability of the charging stations, especially when starting and ending charging processes, is improved through optimized UX concepts, e.g. via audio-visual effects.

10. the charging station has weather protection, i.e. usually a roof.

An info screen for the charging process shows information on the remaining charging time until a desired SoC or a desired range (may require input data from the vehicle).

The information displayed in the charging app and the information displayed on the charging station (e.g. SoC) are synchronized.

2.1.6. WP6 Further development of the target image of the charging chain

WP 6.1 Identification of future charging use cases

In order to speak about charging across sectors on a common basis, an overview of the important charging use cases was developed via the **National Platform Mobility.** This common reference of charging **use cases** was also used in the development of **the BigPicture** here in the funding project. The aim was to create a common understanding with the consortium partners on the current basis for the **7 NPM charging use cases in** order to then incorporate the current ideas and impulses for further development of the charging use case considerations. Today, the charging technologies are assigned to the charging use cases purely in AC, DC and HPC charging technology and charging power classes. In this WP, two dimensions of the analysis were further developed and harmonized. On the one hand, the consortium further developed the **quantity structure of the potential charging functions** from the different perspectives as well as the ideas for **new charging use cases. On the** other hand, the consortium's ideas and impulses for the further development of a **cross-sectoral charging use case** reference were collected and harmonized.

The views of the charging functions were compiled in the houses and, in addition, transferred to a common, harmonized quantity framework of charging functions with the observations from CharIN of the **CharIN CCS step model** and the **grid integration levels 1 to 4.** This **CCS function quantity framework Charging 1.0** (**Figure 21**) can now be the basis for broad coordination within the industry, e.g. via **CharIN**, but also supported and flanked by the **National Charging Infrastructure Control Centre**. As far as the participants know, such a framework is available in this form for the first time. Thanks to the intensive cooperation in the funding project, this proposal could be brought to the point as the result of harmonization and synchronization work. Different views could thus be further developed and defined into a common view.

