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# **SCALE** introduction

SCALE (Smart Charging Alignment for Europe) is a three-year Horizon Europe project that explores and tests smart charging solutions for electric vehicles. It aims to advance smart charging and Vehicle-2-Grid (V2G) ecosystems to shape a new energy system wherein the flexibility of EV batteries' is harnessed.

The project will test and validate a variety of smart charging and V2X solutions and services in 13 use cases in real-life demonstrations in 7 European contexts: Oslo (NO), Rotterdam/Utrecht (NL), Eindhoven (NL), Toulouse (FR), Greater Munich Area (GER), Budapest/Debrecen (HU) and Gothenburg (SE). Going further, project results, best practices, and lessons learned will be shared across EU cities, regions, and relevant e-mobility stakeholders. SCALE aims to create a system blueprint for user-centric smart charging and V2X for European cities and regions.

SCALE's consortium comprises 29 cutting-edge European e-mobility actors covering the entire smart charging and V2X value chain (equipment and charging manufacturers, flexibility service providers, research and knowledge partners, public authorities, consumer associations, etc.) It is led by ElaadNL, one of the world's leading knowledge and innovation centers in smart charging and charging infrastructure.

# List of abbreviations and acronyms

Acronym	Meaning
AC	Alternating Current
ACD	Automated Connection Device
ВРТ	Bidirectional Power Transfer
ccs	Combined Charging System
СРО	Charge Point Operator
CSMS	Charging Station Management System
DC	Direct Current
DSO	Distribution Grid Operator
EMS	Energy Management System
eMSP	e-Mobility Service Provider
EMS	Energy Management System
EN	European Standard
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FCR	Frequency Containment Reserves



FRR	Frequency Restoration Reserves
GUI	Graphical User Interface
IEC	International Electrotechnical Commission
ISO	International Organisation for Standardization
HEMS	Home Energy Management System
OCPI	Open Charge Point Interface protocol
OCPP	Open Charge Point Protocol
OpenADR	Open Automated Demand Response protocol
PKI	Public Key Infrastructure
PWM	Pulse-width modulation
SCALE	Smart Charging Alignment for Europe
SCSP	Smart Charging Service Provider
SoC	State of Charge
ToU	Time-of-use
TSO	Transmission System Operator
V1G	(Unidirectional) smart charging
V2B	Vehicle-2-Building
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
V2X	Vehicle-to-Anything
VDP	Validation Data Provider
WPT	Wireless Power Transfer



# **Report executive summary**

# 1.1 Key words

Electric vehicles, smart charging, bidirectional charging, V2X, ISO 15118, OCPP, OCPI, interoperability

# 1.2 Summary

Advances in smart and bidirectional charging will offer financial and ecological benefits for individuals, create new value streams and business models for market actors while at the same time increase the stability of the electricity grid. To reap all these benefits, it is required that the right hardware, software and regulatory framework is in place.

This report provides an overview of hardware and software requirements for EVs, charging stations and Charge Point Operators required to achieve the targeted outcomes of the V2X system architecture. Based on the desired outcomes of a V2X ecosystem defined in chapter 1, the different open communication protocols and their respective versions were reviewed in chapter 2 and evaluated based on the smart & bidirectional charging capabilities required for the system architecture.

We conclude that already with the use of existing dominant protocol versions some level of smart charging can be performed. But to truly unlock the potential benefits from smart and bidirectional charging for both the consumer as well as the wider electricity system, new capabilities and functionalities are required from the communication infrastructure.

Through desktop research on the functionalities of the different protocols and their respective versions, we conclude that the latest or soon to be released protocol versions of OCPP & OCPI allow for most desired outcomes to be achieved by a V2X ecosystem. Nevertheless, it relies heavily on information availability from the EV to fulfil on the user-centricity guiding principles.

With regards to EV- Charging Station communication, the current dominant protocol for both AC as well as DC charging is IEC 61851. This protocol is not considered future proof due to several reasons such as lack of support for bidirectional charging and an inability to bidirectionally exchange information between the EV and charging station such as present State-of-Charge of the battery. The bidirectional communication capabilities that ISO 15118-20 offers in addition to IEC 61851 would close most of the gaps related to the desired system outcomes for the EV – Charging Station communication.

