evRoaming4EU
Realising cross-border charging in Europe

Comparative analysis of standardized protocols for EV roaming

Report D6.1 for the evRoaming4EU project

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1. Objective of the evRoaming4EU project and Work Package 6 on achieving interoperability

This report is part of the Work Package 6.1 of the evRoaming4EU project. Section 1.1 introduces the overall project, Section 1.2 discusses the context, funding and consortium for the project, and Section 1.3 introduces the role of this specific report.

1.1 The evRoaming4EU project

The main objective of evRoaming4EU is to facilitate roaming services for charging Electric Vehicles (EV) and provide transparent information about locations and rates of charging in Europe, by making use of an open independent protocol. This will be demonstrated through regional and transnational pilots in four different regions, thereby promoting the creation of one European market for EV drivers and related products and services.

The project works towards two distinct goals. The first goal is maximizing interoperability of the EV charging market, especially the ability of different charging infrastructures to communicate with each other in an efficient manner either via a single protocols or multiple interoperable protocols. The second goal is to maximize adoption of a harmonized EV charging protocol, i.e. the number of parties using the protocol. The results of the project should give insight into how these goals can be achieved, and where trade-offs of achieving these goals have to be made.

More information is available on www.evroaming4.eu.

1.2 Project context, funding and consortium

The evRoaming4EU project is an EMEurope Research and Innovation (R&I) project. Electric Mobility Europe[1] is set up by 9 European national and regional government-related organisations with a strong interest in advancing electric mobility in Europe. It is an ERA-NET Cofund under the EU Horizon 2020 programme, aiming to further advance electric mobility in Europe and designed to take transnational e-mobility research and policy exchange towards deployable solutions. The evRoaming4EU project is one of the 14 project selected by Electric Mobility Europe Call 2016, and has grant number EME-31.

The evRoaming4EU consortium consists of Copenhagen Electric, Eindhoven University of Technology, E.ON Denmark, ENIO, MRA-Electric, Smartlab Innovationsgesellschaft mbH, Stromnetz Hamburg SNH, and project coordinator The Netherlands Knowledge Platform for Charging Infrastructure (NKL).

[1] See https://www.electricmobilityeurope.eu

1.3 Objective of this report

This document is part of work package WP6 of the project evRoaming4EU. The objective of WP6 is to offer insights on how to achieve interoperability from a standardisation perspective, through a combination of desk research and stakeholder interviews.

The WP explores whether achieving interoperability feasible (and best done) via harmonization of the different existing protocols into an independent internationally accepted protocol. If not, it will explore other options to achieve interoperability (such as 'gateways' that allow translation and interconnection between systems).

This report presents a comparison of the major existing EV roaming protocols in Europe. These are the Open Clearing House Protocol (OCHP), the Open InterCharge Protocol (OICP), the eMobility Inter-Operation Protocol (eMIP), and the Open Charge Point Interface (OCPI). In Section 2.1 we discuss the selection criteria we used.

The aims of this report are:

- Provide an overview of the governance of our selection of EV roaming protocols;
- Provide an overview of the functionalities of our selection of EV roaming protocols;
- Investigate the strength and weaknesses of the various protocols as seen by relevant stakeholders and stakeholder categories.

This report is one out of three reports produced in the context of WP6. The other two are:

- **D6.2 Achieving interoperability in EV roaming: Pathways to harmonization.** Here, we present several scenarios for how interoperability for e-roaming can be achieved. For each scenario, we discuss advantages and disadvantages and how it fits within trends in e-mobility.
- **D6.3 Design principles for an 'ideal' EV roaming protocol.** In this report, we propose design principles for an 'ideal' e-roaming protocol, 'ideal' meaning in this case that it takes into account the interests of all e-mobility stakeholders to ensure seamless roaming for EV users, fits within the regulatory landscape, and allows for efficient use of public charging infrastructure in the EU.

The rest of this document is organized as follows. Chapter 2 presents our methodology and main data sources. EU. Chapter 3 presents a definition of roaming, the rationale for roaming, and introduces the roaming protocols and roaming hubs. Chapter 4 presents our analysis of each roaming protocol. Chapter 5 presents a comparison of the roaming protocols. Chapter 6 discusses the strengths and weaknesses of the protocols and issues in roaming in general as seen by various stakeholders. Finally, Chapter 7 discusses the results and indicates next steps.

2. Selection of protocols, methodology and data sources

In this chapter, we present the criteria for the selection of EV roaming protocol (Section 2.2) and our methodology and data sources (Section 2.2). We collected data through desk research (Section 2.2.1) and stakeholders interviews (Section 2.2.2).

2.1 Selection of protocols to be investigated.

As explained above, this report aims to present a comparison of the major existing EV roaming protocols in Europe. We used the following criteria for our selection of protocols: (1) the protocol is widely used in Europe, (2) the complete protocol documentation is in a final form and publicly accessible, and (3) the protocol can, in principle, be implemented by any party.

Using the above criteria, our selection includes the following protocols:

- the Open Clearing House Protocol (OCHP),
- the Open InterCharge Protocol (OICP),
- the eMobility Inter-Operation Protocol (eMIP),
- the Open Charge Point Interface (OCPI).

Note that we our selection criteria exclude roaming protocols that are meant for internal use of companies, and also exclude the future IEC 63119 standard for EV roaming, which is was sti/l under development at the time of our investigation and for which full (and final) documentation was not available.

2.2 Methodology and data sources

This report is based on a combination of desk research and stakeholder interviews. Our desk research, with a focus on with a focus on the actual protocol documentation, allows us to investigate the governance and functionalities of the roaming protocols, while the stakeholder interviews give insight in the (perceived) strengths and weaknesses of the protocols.

2.2.1 Desk research

This report analyses and compares the governance and functionalities of the EV roaming protocols OCHP, OICP, eMIP, and OCPI. These four protocols are all published online and freely accessible. We have analysed the documentation of the most recent versions of these protocols (as per December 31st, 2019) to determine which functionalities they support. We compare the protocols on supported functionalities and investigated whether there are any significant differences in their implementation in the protocol.

Another important data source for this research is the 2017 ElaadNL EV Related Protocol study [1]. This study set out with very similar research goals as we for this report. The study compares the functionalities of all major EV-related protocols and contains discussions of smart charging protocols, central system to charge point protocols, roaming protocols, and EV to charge point protocols. The study describes high level use cases the protocols support and discusses differences and overlaps between the protocols. Furthermore, the study was reviewed by people who have been involved in the development of OCPI, OCHP, and eMIP. Since the publication of this study, the OICP protocol was updated in 2017 and the OCPI protocol was updated in 2019. So, in terms of EV roaming protocols covered, our report thus expands the ElaadNL study by including a discussion on the latest (and significant) updates of OICP and OCPI, and also has a wider scope than the ElaadNL study by providing a discussion of how the protocols are used and evaluated by practitioners.

2.2.2 Interviews

We conducted interviews to investigate how the protocols are used and evaluated in practice. In our selection of interviewees, we sought variety in position in the value chain, in which roaming protocols the interviewed party uses, and in geographical location. Figure 1 presents a representation of the various market roles, and how they relate to the overall EV ecosystem. The scheme was designed to guide us in our selection of interviewees and to discuss their specific market roles. We do not claim our scheme on the EV ecosystem to be definitive, there are other valid ways of representation. Furthermore, the EV field is still relatively new and developing, and new roles may emerge in the future. Yet, we believe this scheme allows to identify a relevant set of stakeholders to approach for interviews. Furthermore, we discussed the scheme with several interviewees, who agreed that it is a good overview of the current EV field.

Our interviews were semi-structured, and we sent a summary of the interviews to the interviewees for them to check for potential errors or misinterpretations. We investigated the strengths and weaknesses of the current protocols and explored views about the future of EV charging and the role of roaming therein. We asked questions on several topics, see Apendix A Interview protocol for the complete interview protocol. In this report, we only use results from questions 1-3, which discusses roaming protocols and functionalities. (The other questions were the basis of the work we present in report D6.2; see Section 1.3.)

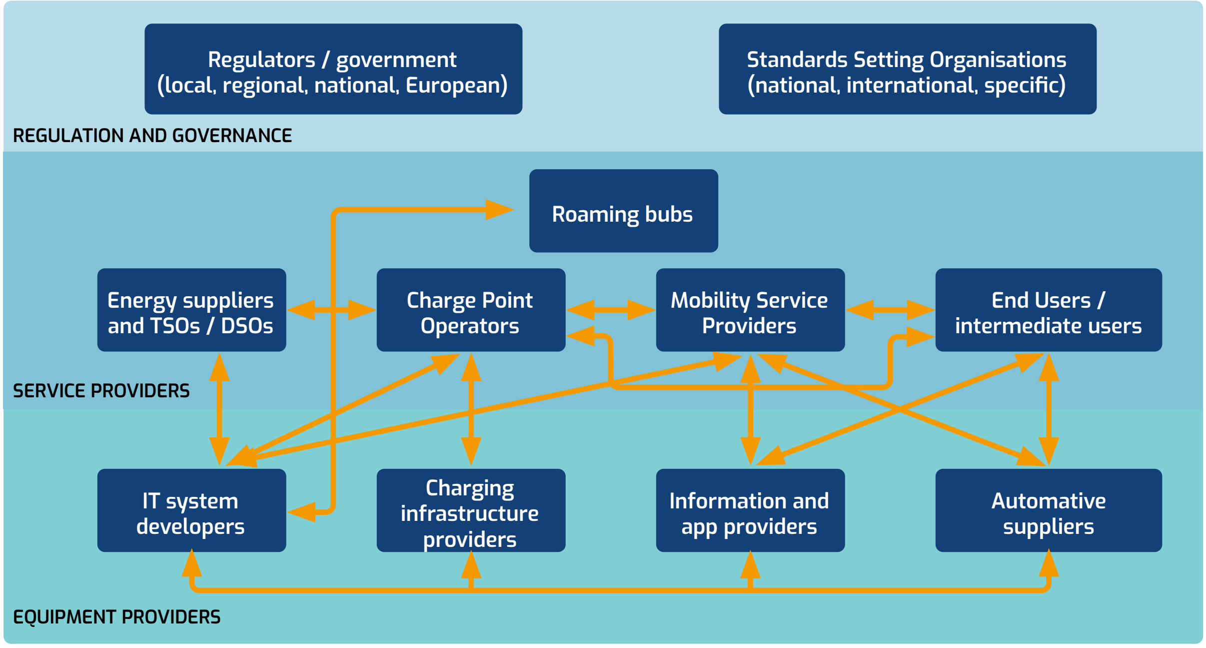

Figure 1. Market involved in the whole value chain roles and connections in the EV ecosystem. Note that we did not draw connections between the regulation and governance level to other stakeholders, since these stakeholders are involved in the whole value chain