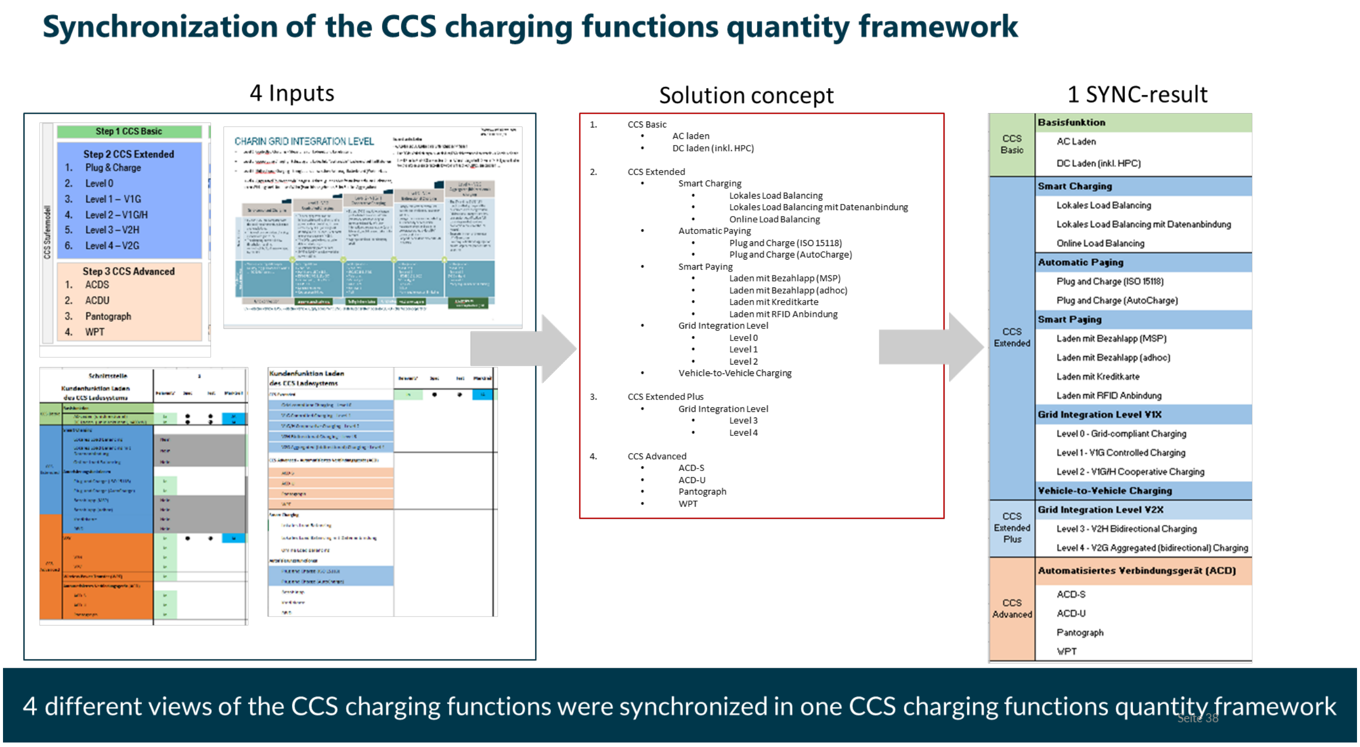

Figure 21 Consolidated and harmonized quantity structure of CCS charging functions

Furthermore, the existing ideas for the further development of the Lade Use Cases will be collected and transparently compiled in an overview as part of the funding project work. This overview is supplemented by a **CharIN** overview and a **Buyers Guide** . This collection has so far been carried out separately from the **7 NPM Charging Use Cases.** Here in the consortium of the funding project, for the first time the various considerations are mapped to the existing charging use cases and the additional ideas for **11 charging use cases of** the consortium partners are compiled and harmonized in a joint overview. It turned out that here, as in the work on the quantity framework of the customer functions of charging, or as in the case of ecosystem charging, the challenge was to categorize and order the different views. In the present project, it was possible to sort the loading use cases into a main structure and a substructure. In the **Figure 22** the terms "main locations for charging infrastructure" and "typical supplementary locations for charging infrastructure" were agreed upon and defined. In this way, the existing work of the **NPM**, the ideas of the **project partners** and the work of the **CharIN** working group have been combined in a charging use cases structure. From the point of view of the consortium partners, this is another milestone on the road to a future with electric mobility.