As adoption of these functionalities to other protocols involved the e-mobility ecosystem happens with some delay to the publication of new protocol like ISO 15118-20, the available draft documentation for the future OCPP 2.1 and OCPI 3.0 was analysed.

The only real critical gaps that would remain are non-discriminatory access to required input data such as technical battery related information (State of Health, round-trip efficiency curves,..), exchange of real-time grid measurements and a better and more complete tariff data model supported by the different protocols so that they can reflect the different tariff structures of consumer electricity bills.

Unfortunately, we also need to conclude that market adoption of the latest protocol versions tends to go very slow. This leads to a market which is lagging behind on unlocking the smart & bidirectional charging capabilities that would otherwise be possible if the market be adopting new protocol versions much sooner. Governments, (inter)national and local, could play a key role in consumer adoption of V2X technologies and related services by pushing for faster protocol adoption through public tendering requirements and point-of-purchase subsidies.

For this target audience, chapter 6 provides a complete overview of requirements that could be imposed to e-mobility infrastructure such as EVs and Charge Point, but also CPOs related to third party control and DSO communication.

By including the requirement for minimum lead times for implementation of newer protocol versions, governments would be able to play a key role in speeding up the adoption of newer protocol versions, bringing us closer to a user-friendly, cyber-secure smart and bidirectional charging physical and digital ecosystem that can operate within the limits of the distribution grid while paving the way for faster adoption and higher penetration rates of renewable energy.



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# Purpose of the deliverable

# 1.3 Attainment of the objectives and explanation of deviations

The objectives related to this deliverable have been achieved in full and as scheduled.

#### 1.4 Intended audience

This report defines general smart & bidirectional charging ecosystem outcomes, reviews the different dominant protocols against these outcomes and defines minimum general hardware and software requirements for the different actors involved in the e-mobility ecosystem. The target audience of the report is therefore diverse due to the scope of the report. This chapter provides a non-exhaustive overview of audiences to which this report is valuable, provides a short description of why they would find this report valuable and where they could find the information in the report that would be of main interest.

#### 1) SCALE consortium partners

In chapter 2, this report provides a detailed analysis and overview of the different functionalities that the different protocols involved in the e-mobility ecosystem can offer with regards to smart & bidirectional charging serving different control topologies and energy services.

It can therefore serve to evaluate whether the hardware and software that the different partners involved in the different pilots are currently able to provide can fulfill the envisioned control topology and targeted energy services. it can also be used by the involved partners to make decisions about required upgrades to other protocols or more recent protocol versions is required necessary to deliver on the required functionalities and desired outcomes.

#### 2) E-mobility actors (car & charging station manufacturers, CPO's,...)

Precious time and effort of resources within e-mobility operators is often primarily spent on scaling their business while delivering a high-performing product or service to the market. Therefore, they often do not have time to analyze how they could respond to what the state-of-the art protocols and their respective functionalities have to offer that could advance and complete the functionalities offered by their product or service.

This report can be used to conduct product research more efficiently as it contains a concentrated and complete source of information about the functionalities and services the different protocols and their respective versions enable and how they can be used with regards to smart and bidirectional charging and its impact on the different roles within the e-mobility ecosystem. It also could be used as a checklist to verify whether potential partners would functionally qualify for their capabilities to achieve the desired system outcomes from a hardware and software perspective.

#### 3) Regulators

Smart and bidirectional charging have the potential to contribute substantially to the deep decarbonization of our electricity system while at the same time minimize the capital investments needed to increase the hosting capacity of our grid infrastructure to accommodate these electricity flows. This requires sound and timely regulatory interventions so that the desired market outcomes can be achieved. Designing such regulation often impacts both the required hardware and software of the targeted actors.

For regulators specifically, chapters 3 and 6 provide a valuable source of information when designing and defining these specific regulations and mandates with regards to AS-IS and TO-BE functionalities enabled by the different communication protocols and their covered actors.