We have conducted 35 semi-structured interviews with 38 roaming experts (three double interviews). We approached potential interviewees through the network of the project evRoaming4EU, by asking interviewees to point us to new potential interviewees, and through visiting the electric vehicle conference EVS32 in Lyon, 19-22 May 2019. We have spoken to stakeholders from the Germany (13), Netherlands (13), Austria (3), France (3), Portugal (2), Sweden (2), Belgium (1), and Spain (1). Our set of interviewees covers all the 11 roles introduced in Figure 1, except that of Automotive Supplier. We have approached several Automotive Suppliers to conduct an interview, but all of them declined. Five of the interviewees are experts on EV roaming but not captured in our scheme: two researchers, one consultant, and two representatives from sector interest organizations. Appendix B. List of interviewees presents the names and organisations of our interviewees (except for eight interviewees who participated under the condition of anonymity).

Please note that the way we identified interviewees (especially when we used our own networks) may have resulted, to some degree, in an overrepresentation of actors that use OCPI. While we did specific efforts also to include interviewees that used (only) other protocols, their final number is lower.

3. EV roaming: definition, rationale, and protocols

In this chapter, we propose the working definition for the concept of EV roaming that will be used in this report (Section 3.1), discuss the rationale of having such roaming functionality (Section 3.2), and introduce the basic system designs for EV-roaming, including peer-to-peer and roaming hub designs (Section 3.3). Finally, we discuss open protocols / open standards in this context (Section 3.4).

3.1 EV roaming definition

Roaming, in the context of e-mobility, means that an EV driver under contract of a Mobility Service Provider (MSP) can charge at a charge point that is operated by a Charge Point Operator (CPO) with which the EV driver does not (directly) have a contract, but with whom the MSP does have a contract, either directly or via a roaming hub. Roaming implies at least the following: (a) a contractual agreement between MSPs and CPOs, either direct (bilateral) or indirect (via a roaming hub or clearing house), (b) the charging point to have an internet connection, (c) a RFID card reader or a function for remote activation, and (d) interoperable communication protocols.

Note that roaming is notably different from ad hoc access to charge points, in which the EV driver is provided access via direct payment. Providing ad hoc access is mandatory for public charge points following EU regulation [2], though the means of payment are not specified, which has resulted in different implementations across CPOs. While roaming and ad-hoc payments are competing ways to achieve seamless charging facilities, they each have advantages and disadvantages, and in the future, there is likely a need for both. We discuss the advantages and disadvantages in the next section.

3.2 Rationale for EV roaming

There several benefits of EV roaming for stakeholders. For MSPs, the rationale for EV roaming is that they can offer access to charging networks outside their own and thereby being more attractive to costumers. For CPOs, the rational for EV roaming is to increase utilization rates of their charging network. Utilization rates can also be increased by providing ad hoc access, but providing ad hoc access for each charge point (e.g. via a credit card terminal) can be expensive, both in terms of CAPEX and OPEX. The disadvantages of roaming for both CPOs and MSPs are the resources needed for establishing and maintaining roaming connections and, if applicable, roaming fees when connected to a roaming hub. Furthermore, for some large MSPs/CPO, offering exclusive access to their network is a central part of their business model (examples are Tesla, and CPOs in the Nordic countries and UK), and such companies rather are the biggest player in a fragmented infrastructure, than a player in an interconnected infrastructure.

For roaming hubs, the rationale is to provide commercial services. By providing roaming services, they hope EVs will get more attractive to potential customers and thus lead to a larger EV market. This is relevant for roaming hubs with stakeholders that will benefit from increased EV uptake, which could be commercial parties, governments, or utilities.

Roaming can extend the flexibility and geographic range of charging for EV users without the need for membership of multiple MSPs. The same can be achieved via ad hoc access, without the need for any MSP contract. The main advantage of roaming over ad hoc access for EV users is thus that MSPs can offer additional services such as localization, providing charge point information, providing tariff information, offer better rating, road-side assistance and ensuring a standardized means of access, e.g. via a mobile app.

3.3 Basic system designs for EV roaming

Roaming is realized by implementing a system of communication protocols. The key functionalities of these protocols are authorization and billing, because these allow charging sessions and payments to take place. Other functionalities that these protocols can support are recording of information on charging sessions, providing charge point information, providing (real-time) tariff scheme information, providing information on surrounding facilities, encryption of data, anonymization of data, smart charging, and reservation. The key parties that communicate via the protocol are the (1) MSP that is contracted by the EV driver, and (2) the CPO that operates the charge point in question where the EV driver would like to charge his/her car. These parties can have direct connections (peer-to-peer, see Figure 2) or, alternatively, can be connected via a roaming hub (see Figure 3).

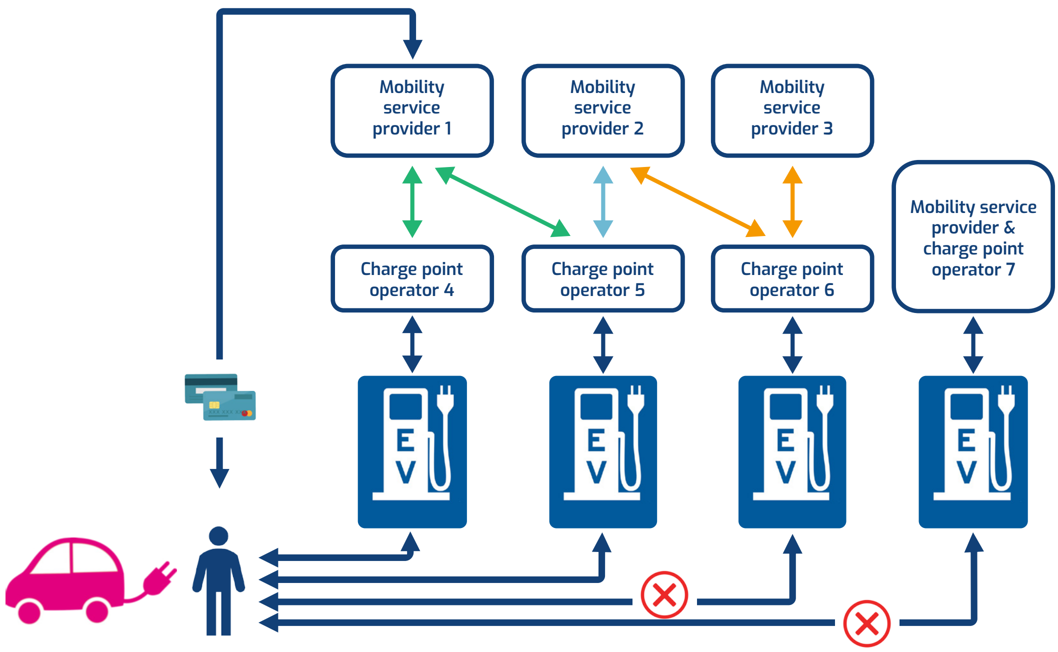

Figure 2. Roaming using peer-to-peer connections only. Different colours indicate different protocols, and the red arrows show when a user cannot charge at stations of that specific charge point operator. Adapted from[3].

Historically, roaming hubs have taken a central role in roaming systems. For many MSPs and CPOs, the advantage of connecting to a roaming hub is that it provides you immediate access to a large network outside of your own. This is a key benefit in the EV charging market, as there are many small CPOs within countries and across Europe. Roaming hubs charge a fee, and because you connect to many parties at the same time, they do prescribe you to connect in a specific way. Peer-to-peer protocols can offer more flexibility in how you connect to partners, because you decide amongst each other on the contract and on how to implement the protocol. This does make establishing and managing peer-to-peer connection more complicated. At the same time, a peer-to-peer connection avoids (commercial) fees or costs to be paid to a roaming hub. Peer-to-peer connections are thus most useful to large players with the resources to manage them, or in a system in which standard basic contracts define a minimum set of criteria for peer-to-peer connections.