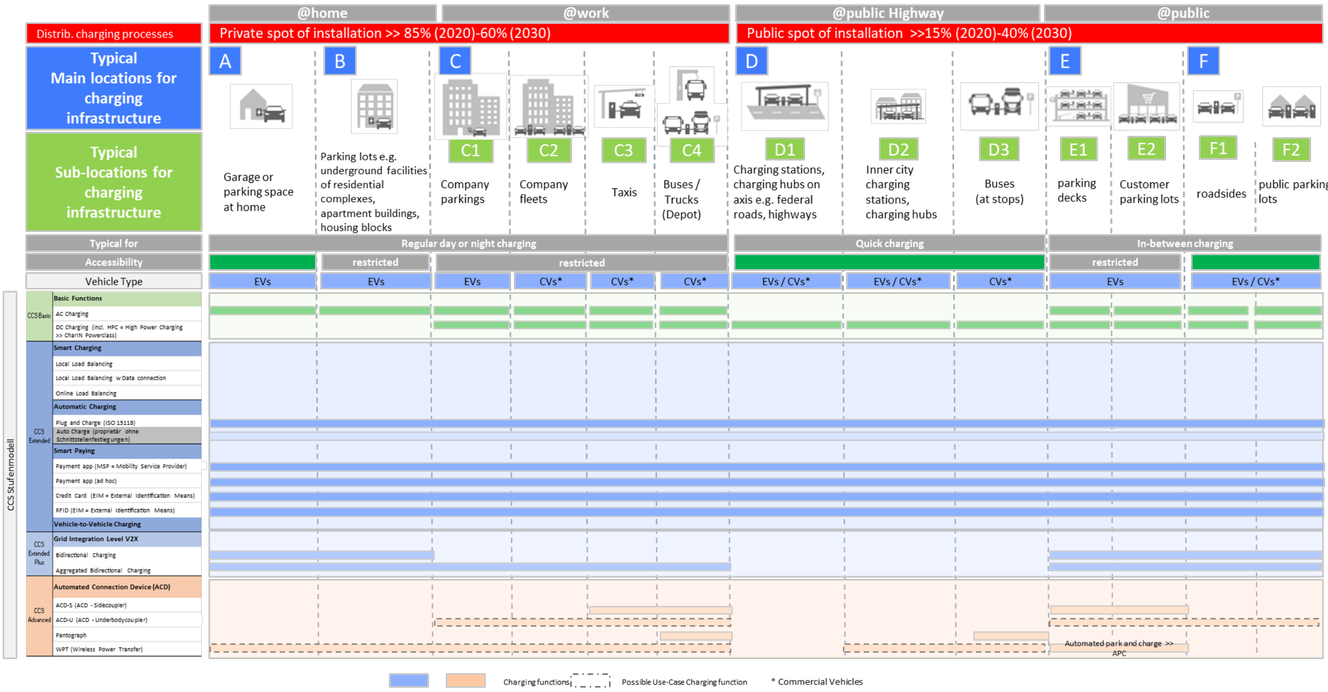

Figure 22 Consolidated further development of the NPM Load Use Case Views > > 11 Charging Use Cases

6.2 Mapping the Consolidated Load Use Cases

In **WP 6.2, the** developed and harmonized core elements of the analysis were then combined for the first time in a charging use cases (CUC) and CCS charging functions (CCS CF) matrix as an integrative approach. This **CUC - CCS CF matrix** shows the complex interdependencies of charging technologies, charging functions and charging use cases in a transparently compressed form. Current ideas for further development are also presented. This integrative approach was developed for the first time within the framework of the funding project consortium and was thus made available in an exemplary manner across all industries. This makes it possible to assign the problem areas of the **"heat map"** charging and the real-lab findings - identified in **WP 3, 4 and 5** - to a specific charging use case or charging function. Within the framework of the project work, the problem areas were systematically identified with the help of the developed references. This made it possible to develop a **catalogue of** specific recommendations for action as design premises for improving the charging user journey. The signals from the consortium for further use, especially by the **charging infrastructure control centre**, are very positive and show the initial effectiveness of the results. Measures are already being implemented to increase the quality of the charging process and reduce charging errors in the charging chain. In the course of the project, it has also become apparent that the consideration extends far beyond the current project focus. Individual problems in the charging chain could be addressed, but a targeted further examination and elimination of errors in the charging chain is proposed for a causal follow-up project, e.g. Charging **Chain 2.0.**

WP 6.3 Critical reflection of the methodologies used in the project with regard to future charging scenarios and customer centricity (VA BMW)

In **WP 6.3,** the applied methodology is in scope. In cooperation with quality management experts from the project consortium, clear recommendations for action from the SIXSIGMA method construction kit could be applied in the project. The core methods used are the ONE pager, problem hierarchy analysis, the component structuring method of the quantity framework, the design thinking approach and the **system-based engineering (SBE)** approach for pattern recognition. In the context of the application in **WP 1** at the BigPicture of the charging ecosystem, these quality methods were able to prove their successful application. Within the scope of the project work, it was possible to represent the same architecture in different characteristics and thus levels of observation congruently and self-similarly in three levels of detail. It must be possible to arrange the essential information on a ONE pager and in a congruent manner. Only in this case, the **management** and the **operative development** do have a common basis for discussion. The same basis is also created for the quantity structure of the charging functions (function matrix) as well as for the further developed charging use cases. Combined with methods of problem hierarchy analysis and component structuring methods of the quantity framework with its structural levels, the existing elements and ideas could be ordered and arranged in a fundamentally suitable way for all participants. In the case of the standards quality index, it became apparent that the basic idea could be applied in the same way. Due to the limited scope of the project, further detailing could not be dealt with. Therefore, the developed approach for a **standards quality index** should be further developed via a **focus group of the CharIN** or in a follow-up project. Ideally, as mentioned elsewhere, partners of the standardization organizations are also involved to contribute their design ideas. The continuation of the **design thinking approach** initiated and applied here, which puts the customer at the centre, is expressly advocated. In particular, to reflect on the effect with which technical solutions ultimately create a charging experience for the customer. From the point of view of quality management, the further development of the charging chain is complemented by the approach of **system-based engineering**. In the course of the project, it has become clear that it is valuable and meaningful to consider the existing elements of ecosystem charging as parts of an overall system. If, within the framework of this methodical approach, the existing elements are repeatedly placed in a systematic relationship to each other, it becomes clear how the gear wheels interlock with each other. The metaphor of ecosystem charging as a gear system helped in the project to recognize the added value of the harmonization work and to realize the associated prioritization and intensive coordination. Last but not least, an effective **change and version management of the** CCS charging system's guiding documents was recognized as a necessary method to ensure that the many necessary documents describing the charging chain and the **ECOSYSTEM Charging** are further developed in a controlled manner. At this point, it is recommended that the **document versioning** and **release management** used by the **standardization organizations** also be applied to the guiding documents of the charging chain.