#### 4) City, regional and local legislators

Charging infrastructure that is rolled out today is expected to still be in operation within 10 years from now. Especially for charging infrastructure that is rolled out with the support of public money, legislators need to make sure that they can define minimum requirements for the different actors so that it is able to meet the needs of the energy and e-mobility system of today as well as in the future.

For legislators, chapter 6 provides a general overview of these different hardware and software requirements for the different actors within such a system to ensure smart and bidirectional charging can take place while achieving the ecosystem outcomes defined in chapter 1 and evaluated in chapter 3.

#### 5) Grid operators

The potential benefits to system resiliency, adequacy and congestion management that smart and bidirectional charging could offer to the transmission and distribution grid are known to grid operators.

In general, the analysis of the different protocols with regards to the available smart and bidirectional charging functionalities under chapter 2 could be helpful to grid operators in gaining understanding and trust in how the different communication protocols and their respective versions involved in the e-mobility ecosystem could be used to achieve the desired grid operator outcomes defined in paragraph 1.4.

For TSOs specifically, when smart or bidirectional charging would be used to provide such services, getting data transparency on asset level will become harder. For TSOs, this report analyses how the different these protocols could be used to provide the grid operator with an independent validation data stream and provides recommendations in paragraph 3.3 on what additionally needs to be covered to achieve the desired outcomes from paragraph 1.3.

For DSO's specifically, this report analyses how the same protocols could be used to deliver non-wire alternatives to deal with congestion management from uncontrolled charging, provide high levels of cyber-security and can be network code compliant and proposes recommendations on how to improve them for these specific purposes in paragraph 3.4.

#### 6) Standardization bodies

This report reviews the different protocols involved in the e-mobility ecosystem with regards to the available and desired functionalities relative to the different desired smart and bidirectional charging ecosystem outcomes defined in chapter 2.

For standardization bodies specifically, Chapter 3 provides a list of recommendations that fill the identified gaps in the different protocols to achieve the desired outcomes described in chapter 1. These recommendations are intended to serve as input for new use cases that could be covered in future protocol improvements that could bring the ecosystem closer to achieving the desired outcomes.

## 1.5 Structure of the deliverable and links with other work packages

In order to define hardware and software requirements for the different actors involved in the SCALE pilots and the overall smart and bidirectional charging ecosystem in general, this report starts with a definition of the desired ecosystem outcomes under chapter 1 and linked to task 1.4.

The definition of these requirements allows to review the in-depth analysis of the relevant functionalities for smart and bidirectional charging covered by the different communication protocols and their respective versions under chapter 2.

This analysis was done through desktop research making use of official protocol documentation and consultation of the different experts part of SCALE consortium members.

Chapter 3 evaluates the fit-for-purpose of the different protocols covered under chapter 2 against the desired outcomes and proposes protocol and regulatory related recommendations per outcome cluster of chapter 1.





These identified and described recommendations will serve as input for work package 2, task 2.2 and 2.3 specifically, and the regulatory analysis of work package 5.

Secondly, the in-depth analysis of chapter 2 and provided conclusions and recommendations of chapter 3 also aim to serve as input for the use case definition of work package 3 so that the partners in different pilots involved could already decide on whether other or newer protocol versions are required in order to deliver certain required smart or bidirectional functionalities without having to wait for the deliverables of task 2.2 and 2.3.

Based on the Chapter 3 conclusions, Chapter 6 defines the minimum hardware and software requirements for the different key actors involved (EV, Charging Station and CSMS) achievable with the most recent versions of the different protocols.





# 1 Guiding principles and clusters digital infrastructure

Before the smart & bidirectional charging requirements can be defined for the physical and digital infrastructure in a V2X ecosystem, one needs to define what outcomes they need to achieve. This chapter describes several key outcome clusters and defines several guiding principles for each outcome cluster.