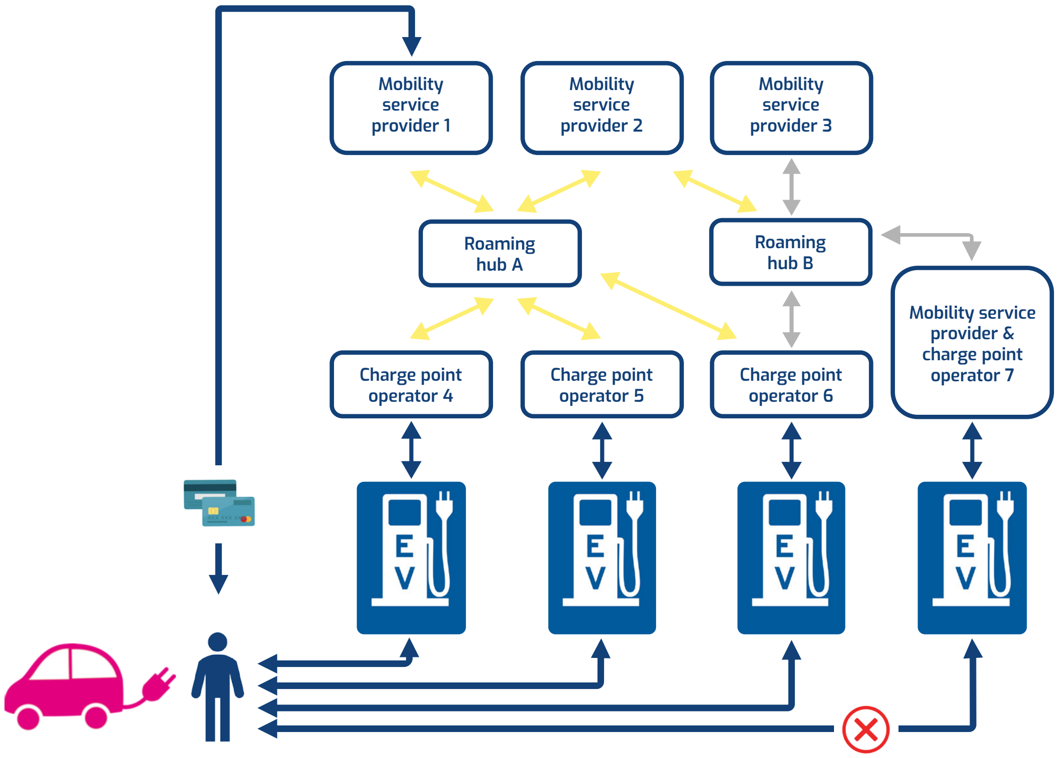

Figure 4. EV roaming using a combination of peer-to-peer communications and roaming hubs. Different colours indicate different protocols, and the red arrows show when a user cannot charge at stations of that specific charge point operator. Adapted from [3].

Other parties that may use the roaming protocol for information exchange are grid operators, navigation system providers, energy suppliers, and original equipment manufacturers (OEMs). E-mobility is relatively new and business models and market roles are still developing [4], [5], meaning that there is still uncertainty about the functionalities that are needed, and the parties that would be communicating. Functionalities that are expected to become more prominent in the future are plug-and-charge (automatic identification via car instead of via a chip or NFC card), vehicle-to-grid, social charging, conflict resolution, real-time authorization, support of new price tariff models, and functionalities relating to national or international law regarding, for instance, metering (such as Eichrecht), or privacy.

Currently, there are several roaming protocols in use in the European Union (EU), of which the Open Clearing House Protocol (OCHP), the Open InterCharge Protocol (OICP), the eMobility Inter-Operation Protocol (eMIP) and the Open Charge Point Interface (OPCI) are the most widely adopted [1], [3]. The roaming protocols differ in functionality, adopters, geographical area usage, ownership and organization structure. Furthermore, there are several roaming protocols developed and used internally by specific countries (e.g. Portugal) or companies (e.g. Plugsurfing), and furthermore, the IEC, an international formal standards setting body, has started developing a standard for EV roaming (IEC 63119). In line with our selection criteria given in Section 2.1, we do not discuss these here because their protocol documentation is not publicly available or as of yet incomplete, or because the protocols are for internal use and cannot be implemented by any other party. This fragmented situation with many roaming protocols has arisen because they were developed by hubs and organizations serving different countries, companies and interests.

3.4 EV roaming and open protocols / open standards

Three of the above-mentioned protocols use the term open in their name. In the context of protocols for EV roaming, this term may refer to open access to charging infrastructure, but it can also imply the protocol to be an open standard. What constitutes open standards is, in the field of standardisation, part of an ongoing discussion, see [6]–[10]. In response to the discussion on open standards, the World Trade Organization's Committee on Technical Barriers to Trade (WTO TBT) formulated the following six conditions for international standardisation processes: (1) transparency (regarding documentation on proposal for standards and final standards), (2) openness (open membership at every stage of standardization process), (3) impartiality and consensus (no privilege or favouring interests of a particular party), (4) effectiveness and relevance (facilitating international trade), (5) coherence (no duplication of or overlapping with other the work of other standardization bodies), and (6) address concerns of developing countries (developing countries should not be excluded de facto from the process) [11]. The degree to which the protocols adhere to these criteria differs. We discuss the degree of openness of the protocols we investigated in the next chapter, together with the other aspects of governance and protocol functionalities.

[2] https://webstore.iec.ch/publication/59496

4. Description of EV roaming protocols

This chapter describes the governance and functionalities of the four EV roaming protocols under investigation. In order of the first time of release, these are the following protocols (the indicated release version is the most recent to date and the one we investigated):

- Open Clearing House Protocol (OCHP) v1.4 and the related OCHPDirect v0.2 (Section 4.1)
- Open InterCharge Protocol (OICP) v2.2 (Section 4.2)
- eMobility Inter-Operation Protocol (eMIP) v0.7.4 (Section 4.3)
- Open Charge Point Interface (OCPI) v2.2 17 (Section 4.4)

Before we discuss these protocols in detail, we note that most of them define (roughly) similar rules, yet use different terminology. Table 1 provides an overview. For the sake of consistent language throughout this report, we as much as possible use the same terminology to describe market roles (denoted as 'General terminology in this report' in the table). We do the same for functionalities and information field names used in the protocols, wherever possible.

Table 1. Roles and terminology as found in the different protocols.

Role (short/general characterisation)	General terminology in this report	OCHP & OCHP Direct terminology	OICP terminology	eMIP terminology	OCPI terminology
A user than can charge an electric car at a charge point	EV user	EV user	User	User	EV user
Party that enters in contract with EV user in order to provide the user access to charge points	Mobility Service Provider (MSP)	Electric Vehicle Service Provider	E-Mobility Service Provider	E-Mobility Services Providers	E-Mobility Service Provider
Party that van influence charging sessions depended on other sources of information. (This role can be performed by MSPs.)					Smart Charging Service Provider (SCSP)
Party that manages, maintains and operates charge points	Charge Point Operator (CPO)	Electric Vehicle Supply Equipment Operator	Charge Point Operator (CPO)	Charge Point Operator (CPO)	Charge Point Operator (CPO)
Party that offers services to the EV user for searching, locating and routing to charge points	Navigation Service Provider (NSP)	Navigation Service Provider (NSP)	*	*	Navigation Service Provider (NSP)
Party that owns/operates parking spots that allow access to charge points		Parking Spot Operator (PSO)			
Party running a software/ connectivity platform to enable data exchange between MSPs, CPOs, and NSPs.	Roaming Hub	Clearing House Operator	Hubject	GIREVE	Roaming Hub
Party running a system that manages charging infrastructure data in a given geographical area				Data Aggregator	

*: Navigation services are supported in the protocol, but no special role is defined.

4.1 Open Clearing House Protocol (OCHP) v1.4 and OCHPDirect v0.2

OCHP is managed and developed by Smartlab Innovationsgesellschaft GmbH and ElaadNL, which are organisations founded by German and Dutch utilities respectively. OCHP is used by the roaming hub e-clearing.net,[3] which is operated by Smartlab and owned by Smartlab and ElaadNL. As a not-for-profit platform, the main interest of e-clearing.net is to develop the e-mobility market.[4] OCHP can be used for communication via a roaming hub, and there is also an extension named OCHPDirect which can be used for peer-to-peer connectivity.[5] We review the most recent versions at the time of investigation: OCHP v1.4 and OCHPDirect v0.2,[6] both released on 15-8-2016 [12], [13]. The conceptual version of OCHP (v0.1) was released 28-2-2012, and the first operating version v1.0 was released 12-12-2013.

The documents that define OCHP are made available for free and do not require registration.[7] OCHP is published under the MIT license, which allows for free distribution and modification. Smartlab/ElaadNL have the sole authority to make edits to the standard as such. Before a party gets access to the e-clearing.net roaming platform, a complete implementation test has to be executed. The developers collect user feedback through yearly workshops and through GitHub, where the protocol is published [1].

OCHP is based on the SOAP computer protocol. It mainly relies on asynchronous communication (opposed to real-time communications). It creates, for instance 'white lists' of users which are allowed to authenticate, instead of having an actual real-time authentication of users using the information present at the MSP. This choice seems to reflect a design strategy, where a single point of failure (SPOF) is avoided: should the roaming hub ever go down, charge sessions still work. e-clearing.net does not store transaction data.

In the OCHP protocol documentation, the following market roles are defined:

- The **EV user** charges an electric car at a charge point and has a direct or indirect contract with an MSP. EV users pay the MSP for charging sessions and related services.
- The **electric vehicle service provider** (a role similar to the role of MSP as we use elsewhere in this report), grants access to charge points to the EV user. The MSP has a direct or indirect contract with the EV user and provides the EV user a means of access, such as an RFID card or certificates. Its service is supported by CPOs and navigation system providers (NSP).

[3] e-clearing.net also offers connectivity via another protocol, OCPI.

[4] See https://e-clearing.net/partners/pricing.

[5] Note that in our report, the term 'OCHP' refers to the regular variant, and we will specifically use the term "OCHPDirect" when we refer to the version that can be used for peer-to-peer connection.

[6] Despite the somewhat unusual version numbering, this is a version that is meant for actual implementation.

[7] See https://github.com/e-clearing-net/OCHP.