2.2. Expected benefits and Exploitability

Design premises

The design premises were developed on an ongoing basis and represent a collection of elaborated recommendations that were discussed and incorporated across projects. It is intended to serve the industry as a guide for the design of a charging station. The implementation of these points avoids misunderstandings and leads to a better charging experience for the customer at the charging station. The consideration of the credit card terminal was excluded because no project results are available on this due to the time frame. The results in the project consortium have shown that the use of credit card terminals can cause potential sources of error. An increase in complexity and the associated susceptibility to errors is to be expected. In a further project, the design premises should also be expanded with regard to accessibility.

Measures serve for utilization

The measures and proposals elaborated within the framework of the funding project are mirrored as input in various committees and working groups. With the English translation, they will also be made available internationally for companies and government organizations. The measures are to be implemented within the framework of further funding projects and contribute to customer-friendly shopping.

Mirroring the results to various bodies (Big Picture, quantity framework)

The various results from the funding project, such as the Big Picture Ecosystem Charging, the charging function quantity framework or the measures to avoid charging errors, are the subject of current discussions in committees and associations. For this purpose, the consortium is in close exchange with NOW GmbH and the Federal Ministry for Digital Affairs and Transport.

Glossary

In the consortium, a glossary of the technical terms used was also created in order to "speak" a uniform language and avoid misunderstandings. At this point, standardization is also needed on a global level. For example, a charging station may consist of several charging points or an EMSP (Electric Mobility Service Provider) may not be known as such elsewhere than in Germany.

2.3. Publication

This section lists some publications by the consortium partners that were produced during the project:

Project website NOW GmbH

- Basic information on the funding project can be found on the project website of NOW GmbH https://www.now-gmbh.de/projektfinder/wirkkette-laden/

- EVS35: Publication of a conference paper ("Holistic approach for identifying weaknesses in the electric vehicle charging ecosystem") and presentation in a "lecture session".

- Presentation of the project at the BMDV charging infrastructure conference on 29.06.2022 as part of the exhibition

- Unit-E²
  https://unit-e2.de/ National Control Centre (November 22)

- Design premises charging station

  Also published on the NOW GmbH website are the proposed 12 design premises. https://www.now-gmbh.de/wp-content/uploads/2021/02/Wirkkette-Laden_Gestaltungspraemissen-fuer-oeffentliche-Ladestationen.pdf

- Social media

  - In social media such as LinkedIN, posts were published that communicated the results of the funding project to the outside world.
  - YouTube links to the real-lab experiments
    These videos show the implementation of the real-lab experiment using inexperienced test persons provided by Fraunhofer IAO.
    - Impact chain charging: Insights into the real-lab trial
    - User experience at charging stations: Findings from the real-lab test of the "Wirkkette Laden" project

- It is also worth mentioning the presentations shared with stakeholders (Hamburg city administration, internal event). The consortium partners involved have contributed to raising awareness of the issue at specialist events or internal staff events.

- Publication Björn Osterkamp in the volume *Hamburger Beiträge zum technischen Klimaschutz - 2021* "Optimierung der Ladevorgänge von Elektrofahrzeugen unter Berücksichtigung der vollständigen Wirkkette" (Optimisation of charging processes for electric vehicles taking into account the complete impact chain)

Link: https://openhsu.ub.hsu-hh.de/bitstream/10.24405/13947/1/openHSU_13947.pdf

3. Performance review report

3.1. Contribution Result to the funding objective

With the unIT-e2 project, a synchronization was started in 02/2022 and also followed up in 11/2022 in order to answer cross-industry questions on ECOSYSTEM Charging as clearly and synchronously as possible. The first promising results and feedback from the unIT-e2 funding project and the idea of and commitment to a joint ECOSYSTEM Charging are still considered highly sensible and could be confirmed.

Using the **BigPicture ecosystem charging a**s a reference to harmonize the ways of looking at things has met with great approval and recognition. In addition, an agreement on the use of the BigPicture was reached between the funding bodies (Federal Ministry of Digital Affairs and Transport) . From the consortium's point of view, this is another important milestone in the current funding project content with regard to the common basis for communication and problem solving.