The desired outcome clusters and related guiding principles will serve as the basis to evaluate the useability and interoperability gaps of the different communication protocols involved in the e-mobility ecosystem that will be evaluated in chapter 3. The collected insights from chapter 2 and derived recommendations from chapter 3 will eventually be integrated in the overall smart and bidirectional charging requirements from chapter 6.

# 1.1 User-centricity

Without the consumer's consent and continued engagement, the potential of smart and bidirectional charging will not be able to be fully exploited. It is therefore important that the consumer is always put at the centre of the V2X ecosystem. That's why we define some guiding principles for what user-centricity could and should mean in the context of V2X.

#### Fulfilling the driver needs should always be prioritized

Failing to meet the mobility needs can lead to consumer disengagement with regards to smart & bidirectional charging. To avoid this, the actor that fulfils the smart charging service towards the driver should have accurate insights into how much it needs to charge by when so that the driver will not notice any difference at the end of the charging session compared to uncontrolled charging.

When the smart charging service provider would fail to fulfil the mobility needs of the driver, a fallback mechanism initiated by another actor, for example by the electric vehicle, should ensure that smart or bidirectional charging would be overruled and switched to charging as fast as possible without any explicit instruction by the driver.

#### • Freedom of smart charging service provider choice without vendor lock-in

A consumer should be able to decide for himself to whom they want to outsource the optimization of his charging session sessions based on the customer value proposition and the level of trust one has in that company to threat his data well. This could be his Car manufacturer, the Charge Point Operator (CPO), an Energy Management System (EMS) or any other third-party actor.

This also requires that non-discriminatory access to the required input data for smart & V2X charging algorithms such as battery State of charge, grid and EVSE measurements, etc. is guaranteed for all actors in the ecosystem based on explicit consumer consent and in line with GPDR. Access to the required input data for the different control topologies is further covered under the desired control topology & energy services outcomes of paragraph 1.2.

Secondly, vendor lock-in with regards to smart and bidirectional charging should always be avoided as this holds back innovation. Therefore, each actor that is assigned by the consumer to optimize their charging sessions should be able to do so in a way that they can achieve the same outcomes and provide the same level of customer experience. Only then would a level playing field be achieved.

Switching of smart charging service provider should ideally be as seamless as switching electricity supplier for the consumer. Although it is assumed that switching will not occur that often, making this process frictionless requires that clear underlying business processes must exist and be supported by the different protocols.

 Smart and Bidirectional charging can only be executed within the technical limits of the EV battery so that the warranty of the vehicle will not be impacted for the consumer

Bidirectional charging creates additional charging & discharging cycles compared to unidirectional charging.





This leads potentially to additional battery degradation impact on the EV. Lack of understanding on this topic backed by data leads to barriers V2X adoption on the consumer-side. Standardization of V2X battery cycling or State of Health constraints from a car manufacturer's perspective combined with data transparency on battery state of health impact of bidirectional charging could help overcome this issue.

Both the consumer as well as the smart charging service provider should therefore be provided with transparent data on the V2X cycling constraints imposed by the car manufacturer so that these can be considered in the optimization. To avoid the risk of losing the warranty on the battery through bidirectional charging activities, exceeding these V2X cycling limits should always be avoided by disablement of the discharging functionality in the EV itself.

Next to the V2X cycling constraints, other technical limits that would apply or could impact the effectiveness of smart and bidirectional charging such as round-trip efficiency curves need to be available to the actor that delivers the service to the user.

# 1.2 Control topology agnostic for the different energy services

An important aspect of smart and bidirectional charging is the communication between different actors in the charging chain. There are different routes that can be used for this and different languages or protocols with which the actors "talk" to each other. Open standards and protocols play an important role here.

#### · Control topology agnostic

Because of the desired user-centricity outcomes, different control topologies must be supported by the V2X ecosystem architecture so that the consumer freedom of choice criterium related to smart & bidirectional charging services can be fulfilled. A control topology defines the communication architecture needed to get messages to the actor that performs smart or bidirectional charging and allows to transport the resulting charging schedules towards the charging station for execution.