- The **electric vehicle supply equipment operator** (a role similar to the role of CPO as we use elsewhere in this report), operates charge points and operates as contract party for the MSP, for who's contracted EV users it provides access to the charge points. The MSP pays the CPO for charging sessions by its EV users.
- The **navigation service provider** (NSP) offers service towards the EV user for searching, locating and routing to charge points. It may have contracts with CPOs or MSPs.
- The **parking spot operator** (PSO) owns and/or operates the parking spots that allow access to the charging infrastructure owned/operated by the CPO. THE PSO offers access to a parking spot where a charge point is located and can provide information on parking spot location and availability to the CPO.
- The **clearing house operator** (a role similar to the role of 'roaming hub' as we use elsewhere in this report), runs a software platform to enable data exchange between MSPs, CPOs, and NSPs.

OCHP supports the following functionalities:

- **Roaming via hub**
  The roaming hub runs the roaming platform which connects the relevant parties. OCHP is used by the roaming hub e-clearing.net, but it is not made specific in the OCHP documentation that the roaming hub should necessarily be run by e-clearing.net.
- **Authorization**
  EV users are identified by tokens. MSPs upload a list with contract IDs of their EV users to the roaming hub, which can then by downloaded by CPOs. If an EV user charges at a CPO, the CPO checks the ID against the roaming authorisation list downloaded from the roaming hub.
- **Billing**
  Charge data is collected in charge detail records (CDRs), which inform billing. The CPO sends the CDR to the roaming hub. The roaming hub performs a basic plausibility check. Correct CDRs get forwarded to the MSP If the CDR fails the plausibility check it will be sent back to the CPO for correction. The CDR can also be rejected by the CPO. The roaming hub archives CDRs.
- **Provide static charge point information**
  The CPO provides static charge point information to the roaming hub, which the MSP can then retrieve and communicate to contracted EV users. OCHP can be used to indicate the charge point ID, CPO, charge point site host, charge point location (name, address, geocode, type, image), nearby facilities, link to website, time zone, opening times, current availability status, scheduled availability status, accessibility, tariffs, authorization modes, means of payment, charge mode, connector type, maximum power, guaranteed power, voltage, hotline telephone number, reservation possible, maximum time for reservation language(s) of use interface,

user feedback form, and the time of last update. The tariff model can handle complicated tariff schemes based on time of the day, date, energy charged, charging speed, and duration based on input from CPO.

- **Provide real-time charge point information**
  The CPO provides real-time charge point information to the roaming hub, which the MSP can then retrieve and communicate to contracted EV users. OCHP can indicate the current status of a charge point (available, reserved, occupied, blocked, out of order, unknown). OCHP separates live data from static fields, even using sperate end-points, because the live data is stored in a different kind of database, which is optimized for this kind of access.
- **Provide session information**
  The session information that gets exchanged are CDR ID, charge point ID, token ID, contract ID, CDR status, start time, end time, duration, charge point address, charge point type, connector type, tariffs, meter ID, total cost, and currency.
- **Remote start/stop**
  Charging sessions can be started and ended via an MSP app.

The extension OCHPDirect supports the following additional functionalities:

- **Roaming peer-to-peer**
  Roaming functionalities are enabled without connecting to a roaming hub.
- **Authorization**
  Charging sessions can be started and ended via an MSP app.
- **Provide real-time sessions information**
  Start of a charging session, end of a charging session, metering information, power management information, invoicing ready.
- **Remote start/stop**
  The charging process can be controlled when it was not remotely started by the MSP app.

4.2 Open InterCharge Protocol (OICP) v2.2

OICP was created by Hubject in 2013. Hubject's stakeholders are the BMW Group, Daimler, Bosch, EnBW, Enel X, Siemens, Volkswagen, and Innogy – all German parties. OICP can be used to communicate within Hubject's platform, enabling communication between MSPs and CPOs. Unlike the other roaming platforms, Hubject does not only offer a technical connection between parties but also a contractual framework for roaming. The protocol consists of two parts: the MSP and the CPO each use a part of the protocol especially designed for them se. According to Hubject, it is "the most widely implemented communication standard between European EMSP and CPO systems". We review the most recent protocol documentation, which is for version 2.2, which was released in October 2017 [14], [15].

OICP is publicly available at no cost and without registration. On May 15, 2019, Hubject announced that they will release OICP as an open source protocol, free of charge, published on both their website as on open code distribution systems.[8], [9] The aim is to involve more stakeholders in the development of OICP. OICP is published under the Creative Commons Attribution-ShareAlike 4.0 International License, which allows for free distribution when given appropriate credit, and requires contributions to the protocol to be distributed under the same license. Hubject offers certification for Hubject-compatibility.

OICP is based on SOAP (like the previous protocol we discussed) and uses an object-based approach. It is a real-time protocol, although asynchronous operation is also possible. Hubject does have a database as back-up, but they are not actively supporting downloads from their database to the charging station. Hubject's platform keeps track of the transaction data.

In the OICP protocol documentation, the following market roles are defined:

- The **EV user** wants to charge an EV at a charge point, and has (in most cases) a contract with the MSP.
- The **e-mobility service provider** (a role similar to the role of MSP as we use elsewhere in this report) wants to enable EV users to access charge points. In most cases, it has a contract and exchanges information with the CPO via Hubject's interface. Multiple MSPs can be integrated in to a MSP aggregator, for which the sub partners do not need to register with Hubject, because they communicate with Hubject via the MSP aggregator.
- The **charge point operator** (CPO) operates a charge point. In most cases, it has a contract and exchanges information with the CPO via Hubject's interface. Multiple CPOs can be integrated in a CPO aggregator, for which the sub partners do not need to register with Hubject, because they communicate with Hubject via the CPO aggregator.
- **Hubject** (playing a role similar to the role of 'roaming hub' as we use elsewhere in this report), facilitates communication between MSPs and CPOs via the EV roaming platform Hubject Brokering System.

OICP supports the following functionalities:

- **Roaming via hub**
  The charge point management system of the CPO and the customer management system of the MSP connect to the Hubject B2B Service Platform which is based on web services. The CPO and MSP have an eRoaming contract via Hubject.

[8] See https://www.hubject.com/en/oicp-goes-open-source.

[9] Note that this announcement came halfway our interview round, so not out all interviewees could have known about this when we talked to them.

- **Ad hoc payment**
  Hubject offers an ad hoc payment solution called intercharge direct, which is integrated in OICP and the Hubject platform.
- **Authorization**
  Hubject compares the MSP ID or CPO ID and SSL certificate information and then either does or does not authorize the charge session. Hubject does have a database as back-up, but they are not actively supporting downloads from their database to the charging station.
- **Reservation**
  An EV driver can reserve a charge point via its MSP, e.g. via an app. Hubject will check charge point compatibility with the EV and, if compatible, forward the request to the CPO, which in turn must indicate whether the reservation was successful. A reservation can also be cancelled.
- **Billing**
  Charge session data is recorded in CDRs. Hubject forwards the CDR to the MSP and stores the CDR in its system.
- **Provide charge point information**
  A CPO can upload charge point information to Hubject's platform and MSP can download this information. The charge point information fields are charge point ID, CPO, charge point name, charge point location (name, address, geocode, type), time zone, opening times, current availability status, accessibility, tariffs, authorization modes, means of payment, charge mode, connector type, maximum power, hub connection, hotline telephone number, reservation possible, real-time status information possible, predictive charge point usage, smart charging services, and the time of last update. OICP supports flexible pricing based on charge facility, charge point location, and time-of-use.
- **Provide real-time charge point information**
  CPOs can provide dynamic charge point availability status and tariff information by uploading the current status the Hubject's platform.
- **Provide session information**
  The session information that gets exchanged are Session ID, service specifics, charge point ID, authentication data, start time of charging, end time of charging, start time of connection, end time of connection, starting meter value, ending meter value, meter value in between, consumed energy, CPO ID, MSP ID.
- **Remote start/stop**
  A charging session can start or stop via an app of the MSP.

4.3 eMobility Inter-Operation Protocol (eMIP) v0.7.4

The eMIP specification is designed and managed by GIREVE.[10] The core business of GIREVE is to offer a roaming platform for MSPs and CPOs. GIREVE was founded by EDF, Renault, CNR and Caisse des Dépôts, and its main objective is to provide "open access to vehicle charging stations".
The eMIP protocol enables roaming via a data clearing house, provide access to charging point databases, and provide smart charging features. GIREVE's main market is France. The most recent version, eMIP 0.7.4, was released 27-05-2015 [16]. This version is also the first official release of the protocol.

eMIP is available for free, but registration is required. GIREVE also offers certification services, and such certification is in fact required to connect to GIREVE's platform. The eMIP protocol, for instance, is open in the sense that anyone interested is given access to the specifications (although this is request-based, they are not publicly posted), and, when authorized by GIREVE, allowed to use them in the way they want to (also for connecting to a different hub platform or peer-to-peer connections if that party wishes so). However, the protocol documentation explicitly mentions GIREVE as the hub platform, and we understand that eMIP is not used for peer-to-peer connections in practice. We also understand that, as far as known, no royalty bearing patent licenses are required to implement the protocol as far as we know. In order to ensure a high degree of architectural openness, GIREVE regularly consults with stakeholders about potential future functionalities, for instance via AFIREV, eMI3, and the OCPI management board. GIREVE is solely responsible for the eMIP protocol, there is no formal 'eMIP-member club'.

eMIP is based on SOAP (like both previous protocols we described). It is designed as a real-time protocol and advised to be used as such, but it does also support asynchronous operations. eMIP has an architecture that makes the protocol quite flexible. New types of data messages, but for example also new identification methods, can easily be added, by means of definition tables. This means that not even a standard update is required to do so. So, in a sense, the standard is less 'hard-wired', and the developers have not yet felt a need to update the current version, which is from 2015, as explained above.