The project outcome in relation to the expected outcome of the funding call

The results aimed for at the beginning of the project have been achieved. A cross-sectoral overview of the charging ecosystem with all interfaces involved was created. A charging function overview across all interfaces together with an evaluation of the specification as well as an initial evaluation of the test and maturity levels can be chalked up as project successes. A catalogue of measures was created from the findings of the evaluated charging faults and made available to the industry and the relevant ministries. Further future charging scenarios were also dealt with and developed in the consortium. The results of the work packages are described in section 2.1. Even though the data basis for the evaluation of the charging events was limited within the scope of this project, important and groundbreaking results were achieved, and in addition, necessary follow-up activities were presented.

3.2. Scientific or technical prospects of success

In this section, the achieved work results, whether technical or scientific, are explained in more detail. The findings from the evaluations and discussions continuously collected in the project are also recorded here.

For the first time in a project with so many partners from the industry, a scientific evaluation of the errors that occurred in the charging processes was carried out. It is a benchmark project on a national level (scientific). This study is intended to give an understanding of charging errors that have occurred in order to avoid and/or mitigate them in the future.

- Potential measures identified →measures realized also directly in the project
    - Changing the labeling on the connectors
    - Replacement of defective displays on charging points and/or instructions on how to activate the charging point without a display.
    - Potential security risk with QR codes through QR code phishing

- The project has processed the extensive context of the different system elements in the big picture and recorded their interrelationships for a successful charging process. Measured against the overall system complexity and the resulting risk of faulty charging processes, the error rates achieved can be rated as good. The project has shown that significant improvements cannot be achieved by fixing obvious causes but require detailed analyses and the creation of **"heat maps". In the** next few years,

this will become increasingly important as both the number of market participants and the complexity increase significantly due to new functional features of the charging interface.
- Overview of errors in the interfaces through a common understanding of key industry representatives
- Detailed view of errors in the field and restart of the loading process
- foundation project that can be further built upon. In further activities, more data should be collected on a larger number of operators and mobility providers in order to be able to make well-founded statements about the entire ecosystem and identify potentials for further developments and improvements.

3.3. Outlook

In the course of the presentation and discussion of the results, the consortium partners agreed with the Federal Ministry for Digital Affairs and Transport and NOW GmbH to initiate further follow-up activities. This includes the establishment of a new cross-sectoral working group on the charging ecosystem. Further project approaches are also in the foreground, such as the implementation of the measure to standardize charging errors in an error catalogue, standardization of the roaming protocols, dissemination of the Plug & Charge functionality and further projects on autonomous charging. As can be seen in the step-by-step model, although user-friendliness will increase through technologies such as Plug & Charge, the complexity between the back-end systems in the area of electric vehicle charging will increase in the future. Therefore, the described extension of the active chain charging approach is necessary in order to support the user-friendly technologies for a successful market introduction.

3.4. Compliance with costs and scheduling

The initially planned cost limits were adhered to and not exceeded. The work started immediately after the approval was received.

The project could not start as planned due to the delayed approval process. Thus, the project work could only be fully started with a time delay. Due to this situation and the pandemic situation, the time planning had to be revised and a cost-neutral extension applied for. The updated goal of completing all work packages according to the application by the end of October 2022 was met in full. Due to the unexpected complexity of the scope of work, it was not possible to develop all results in the planned depth and detail at every point within the set time frame. At this point, we recommend a follow-up project based causally on this funding project, e.g. Wirkkette Laden 2.0.

4. References

Globisch, J., Plötz, P., Dütschke, E., & Wietschel, M. (2019). *Consumer preferences for public charging infrastructure for electric vehicles. Transport Policy* .

National Charging Infrastructure Control Centre. (2020). *Charging infrastructure after 2025/2030: scenarios for market ramp-up*. Retrieved from https://www.now-gmbh.de/wp-content/uploads/2020/11/Studie_Ladeinfrastruktur-nach-2025-2.pdf

Philipsen, R., Brell, T., Brost, W., Eickels, T., & Ziefle, M. (2018). *Running on empty - Users' charging behaviour of electric vehicles versus traditional refuelling*.

5. Appendix

- Glossary
- Big Picture
- Document/interface overview
- Final presentation