We have defined the following control topologies that need to be supported by the system architecture:

- a) Control by the Car manufacturer through an EV Charge Point communication flow
- b) Control by an EMS through an EMS Charge Point communication flow
- c) Control by a CPO through a CPO Charge Point communication flow
- d) Control by a third party through third party CPO Charge Point communication flow

From a protocol perspective, the selected control topologies combined with the targeted energy services impact the messaging requirements and functional capabilities of the communication protocols to be used. This varies by the data requirements, applicability of protocols to each role in the architecture, and technical or non-technical considerations for protocol selection such as maturity and market adoption. Chapter 2 will dig deeper into the smart charging functionalities that the different existing protocols and their respective protocol versions have to offer to support the different control topologies of the V2X ecosystem architecture.

## • Energy services agnostic

Being able to generate customer value with smart & bidirectional charging is a prerequisite to generate V2X consumer adoption. To ensure that a positive business case can be created for smart & bidirectional charging, the financial or ecological benefits must justify the additional investment for the technology itself by the consumer.

To maximize the financial and ecological benefits smart and bidirectional charging could generate for consumer, different energy services should be able to be supported with the same ecosystem architecture and different control topologies. This requires that the required input data to optimally generate a charging schedule to deliver a specific energy service should be available to all possible actors covered by the different control topologies.

These energy services can be distinguished between behind-the-meter and front-of-the-meter services. Behind-the-meter services are services that don't require active interaction with other energy-system-side actors besides the site owner and user themselves. Four different targeted behind-the-meter energy services and their required input data are shortly described below.





#### 1) Increase self-consumption of on-site renewable energy generation:

By adjusting the charging speed based on the availability of excess on-site renewable energy generation, the total consumption of on-site renewable energy could be increased. this energy service will generate financial benefits next to the ecological benefits in the case when a consumer has rooftop solar with a feed-in tariff different from the consumption tariff.

This energy service requires access to real-time grid measurements for the algorithm so that the charging power can be adjusted to the availability of excess renewable energy in real-time. Tariff information is also required to provide insights into the generated financial savings or when this energy service is combined with other energy services so that a charging schedule can be generated that provides the most optimal financial benefits for the consumer.

As excess solar is only available during daytime hours, it must also be possible to delay charging for several hours until enough excess solar is available. As charging on excess solar often means charging at low charging power, the round-trip efficiency of the onboard inverter could be lower when this service would be applied. Access to round-trip efficiency data of the vehicle would allow the algorithm to account for such energy losses in the charging schedule optimization.

#### 2) Reduce demand charges from capacity-based grid tariffs:

When a consumer is exposed to capacity related charges (€/kW over a certain time period) in the electricity bill, uncontrolled charging would generate additional peak demand, increasing the consumer's electricity bill. These cost effects could be mitigated through smart charging. This could be done by making sure the additional charging load doesn't create a higher peak demand than the residual household load itself. While smart charging can only avoid the cost impact of EV charging, bidirectional charging could also help to offset the peak demand of the residual site consumption, reducing the electricity bill even further.

In order to make optimal decisions on the charging schedule for the driver, this service requires next to the availability of a real-time grid measurement that the capacity tariff and it time period recurrency is known to the algorithm.

#### 3) Price arbitrage on time-of-use tariffs:

When a site is subject to time varying electricity prices in the form of static or dynamic time-of-use tariffs, maximizing the charging speed at times of low prices through smart charging could reduce the overall charging cost for the driver. Bidirectional charging technology could further improve the financial value of this energy service for the site owner by discharging cheap electricity stored in the electric vehicle at times of high prices towards the site. As lower prices don't coincide with times when the electricity system demand is high, it requires that charging can be delayed for several hours similar to the self-consumption energy service. In order to optimally benefit from the time periods within a charging session when prices are lowest, charging must both be able to be delayed as well as be executed at the maximum available charging speed within the limits of the available grid connection capacity.

#### 4) Back-up power to a site from the electricity stored in the EV:

When a grid outage occurs, the electricity stored in the electric vehicle could potentially be used to provide back-up power to the site it is connected to through the charging station through bidirectional charging technology. This requires the V2X infrastructure to be able to detect when a grid outage occurs and transition safely into islanding mode and act as a generator. Besides the required software to ensure network code compliance, the realization of such an energy service also induces some hardware impact which will be briefly elaborated upon in paragraph 2.1.2.