In the eMIP protocol documentation, the following market roles are defined:

- The **EV user** has a vehicle which wants to charge at a charge point and an authorization medium.
- The **e-mobility services providers** provider (a role similar to the role of MSP as we use elsewhere in this report), providers EV users with various services amongst which EV charging service, rental, car-sharing, navigation services, etc. The MSP has a B2C contract with the EV user and a subscription to GIREVE's platform.

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[10] Note, however, that GIREVE does not exclusively uses its 'own' eMIP specification, but also started offering OCPI based services, and joined the formal OCPI Management Board (see https://www.GIREVE.com/en/archives/5659 and https://www.gireve.com/en/archives/5840)

- The **charge point operator** (CPO) provides charging infrastructure and additional services to EV users and has a subscription to GIREVE's platform.
- The **data aggregator** is a system that manages charging infrastructure data in a given area and which can be requested via GIREVE's platform.
- **GIREVE** (playing a role similar to the role of 'roaming hub' as we use elsewhere in this report), manages the eMobility Services Platform that provides technical and functional means to intermediate services between the MSPs, CPOs, and data aggregators.

eMIP supports the following functionalities:

- **Roaming via hub**
  MSPs, CPOs and data aggregators connect to GIREVE's roaming platform, which is based on web services. The protocol documentation explicitly mentions GIREVE as the hub platform.
- **Authorization**
  eMIP supports several authorization processes. The nominal process is called Synchronous Authorization, in which the user checks in either via the charge point, e.g. with an RFID card, or via the MSP, e.g. via an app. Another possibility is Asynchronous Authorisation: Authentication Data Exchange, in which the MSPs upload a list of authorized subscribers to GIREVE's platform to be downloaded by CPOs. When an EV user wants to start the charging process at the charge point, e.g. via a RFID card, the CPO checks the EV user ID against this list. Finally, charging sessions can be authorized via Asynchronous Authentication Data Exchange & Synchronous Authorisation, which also makes use of the list of authorized subscribers as provided by the MSPs. Here, CPOs do not download this list but request GIREVE to check the EV user ID against the list. Which choice suits best depends on the CPO.
- **Reservation**
  An EV driver can reserve a charge point via its MSP.[11]
- **Billing**
  GIRIVE's platform exchanges CDRs between CPOs and MSPs which will form the basis for invoicing, either via Asynchronous Exchange, in which the MSP can download a CDR uploaded by the CPO at any time, or Synchronous Exchange, in which the MSP gets send a CDR uploaded by the CPO immediately.
- **Provide static charge point information**
  CPOs upload charge point information to GIREVE's platform. This data can be retrieved by CPOs, MSPs, and data aggregators. GIREVE checks the validity of the CPOs contract before updating their repository. The information fields include charge point ID, CPO, charge point manufacturer, charge point name, charge point location (address, geocode,

[11] This functionality is not described in the most recent public protocol documentation, but announced on GIREVE's website: https://www.gireve.com/en/archives/9176

type), time zone, opening times, current availability status, scheduled availability status, accessibility, tariffs, authorization modes, means of payment, charge mode, connector type, maximum power, guaranteed power, voltage, amperage, hotline telephone number, remote start/stop possible, reservation possible, and the time of last update.

- **Provide real-time charge point information**
  CPOs upload the current availability status of the charge point to GIREVE's platform. GIRIVE checks the validity of the CPOs contract before updating their repository. It includes scheduled status changes (e.g. for reservation).
- **Charge point search functionality**
  The "charge point finder" service of GIREVE allows MSPs to retrieve a list of charge points located in a given area and fulfilling a set of criteria, such as plug type.
- **Provide session information**
  Session information is recorded and send in the CDR. It includes the following information: Session ID, CPO ID, MSP ID, EV user ID, charge point ID, contract ID, start time of charging session, end time of charging session, metering report
- **Provide real-time session information**
  eMIP offers a message service, enabling CPOs to report events to MSPs and MSPs to request actions of COPs during a charging session.
- **Remote start/stop**
  A charging session can be started or stopped via the MSP.
- **Platform monitoring**
  GIREVE's platform includes a monitoring capability to check whether MSPs, CPOs, and Data aggregators have an "alive" connection to the platform. It does so by sending so-called "Heartbeat" request to the connected parties, which is meant to test the connection.

4.4 Open Charge Point Interface (OCPI) v2.2

The first OCPI protocol was originally developed by eViolin, a collaboration of several Dutch CPOs and EMSPs, in cooperation with ElaadNL, a collaboration of all major Dutch grid operators (elaadNL was already mentioned above when we discussed the OHCP protocol). OCPI is currently managed by the Netherlands Knowledge Platform for Public Charging Infrastructure (NKL),[12] which is a collaboration of trade organizations, governmental bodies and research institutes. As we will discuss below, OCPI supports roaming hub operation, but NKL itself is not a roaming hub. Recently, an interim Advisory Board was established to govern OCPI, and in the future, an elected, final Advisory Board will govern the protocol. (See Section 5.2 for more details on the governance of OCPIs.) Any party can join its OCPI development community and contribute to its development via the online developer's platform Slack

[12] Its Dutch name is Nederlands Kennisplatform Laadinfrastructuur (NKL).

[13] Because of the this condition, OCPI cannot be characterized as an open source protocol. The condition does make sense, however, otherwise there is a risk that different and incompatible versions get into circulation.

OCPI is publicly available at no cost and without registration. OCPI is published under the Creative Commons Attribution-NoDerivatives 4.0 International Public License, which allows for free distribution when given appropriate credit, but prohibits distribution of the modified versions of the protocol.[13] The first official version was released on 30-12-2015, and the most recent version (v2.2) was released on 04-10-2019 [17]. OCPI has a modular set-up, meaning that parties can choose the modules they incorporate. It also includes a version check, which is crucial for peer-to-peer connections as there is no central actor enforcing updates or stopping to support older protocols versions.

OCPI is based on JSON/rest and is real-time protocol (in contrast to previous three protocols we discussed, which were all based on SOAP). It supports synchronous as well as asynchronous operations.

In the OCPI protocol documentation, the following market roles are defined:

- The **EV user** connects to a charge point in can be provided information from the MSP
- The **e-mobility service provider**, (a role similar to the role of MSP as we use elsewhere in this report), provides EV services to EV users. MSPs connect to CPOs to offer roaming services.
- The **charge point operator** (CPO) manages, maintains and operates charge points, both the technical and administrative operations. CPOs connect to MSPs to offer roaming services.
- The **navigation service provider** (NSP) provides charge point location information. This role can be performed by MSPs.
- The **smart charging service provider** (SCSP) influence charging sessions depended on other sources of information. This role can be performed by MSPs.

The roaming hub facilitate information exchange between market actors. OCPI supports the following functionalities:

- **Roaming via hub**
  OCPI facilitates data exchange between MSPs and CPOs via hubs, for which it has a separate module offering hub support.
- **Roaming peer-to-peer**
  MSPs and CPOs can connect directly via OCPI. There are separate interfaces for both MSPs and CPOs
- **Authorization**
  OCPI has the token module that gives CPOs knowledge of the token information of an MSP. Authorization can be done real-time or via a whitelist.
- **Reservation**
  OCPI supports making a reservation and cancelling the reservation via an MSP.

- **Billing**
  OCPI supports sending CDRs that are the basis for invoicing.
- **Provide static charge point information**
  The information field it supports are charge point ID, CPO, charge point site host, charge point name, charge point location (name, address, geocode, type, image, floor level, directions), nearby facilities, link to website, time zone, opening times, current availability status, scheduled availability status, accessibility, tariffs, authorization modes, means of payment, terms and conditions, charge mode, connector type, maximum power, voltage, amperage, energy mix, remote start/stop possible, reservation possible, smart charging services, and the time of last update. The tariff module supports complex tariff calculations that depend on the time charged and energy mix.
- **Provide real-time charge point information**
  The status can be available, blocked, charging, inoperative, out of order, planned, removed, and reserved.
- **Provide session information**
  The information fields it supports are sessions ID, start time, end time, energy charged, CDR ID, authorization method, location, charge point ID, meter ID, currency, charging periods, total cast, sessions status, and last update.
- **Support signed meter data**
  OCPI supports exchange of signed meter data which can be used to conform to Eichrecht (German calibration law).[14]
- **Provide real-time session information**
  The same information can also be retrieved real-time
- **Remote start/stop**
  Charging sessions can be started or stopped via an MSP
- **Smart charging**
  OCPI supports several charging profiles: to charge as cheap as possible, to charge as fast as possible, with as much green energy as possible, or no specific preferences. The EV user can indicate the preferences per session, including when the EV should be charged and how much energy is needed. The CPO can accept or decline the preference. The charging profile module cannot guarantee that an EV will charge at the exact given limit, since other factors influence the charging session.
- **Platform monitoring**
  A still alive check is available in the hub module

[14] OCPI supports multiple solutions for Eichrecht, as proposed by the companies Has-to-be, Alfen, eBee, and Mennekes.

5. Comparative analysis

The previous chapters discussed the roaming protocols one by one. In this Chapter, we summarize and compare the four protocols, on governance (Section 5.1), functionalities (Section 5.2), data exchange characteristics (Section 5.3), and supported charge point information fields (Section 5.4).

5.1 Governance

There are significant differences between the ways the protocols are governed. Table 2 provides a summary. The developers/managers of OCHP, OICP, and eMIP themselves also operate roaming hubs (e-clearing.net, Hubject, and GIREVE respectively), while the current (and future) developer/manager of OCPI does not.