## 1.3 Provide independent validation data streams to the grid operator

Historically, flexibility to ensure the electricity system remains in balance has been provided by supply-side resources such as large scale centralized thermal power plants. In the future, the Transmission System Operator (TSO) will have to rely more and more on other sources of flexibility to balance the electricity system as more and more volatile renewable production is displacing flexible and dispatchable thermal generation. A TSO has access to four different balancing reserves (FCR/aFRR/mFRR/RR), distinguished by the response time, ramp rates, and method of activation (automatic/manual). The aggregated storage capacity of electric vehicles provides enormous potential as a new distributed energy resource (DER) for such TSO balancing services as well as to alleviate congestion on the distribution grid for the DSO.





Besides the required accessibility for DERs for such TSO grid balancing services, it is essential that the hardware, software and communication protocols used in the ecosystem allow for the required data exchange with the desired data quality for such energy services to be delivered to the consumer. These data quality requirements will be investigated more in detail in Task 2.2.

This also creates new requirements to the ecosystem related to 'proof of delivery', ideally through independent validation data streams for grid operators. The Crowd Balancing Platform of SCALE partner Equigy creates a trusted data exchange to enable aggregators to participate in TSO balancing services with smaller flexible assets like charging stations. To provide such independent validation data streams for grid operators through the Crowd Balancing Platform, the role of 'Validation Data Provider' (VDP) has been created by Equigy.

Paragraph 3.3 will investigate and recommend how the functionalities provided by the different communication protocols in the e-mobility ecosystem could be used to fulfil this requirement for grid operators and which actor could play the role of VDP.

# 1.4 Minimize impact on the distribution grid

The uptake of electric mobility will have profound impact on the distribution grid if the charging and discharging of electric vehicles is not managed well within the physical and operational limits of the local electricity grid. If managed and coordinated well, smart charging could mitigate the impact of electric mobility on the distribution grid, while bidirectional charging could even help to offset the impact of the electrification of heating through heatpumps. Secondly, the charging and discharging of electric vehicles could also impact the power quality of the grid. Different desired outcomes to mitigate impact of EVs on the distribution grid can be defined:

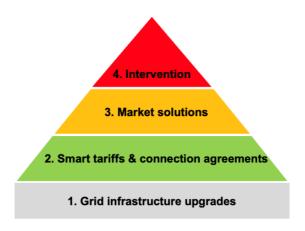
## • Power quality & network code compliance:

Charging and discharging an electric vehicle can affect the quality of the electricity in the grid, and at its turn the power grid can also influence the charging behavior. When charging, a vehicle can affect the voltage of the power grid, while the quality of the voltage has an influence on the quality of the power that the vehicle consumes.

When EVs get discharged and stored energy flows back into the electricity grid, the V2X system composed of the electric vehicle, a charging cable and charging station acts as a generator. This requires that the V2X system complies with the requirements for generators and local and international standards governing power quality and network codes.

#### Indirect or direct control by the DSO over charging sessions

When penetration rates of electric vehicles into our economy increases, so does the impact it will create on the hosting capacity of the distribution grid to accommodate for these additional loads. As the uptake of electric vehicle is expected to rise exponentially, the classical means of dealing with congested distribution grids through grid infrastructure upgrades will therefore not be sufficient anymore. This will require other non-wire alternatives to limit the impact of uncontrolled charging which are depicted in categories in the following illustration and further explained below.





#### 2) Smart tariffs and connection agreements

These are the set of instruments a DSO could use when no congestion within the local grid is expected. By making use of these instruments, the DSO can avoid some of the impact of uncontrolled charging. This can be done by introducing new price signals for the grid tariff component within the electricity bill such as (time varying) capacity-based components or through connection agreements.

Examples of connection agreements could be offering less grid capacity during fixed peak hour moments whether or not in exchange for a lower grid connection fee or grid tariff or imposing default charging limitations during certain hours of the day following the example of the UK smart charging regulation introduced in 2022 for home and workplace charging.

#### 3) Market solutions

When congestion is expected in the local grid by the DSO, market-based re-dispatch capacity procurement could help to relieve it. Through the enforcement of the EU Clean Energy Package, DSOs are required to set-up such markets as an additional non-wire alternative for grid infrastructure upgrades.

Procurement of re-dispatch procurement could be organised through different markets and congestion management products and over different time scales, such as year-ahead or day-ahead. How these markets could be organised and how activation signals are communicated from the DSO to the aggregator is considered out-of-scope for this report. Within the context of this report, it assumed that the aggregator fulfils a role covered by the different to be supported control topologies.

#### 4) Interventions

When congestion is occurring after all the other measures at hand have been applied by the DSO, direct or indirect interventions targeted at specific charging infrastructure should ideally still be made possible to avoid that local grid users would be left without electricity. Here, both local and cloud control instruments for a DSO could be envisioned. With local control, the DSO would be allowed to influence the charging speed through a local interface with the physical charging infrastructure. In cloud control, the DSO would be able to impose a specific charging profile for a limited period of time to specific charging stations located in the congested area. Which form of control is desirable will also depend on what is socially acceptable and desirable in a specific region or country.

Paragraph 3.3 provides an overview on how these different use cases can be covered by making use of the different relevant functionalities covered within the different protocols. Secondly, it also proposes some recommendations on possible measures that could be taken to make these protocols fit-for-purpose.

#### High levels of cyber security:

Non-controlled charging could impose significant impact on the hosting capacity of the distribution grid, but also perfectly managed EV charging could endanger the electricity system. When different control topologies would be supported by the system architecture, the system becomes vulnerable from different angles towards malicious cyber-security attacks that could potentially bring down the electricity infrastructure having profound effects on livelihoods and the overall economy. This means that the resilience of the total system is only as strong as its weakest link with regards to cyber-security. This report will therefore investigate how resiliency against such attacks could be built into the system architecture by imposing the right cyber-security requirements.

In terms of cyber-security requirements, the system needs to satisfy data confidentiality, data integrity and authenticity criteria. With strong data confidentiality, no third party can decouple information being exchanged between different actors through encryption while being in transit. With strong data integrity, the different actors must be able to detect whether a third party has tempered with the data. Through strong authenticity in place, the different actors must be able to verity the authenticity of the other actor to which it is communicating and vice versa.

Chapter 2 will analyse how the different communication protocols fulfil these 3 criteria while paragraph 3.4 will make recommendations on how the identified gaps could be closed.





# 2 Smart Charging & Bidirectional protocol analysis

Smart charging related activities requires coordination and communication between various e-mobility and energy actors. Historically, the most common open communication protocols applied in the e-mobility ecosystem have focused on supporting functionalities that relate to the remote management of charging station networks (ex. OCPP) and ensuring drivers can charge their EVs at different charging networks using one unique subscription (ex. OCPI). This has allowed the e-mobility sector to improve the primary charging experience for the driver.

With the advent of smart and bidirectional charging, the e-mobility and electricity sector become more and more intertwined, increasing the number of different roles that gets involved in the e-mobility ecosystem. This requires that new capabilities and new functionalities are to be supported by the different communication protocols involved in the ecosystem.

This chapter reviews the different open communication protocols available in the different links of the communication chain with regards to its smart & bidirectional charging related functionalities and their capacity to deliver on the desired ecosystem outcomes defined in chapter 7. It explores how the different protocol version can be used to deliver smart & bidirectional charging use cases and what the gaps are in the context of the desired ecosystem outcomes. The generated insights will provide the foundation for the software requirements conclusions and recommendations provided in chapter 3.