Table 2. Various governance aspects of the roaming protocols

	OCHP v1.4 & OCHP Direct v.02	OICP v.2.2	eMIP v0.7.4	OCPI v2.2
Managed by	e-clearing.net	Hubject	GIREVE	NKL (to be transferred to OCPI management board)
Managing organisation is not at the same time the operator of an associated roaming hub	No (but hub role is non-exclusive)	No	No	Yes
Download documentation and protocol free of charge	Yes	Yes	Yes	Yes
Download documentation and protocol without registration	Yes	Yes	No	Yes
Public copyright license	MIT license	Creative Commons ShareAlike 4.0 International	None	Creative Commons Attribution-NoDerivatives 4.0 International
Protocol is open source[15]	Yes	Yes	No	No
Organization of user feedback	Yes	Yes	Yes	Yes
Open community-based development	No	No	No	Yes (OCPI community)

Several governance aspects presented in the table can all be related to the discussion of openness in standards. Using the six conditions of the WTO TBT for open international standardization [11] we evaluate the protocols as follows:

- **Transparancy (regarding documentation on proposal for standards and final standards)**
  All protocols are extensively documented, and for each, the documentation is made freely available via the internet. Changes in OCHP, OICP and OCPI are traceable via GitHub repositories. These three protocols are therefore evaluated as having high transparency, and eMIP as having medium transparency.

[15] This indicated whether all formal requirements for open source are satisfied. Note, however, that this requires, among other things, that licensers themselves are allowed to make derivate works (that is, modified versions), and are themselves allowed to distribute those. This creates the risk that different and incompatible versions get into circulation.

- **Openness (open membership at every stage of standardization process)**
  For OCPI, any party can join its OCPI development community and contribute to its development via the online developer's platform Slack. OCPI management was initiated from within Netherlands Knowledge Platform for Public Charging Infrastructure (NKL),[16] which is, as discussed above, a collaboration of trade organizations, governmental bodies and research institutes. In 2018, an interim Management Board was established with 7 stakeholders of different backgrounds. This board this represents OCPI users in a broader sense, significantly increasing the openness of the protocol. This was the first step in a transitional process: it has been announced that in the future, this interim board will be followed up by an elected, (non-interim) board, which will have the authority for final decisions regarding the protocol. Also, a new, independent management organisation will be established (independent from NKL, who currently carries out this task). The copyright of the protocol will also be transferred from NKL to this new management organisation.[17] Overall, we evaluate the current openness of OCPI as medium to high, and after the transition has been finalized, as high. OCHP developers organize open workshops to collect user feedback which they may use to incorporate into the protocol, but do not allow for direct involvement of any party in the development process. We evaluate the openness of OCHP as medium. eMIP is not based on open membership and has, to our knowledge, not organized open workshops to contribute to protocol development. Its openness is therefore evaluated as low. Until recently, this was the same for OICP, but recently, Hubject released OICP as open source to allow more parties to contribute to its development by providing feedback, thus increasing its openness. We therefore evaluate the openness of OICP as medium.
- **Impartiality and consensus (no privilege or favouring interests of a particular party)**
  Concerning decisions taken on OCPI, the above-mentioned interim board (and future final board) play a role in safeguarding impartiality. This is also facilitated by the fact that the protocol is business model-agnostic. While decision-making for OCPI is strictly speaking not consensus-based,[18] we rate OCPI as 'medium to high' on this dimension, considerably higher than the other EV roaming protocols. OCHP uses input from market parties in protocol development through open workshops and is business model-agnostic. Bit is does not have something like a board or consensus-based decisions. We therefore consider its score as medium. OICP and eMIP are not based on open membership, and the protocol documentation explicitly mentions Hubject and GIREVE as the roaming hub respectively. We consider score on this dimension as low.

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[16] Its Dutch name is Nederlands Kennisplatform Laadinfrastructuur (NKL).

[17] See https://ocpi-protocol.org/about-us.

[18] In the field of standardisation, 'consensus' is usually defined as "a general agreement, characterized by the absence of sustained opposition to substantial issues by any important part of the concerned interests and by a process that involves seeking to take into account the views of all parties concerned and to reconcile any conflicting arguments." (See the definition in (ISO/IEC (2004). ISO/IEC GUIDE 2:2004; Standardization and related activities — General vocabulary), which is also adopted by many other standard setting organisations.

- **Effectiveness and relevance (facilitating international trade)**[19]
  All protocols aim at realizing seamless cross-border charging for EV drivers. OCPI and OCHP are business model agnostic, OICP and eMIP are not. However, the strictness of OICP and eMIP may also have benefits in connecting diverse EV charging markets. Which of these models better facilitates international trade is outside the scope of this study. We consider the effectiveness and relevance of all protocols as high.
- **Coherence (no duplication of or overlapping with other the work of other standardization bodies)**
  There certainly is overlap in the activities and scope of all three protocol developments. At the same time, the developers of all these protocols are working together in projects such as evRoaming4EU[20] and NEMO.[21] Furthermore, OCPI is implemented by e-clearing.net, Hubject, and GIREVE, and GIREVE is member of the OCPI management board. We therefore consider the coherence of all protocols as high.
- **Development dimension (developing countries should not be excluded de facto from the process)**
  To our knowledge, developing countries are not currently involved any EV roaming protocol development, and no attempt is made to include developing countries – even if we believe they are not de facto excluded by any protocol, either by rules, or by other aspects, such as implementation choices. OCHP and OCPI are business model-agnostic, while the protocol documentations of OICP and eMIP define the roaming hub operator.[22] Hence, OCHP and OCPI protocols are easier to adapt to the local needs of developing countries than OICP and eMIP. All-in-all, we consider the development dimension to be medium for OCHP and OCPI, and medium/low for OICP and eMIP.

[19] Note that here we mean 'effectiveness and relevance' as meant in the aforementioned WTO TBT criteria for open international standardization [11].

[20] See https://www.evroaming4.eu.

[21] See https://nemo-emobility.eu.

[22] We do not know whether involved parties would allow/support/encourage others to take up roaming hub role.

Table 3 summarizes our assessment of the openness of the governance on the protocols. It is clear that there are significant differences between the protocols, the governance of OCPI being the most open out of these four.

Table 3. Our evaluation on how the governance of the protocol score on the WTO TBT criteria for open standards following [11]. '+' indicates high, '0' indicates medium, '–' indicates low

	OCHP & OCHP Direct	OICP	eMIP	OCPI
Transparency	+	+	0	+
Openness	0	0	–	Current: +/0 Future: +
Impartiality and consensus	0	–	–	+/0
Effectiveness and relevance	+	+	+	+
Coherence	+	+	+	+
Development dimension	0	0/–	0/–	0

For all protocols, the documentation defines the market roles of EV users, MSPs, CPOs, and roaming hubs, be it with differing terminology (see Table 1). Additionally, the OCHP documentation discusses the roles of parking spot operator and navigation service provider, the eMIP documentation the role of data aggregator, and the OCPI documentation the roles of navigation service provider and smart charging service providers. These additional roles do not have major implications for the protocol design. For example, the OICP and eMIP protocols also support navigation services, but they have not defined a separate role for these services.

5.2 Functionalities

Table 4 shows that the protocols share many basic functionalities. We will now mainly focus on where the differences lie. The most important difference is whether the protocols support only roaming via hubs (OICP) or roaming via hub as well as peer-to-peer connections (OCHP+OCHPDirect, eMIP, and OCPI). The protocol documentations of OICP and eMIP explicitly mention Hubject and GIREVE as being the roaming hub respectively, while OCHP and OCPI do not limit the role of hub to one specific party only. There are some further differences: OICP is the only protocol that supports ad hoc access, OICP, eMIP and OCPI are the only protocols that support reservation for a charge session, eMIP is the only protocol that supports a charge point search module, OCPI is the only protocol that supports signed meter data exchange (relevant to conform to German calibration law), OCHPDirect, eMIP and OCPI are the only protocols that provide real-time session information, OCPI is the only protocol with a smart charging module, and only eMIP and OCPI offer platform monitoring functionality.

Table 4. Supported functionalities. We have highlighted functionalities not supported by all protocols.

	OCHP v1.4	OCHP Direct v.02	OICP v.2.2	eMIP v0.7.4	OCPI v2.2
Roaming via hub	**X**		**X**	**X**	**X**
Protocol documentation defines who is the hub operator			**X**	**X**	
Roaming peer-to-peer		**X**		**X**	**X**
Ad hoc payment			**X**		
Authorization	X	X	X	X	X
Reservation			**X**	**X**	**X**
Billing	X	X	X	X	X
Provide static charge point information	X	X	X	X	X
Provide real-time charge point status information	X	X	X	X	X
Charge point search functionality				**X**	
Provide session information	X	X	X	X	X
Support signed meter data (Eichrecht)					**X**
Provide real-time session information		**X**		**X**	**X**
Remote start/stop	X	X	X	X	X
Smart Charging					**X**
Platform monitoring				**X**	**X**

5.3 Data exchange characteristics

There are also differences in how the protocols exchange data, see Table 5. OCHP characterizes itself as an asynchronous protocol, by which is meant that that parties can upload to and download data from a central storage space, where both MSP and CPO data is stored. OCPI characterizes itself as a synchronous protocol, where a request is directly answered by a response, and there is no central storage area. For OICP and eMIP, the pattern used depends on the specific message. This is relevant for instance for authorization: If, in a synchronous protocol, an EV user is authorized to start a charging session, the MSP is not informed at that specific time. This functionality is needed if an MSP wants to offer the service to communicate time-based tariffs to the consumer, which is expected to become more relevant in the future with the advent of smart charging.

*Table 5. Types of supported data exchange. * indicates that the pattern used depends on the specific message*

	OCHP v1.4	OCHP Direct v.02	OICP v.2.2	eMIP v0.7.4	OCPI v2.2
Asynchronous data exchange	X	X	X*	X*	X*
Synchronous data exchange			X*	X*	X*

5.4 Charge point information fields

Table 6 presents the charge point information fields the protocols support. Some protocols support more fields for location and technical specifications than others, but there is significant overlap between the protocols. Some notable differences are:

- OICP is the only protocol that does not support the scheduled availability of a charge point (e.g. whether it is reserved in the future),
- OICP does offer more information than the other protocols on whether a charge point has added services, such as roaming hub connection and to which roaming hub, and whether the CPO offers usage information relevant to estimate the chance that the charge point is available,
- OCPI supports information on the local energy mix and detailed information on smart charging services,
- OCHP, OICP and OCPI offer complex tariff modules that can include time-based fees, starting fees, reservation fees, etc. eMIP can provide tariff information but does not explicitly support these multiple components.

Table 6. Supported fields for charge point information. We have highlighted information fields not supported by all protocols

	OCHP v1.4	OCHP Direct v.02	OICP v.2.2	eMIP v0.7.4	OCPI v2.2
Charge point ID	X	X	X	X	X
CPO	X	X	X	X	X
Charge point site host	**X**	**X**			**X**
Charge point manufacturer				**X**	
Charge point name			**X**	**X**	**X**
Charge point location name	X	X	X	X	X
Charge point location address	X	X	X	X	X
Charge point location geocode	X	X	X	X	X
Charge point location type	X	X	X	X	X
Charge point location image	**X**	**X**			**X**
Charge point location floor level					**X**
Directions					**X**
Nearby facilities	**X**	**X**			**X**
Link to website	**X**	**X**			**X**
Time zone	X	X	X	X	X
Opening times	X	X	X	X	X
Current availability status	X	X	X	X	X
Scheduled availability status	**X**	**X**		**X**	**X**
Accessibility	X	X	X	X	X
Tariffs	X	X	X	X	X
Authorization modes	X	X	X	X	X
Means of payment	X	X	X	X	X
Terms and conditions					**X**
Charge mode	X	X	X	X	X
Connector type	X	X	X	X	X
Maximum power	X	X	X	X	X
Guaranteed power	**X**	**X**		**X**	
Voltage	**X**	**X**		**X**	**X**
Amperage				**X**	**X**
Energy mix					**X**
Hub connection			**X**		
Hotline telephone number	**X**	**X**	**X**	**X**	
Remote start/stop possible				**X**	**X**
Reservation possible	X	X	X	X	X
Maximum time for reservation	**X**	**X**			
Real-time status information possible			**X**		
Predictive charge point usage			**X**		
Smart charging services			**X**		**X**
Language(s) of use interface	**X**	**X**			
User feedback form	**X**	**X**			
Last updated	X	X	X	X	X

6. Stakeholder views on roaming

This chapter discusses the evaluation of roaming protocols and roaming in general by relevant stakeholders, based on our interviews (see Section 2.2.2 for more information on the selection of interviewees).

We first discuss some general aspects of the interview round (Section 6.1). We then discuss protocol governance (Section 6.2), protocol functionalities (Section 6.3) and other issues in roaming (Section 6.4). We finish this chapter with a discussion on how to achieve seamless interoperability (Section 6.5.

6.1 General aspects

Of the 35 stakeholders we interviewed, 25 actually use roaming protocols in their own organization, of which many have implemented more than one protocol. Of these parties, 22 use OCPI, 17 use OICP, 10 use OCHP and 7 use eMIP. These stakeholders use roaming protocols in their role of CPO, MSP and roaming hub. We use results from these and the remainder of interviews to discuss other issues in the current functioning of EV roaming in Europe. As already noted, our interview round likely has an overrepresentation of stakeholders using OCPI, which might colour our results to some degree.

6.2 Protocol governance

In Section 5.1, it was already explained that OCPI was the only protocol where development was community-based, and where the managing organisation was not at the same time operating the associated roaming hub. The value of this was reflected in interviews: a high number of interviewees appreciate the openness of OCPI. They like that the protocol is business model agnostic, publicly accessible, does not require the use of patented inventions insofar they require royalties, and that there is the possibility to propose new functionalities. Furthermore, several interviewees welcome the recent effort to include non-Dutch parties in the OCPI community – previously, it was seen as a bit of a national affair. Four interviewees also raised criticisms, while still being overall positive of OCPI governance. One criticism that was made is that the OCPI board is too involved in deciding which new functionalities should be added, and would rather see this completely handed over to the OCPI community. Two interviewees added that board membership is on invitation (and thus not open to anyone) and consists of members from commercial parties. These might push their own interests in the protocol development.

Another interviewee stated that even though it is possible to be involved in OCPI development via digital communication, physical meetings continue to be of importance, and because many involved parties are located in the Netherlands, France, and Germany, the protocol's development is still dominated by parties from these countries.

The degree to which the open governance of OCPI matters to our interviewees, depends on how active they want to contribute to protocol development. Interviewees that do want to contribute actively to protocol development, appreciate an open governance mode, which allows them to do so. Several other interviewees do not have a strong opinion on open governance, because they do not have the desire or resources to contribute, or are already happy with what current roaming protocols have to offer. No interviewee mentioned any particular positive aspect of the governance of the other protocols, but many interviewees appreciate the services the roaming hubs provide. One interviewee stated that even though the involvement of market stakeholders could contribute to OCPI responding faster to market demands than the other protocols, the difference in development speed will probably be small.

When compared to OICP and eMIP, the openness of OCHP can be classified as high (see Section 5.1). Still, in our interviews, OCPI was named as an example of an open protocol or 'the' peer-to-peer protocol more often than OCHP. Some reasons that were named are (1) the development community of OCPI is more inclusive, (2) OCPI is perceived to have a higher adoption rate than OCHP, (3) OCPI is perceived to have more resources for further development than OCHP, and (4) stakeholders are not aware of OCHP or of the peer-to-peer variant OCHPDirect.

6.3 Protocol functionalities

The interviewees stated that the protocols they use are crucial for their business model, and are mostly satisfied with the functionalities offered. However, some interviewees expressed concerns about a lack of attention to security and privacy. Another issue, named several times, is that roaming protocols do not support all potential future price tariff models.

Many interviewees name the business models supported by the protocols as the most important difference in functionalities. When it comes to other functionalities, the general view that emerges from our interviews is that on a high level, the roaming protocols are very similar, and that the technical differences are only relevant to low-level implementation. The protocols mostly overlap in their goals, functionalities, and maturity. The protocol developers respond to the same market pressures that are increasingly influencing protocol development, which is why the developers often add similar functionalities to new versions. Several interviewees stated the OCPI is currently less mature than the other protocols, but expected the protocol to become more mature soon due to more experience gained in implementation.

Another relevant dimension on which the protocols differ is flexible versus strict implementation. OCPI is a modular protocol that allows for flexibility in its implementation. This flexibility has advantages and disadvantages. Several interviewees like it that they can make custom connections, but this also requires more effort than connecting via a roaming hub, which has more strict demands on how parties implement the protocol.

Especially Hubject is considered strict in this matter. The more standardized connection offered by roaming hubs is seen as an easy solution to connect to many parties at ones. One interviewee stated that the strictness of Hubject's platform prevents to do your own quality checks on parties that you connect with. For other protocols, the related platforms offer a technical connection, but leave contractual matters up to the CPOs/MSPs.

6.4 Other issues in roaming

The roaming protocols are only one aspect of achieving a well-functioning roaming system, and there are still several other aspects that merit attention. Interviewees mentioned, among others, the following concerns: (a) parties having different, not fully compatible implementations of protocols, (b) lack of data sharing, (c) errors in data input, (d) lagging updates of dynamic data fields, (e) the lack of a centralized database for charge points, (f) no universally adopted definitions for the type and format of data input, (g) back-end system outages, (h) unfair pricing, (i) a large number of different pricing models, and (j) differences between national legislations.

Interviewees also expressed concerns about not all CPOs offering roaming functionality. There are two main reasons why they may not do so. Firstly, some small CPOs do not have the resources to establish an IT department to implement roaming protocols. Secondly, some large CPOs do not offer roaming functionality because their business model is centred on offering exclusivity for their customers. The interviewees who discussed this issue all thought that as the market matures, these large CPOs will be compelled start to offer roaming services, because parties that do offer roaming will become more dominant in the market. Several interviewees stated that legislation should require (partly) publicly funded charging stations to connect to a roaming platform. One interviewee saw as a threat, based on current trends, that MSPs may charge different tariffs to their own costumers than to roaming costumers. This may create the situation that even in an interoperable charging infrastructure EV drivers still need to have multiple charging passes to be able to charge at lower costs.

While roaming gets increasingly popular, EV users still experience issues both with roaming systems and with charge points offering ad hoc systems. A representative of an EV user association summed up the user concerns as follows:

- *Incomplete localization data*[23]
  Apps often just give a street address, but if the address is a big area such as a shopping centre parking lot, it still not so easy to find it. If the apps include pictures of charge points that would already help a great deal.

[23] Note that more detailed localization information (e.g. geocode, description of the type of location) is already supported by the all roaming protocols, and OCHP and OCPI support images of charge points. It depends on information provider, however, whether such information is entered, and on the CPO or on the app makers whether such information is used.

- *Lack of information*
  There is a lack of information on matters such as the type of plugs, the number of plugs, and tariff schemes. Not every charge point has the same type of plug, and it is important for the EV driver to know whether the EV can be charged at that point. The number of plugs can give you an indication on your chances of the charge point being available to you (real-time information on availability, information on scheduled availability, and historical information on availability can also help to indicate these chances). Tariff schemes differ between CPOs, and you should know upfront how much you have to pay for a charging session.
- *Lack of a single app or database with all charge points*
  There is no European-wide centralized database that contains all information on charge points and can give you access to all charge points. This is very annoying for EV users. There should be one database for information which is updated every day in the EV navigation system, and one (or multiple) means for authorization as a minimum requirement for access at charge points. This could by either one EU-wide adopted card or app, or something that users already own, such a credit or debit card. Plug-and-charge (identification by car, for instance based on ISO/IEC 15118) could be the solution in the future.
- *Insufficient road-side assistance and problems when authorisation fails for technical reasons*
  Hotlines at charge points often do not provide 24/7 service, and even if they do, it is not always possible to remotely start the charge point. If authorization or payment fails for a technical reason, charge points should just provide the electricity for free. This is not because of an unwillingness to pay, but just so that you are not going to be stuck on the road.
- *Tariff schemes being unfair*
  Tariff schemes are not always considered fair. According to this interviewee, tariffs should be based on energy charged, not on minutes parked. A time-based fee for staying parked after the EV has fully charged does make sense, so that the charge points become available for the next EV needing to charge.

6.5 Achieving seamless interoperability

In the context of EV roaming, seamless interoperability means that, ultimately, a user (EV driver) can charge at any public charge station, regardless the CPO that station and regardless the MSP the user has selected for mobility services and payment.

Seamless interoperability of EV charging infrastructure requires (1) technical interoperability of charge points and plugs, (2) interoperability of payment systems, and (3) interoperability of charge point information exchange systems. Ensuring interoperability of items 2 and 3 via roaming requires that either all relevant stakeholders use the same roaming protocol, or that they use gateway technologies that allow translation and interconnection between systems to the best degree possible. Currently, there are several parties acting as gateways: the roaming hubs e-clearing and GIREVE have started to implement OCPI and several MSPs and CPOs have implemented multiple roaming protocols. We discussed with our interviewees whether this situation will last, or whether the market will move towards roaming via a single protocol. We will discuss the results of these discussions in report D6.2 (Section 1.3). We name this issue in this report because developing well-functioning gateways for the protocols was often named as one of the most important current challenges in protocol development.

7. Summary and discussion

The main results from our interviews as well as the protocol documentation concerning the similarities and differences are summarized in Table 7. Our analysis reveals that the most important differences between protocols are the governance structure and supported business models of the protocols. This is supported both by our desk research and our interviews.

Table 7. Summary of similarities and differences between the roaming protocols

	OCHP	OICP	eMIP	OCPI
Governance	By a non-commercial roaming hub operator	By a commercial roaming hub operator	By a commercial roaming hub operator	By knowledge platform, to be moved to independent board
Accordance to WTO criteria for open standards	Medium-high	Medium	Medium-low	Current: Medium-high Future: High
Supported business models	Both P2P (OCHPdirect) and (any) roaming hub	Only via Hubject roaming hub[24]	Only via GIREVE roaming hub[24]	Both P2P and (any) roaming hub
Other functionalities	To a high degree similar			
Supported Charge Pint information fields	To a high degree similar			

In terms of governance, OCHP, OICP and eMIP are all developed and managed by a roaming hub operator. Two of these operators, Hubject (who governs OICP) and GIREVE (who governs eMIP) are commercial parties that only allow the protocol to be used for their own roaming platform. e clearing.net (who governs OCHP), however, is a non-profit platform in the sense that its stakeholders (Smartlab/ ElaadNL) invest all of the profits in the platform. As discussed in Section 5.2, OCPI was originally developed and managed by NKL, a collaboration of trade organizations, governmental bodies and research institutes. Recently, an interim Advisory Board was established to govern OCPI, and in the future, an elected, final Advisory Board will govern the protocol. These different governance modes are reflected in our evaluation for their respective accordance with the WTO criteria for open standards. Specifically, we found that protocols that are not governed by commercial roaming hubs to offer more opportunities to provide input for the development process. Furthermore, OCPI (the only roaming protocol not attached to a roaming platform) will in the future also have a democratic process in place for further protocol development.

[24] The protocol documentations of OICP v2.2 [14], [15] and eMIP v0.7.4 [16] explicitly mention as the roaming platform Hubject and GIREVE respectively. However, in our interview round it was stated that both protocols are free to use by anybody as they wish, so it could also be used to connect to other roaming platforms or peer-to-peer.

In terms of supported business models, OCHP and OCPI support roaming both via hub as well as peer-to-peer. In that sense, they can be considered business-model agnostic. eMIP can, in theory, support both business models, but in practice is only used to connect to a hub, being GIREVE's platform. In contrast, OICP only supports roaming via Hubject's platform, and this protocol is thus linked to a single business model by a specific party. (Note that, as discussed above, e-clearing and GIREVE not only offer connection with their 'own' protocols, but also with OCPI.)

In terms of functionalities (apart from support for hubs respectively peer-to-peer connections), the four roaming protocols we looked are not very different. The most significant difference seems to be the smart charging module OCPI offers in its newest version, and OCHP is planning to support smart charging in their next update. The most recent OCPI version was published in 2019, while the most recent versions of the other protocols were published in 2015-2017. It is unknown when the other protocols will release updates, but it will be interesting to see if and how they incorporate smart charging in the new versions. The roaming protocols fulfil current market demands, but the market is still developing and new functionalities such as plug-and-charge will need to be incorporated in the protocols in the future. Furthermore, several interviewees expressed concern about security and privacy issues. Security and privacy are discussed in the protocol documentation but only to a very limited degree, making it difficult to assess how these issues are handled. The roaming protocols are also fairly similar in terms of supported charge point information fields.

Appendix A. Interview protocol

1. Roaming protocol development
Currently, there are several roaming protocols in use. We would like to discuss:
a. Your organizations' use of roaming protocols
b. Your awareness of the different roaming protocols
c. The technical and functional differences between the roaming protocols
d. Progress and challenges roaming protocol development
e. The role of regulation in roaming protocol development and innovation

2. Your current business model and support of existing charging protocols
We would like to discuss your organizations' business model and position in the value chain of EV charging. Here, we discuss charging protocols in the broad sense (i.e. not limited to roaming protocols). We would like to discuss:
a. Your business model and position in the value chain
b. How charging protocols you currently use support, but also hinder your business model

3. The future of your business model
E-mobility is relatively new and the field is developing rapidly. We would like to discuss:
a. The future business model of your organisation
b. New activities in the value chain
c. What functionalities charging protocols should have to facilitate these activities

4. Your view on the future of the public EV charging infrastructure
Related to the previous point, we would like to discuss your view on the future of the public EV charging infrastructure. We would like to discuss:
a. Trends in public EV charging infrastructure
b. Number of parties active in EV charging infrastructure in the future (many versus few firms with monopolistic tendencies)
c. Role of traditional automotive firms versus the role of new players and firms from sectors such as energy and ICT

5. Pathways to harmonization
There are several scenarios for achieving full roaming functionality between all public charge points worldwide. We can think of a scenario in which existing roaming protocols merge in one single standard and a scenario in which gateway technologies are used to achieve interoperability. Gateway technologies are systems that interface with two or more different protocols to the best degree possible.
We would like to discuss:
a. Importance of achieving interoperability
b. Likeliness of both scenarios
c. Whether another scenario is likely

d. Advantages and disadvantages of the scenarios
e. Main lessons from sectors such as telecommunication, the Internet and banking in achieving a standard for roaming
f. Applying these lessons to e-mobility

6. Involvement in roaming protocol development

Currently several efforts are undertaken to set up organizations for the development and management of roaming protocols. We can also imagine a future in which such responsibilities are transferred to large standard setting organisations such as ISO, IEC, IEEE, or CEN/CENELEC. We would like to discuss:

a. Desirability of such efforts
b. Your interest in being involved in further developing these protocols and in what manner

Appendix B. List of interviewees

Table 8. List of interviewees. Eight interviewees participated under the condition of anonymity and are not presented in the list.

Interviewee	Organisation	Country
Michel Bayings	eMobility consulting	Netherlands
Gilles Bernard	AFIREV	France
Alfred Böhm	Stromquelle Energietechnik GmbH	Austria
Nuno Maria Bonneville	MOBI-E	Portugal
Diego García Carvajal	European Copper Institute	Spain
Onno Ceelen	EVBox	Netherlands
André Martins Dias	CEIIA	Portugal
Moritz Dickehage	Smartlab GmbH	Germany
Lonneke Driessen	ElaadNL	Netherlands
Roland Ferwerda	NKL	Netherlands
Christian Hahn	Hubject	Germany
Doris Holler-Bruckner	Austrian Sustainable Mobility Association	Austria
Daniel Kulin	Power Circle	Sweden
Kor Meelker	Allego	Netherlands
Freerik Meeuwes	EVBox	Netherlands
Anas Munir	Smartlab GmbH	Germany
Eric Munneke	Eco-movement	Netherlands
Fredrik Nordin	Bee Charging Solutions	Sweden
Christian Peter	Electro-Mobility Club	Austria
Arne Richters	Allego	Netherlands
Stephan Riechel	ENBW	Germany
Jean-Marc Rives	GIREVE	France
Maxime Roux	Freshmile	France
Ernesto Ruge	Giro-e	Germany
Martijn Santbergen	Vattenfall	Netherlands
Tobias Schneider	Innogy	Germany
Dietrich Sümmermann	Share and Charge	Germany
Kai Weber	Bosch	Germany
Ewoud Werkman	TNO	Netherlands
Kristian Winge	Sycada	Netherlands

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