# 2.1 EV – Charging Station

#### 2.1.1 IEC 61851

IEC 61851 is the de facto standard used today to establish communication between an EV and a EVSE for both AC & DC charging. For AC charging, basic signaling according to IEC 61851:1 facilitates a 1 kHz pulse-width-modulated (PWM) square-wave signal on the CP cable connection. Communication is based on a 1 kHz ±12 V pulse-width modulated (PWM) pilot signal. The EVSE generates the 12 V signal. When the charging plug is properly engaged, the EV places a resistive load that drops the voltage to 9 V. The EVSE then applies PWM and adjusts the duty cycle to indicate its own output current rating. This is the maximum charging current the vehicle is permitted to draw. At the same time, the EVSE closes its output relays to allow charging to begin. At this point the EV applies a lower resistance to the pilot signal line, reducing the voltage to 6 V as an indication that charging is in progress. Because the interface doesn't allow it to detect when the vehicle is fully charged, charging is terminated when the cable is unplugged. When this occurs, the pilot signal voltage returns to 12 V and the EVSE turns the output off to prevent current from flowing.

Due to the limitations of PWM signaling, communication possibilities between the EV and Charging station are limited to the following aspects:

- indicate that the EV & EVSE are properly connected
- signaling that the EV is ready to receive power
- signal to the EC what the maximum current is the vehicle is allowed to draw

For DC or Mode-4-charging, the onboard BMS must communicate with the charger-controller inside the charge point to request the required DC voltage and current and receive the maximum available DC voltage and current.

To be able to facilitate more enhanced bidirectional communication for this use case, high level communication via Powerline is established for which the requirements are defined in the IEC 61851:23 and IEC 61851:24.

Besides the general bidirectional communication limitations of IEC 61851-1 for AC charging, both parts of this IEC standard don't cover bidirectional charging use cases. The current de facto standard for EV – charging station communication can therefore not be considered future proof.



#### 2.1.2 ISO 15118

The ISO/IEC JWG 15118 for the Vehicle to Grid Communication Interface (V2G CI) was founded in 2009 based on the need of a complementary international standard to IEC 61851-1 providing bi-directional digital communication based on Internet protocols.

The major purpose of 15118 is to establish a more advanced and autonomously working charge control mechanism between EVs and charging infrastructure. The first version of ISO 15118, ISO 15118-2, was published in 2015 with a new ISO 15118-20 version released in 2022. ISO 15118-20 is not backwards compatible to ISO 15118-2 due to new message structures.

Compared to IEC 61851-1, ISO 15118 allows the EV and charging station to dynamically exchange information based on which a proper charging schedule can be (re-)negotiated. In the dynamic control mode, actors other than the car manufacturer can also calculate an individual charging schedule for each EV by using the information available about the state of the electrical grid, the current state of charge of each EV, and the mobility needs of each driver. This way, each charging session can perfectly match the capacity of the grid to the electricity demand of simultaneously charging EVs.

## 2.1.2.1 Key features

Compared to IEC 61851-1, ISO 15118 brings many new functionalities to the e-mobility and electricity ecosystem. The most important & applicable ones that allow to generate the desired outcomes highlighted in chapter 7 are listed and explained below.

#### 1) Plug & Charge as additional identification means

ISO 15118 comes with a feature called Plug & Charge through which the EV can authenticate itself towards the charging station for the driver, removing the need to use external authentication means like an RFID card. Making use of digital certificates & public-key infrastructures, Plug & Charge deploys several cryptographic mechanisms to secure this communication and guarantee the confidentiality, integrity, and authenticity of all exchanged data.

#### 2) Support for all charging technologies & bidirectional charging

Although ISO 15118 is oriented to the charging of electric road vehicles, it is open for other vehicles as well. As part of the Combined Charging System (CCS), ISO 15118 covers wired (AC and DC), wireless power transfer (WPT) and Automatic Connected Devices like pantographs (ACD) and enables the integration of EVs into the smart grid through support for bidirectional power transfer (BPT).

The table below describes for both ISO 15118-2 and ISO 15118-20 which of these charging technologies are supported. Compared to ISO 15118-2, ISO 15118-20 adds support for WPT and ACD and BPT for all supported charging technologies.

	AC	DC	WPT	ACD	BPT
ISO 15118-2	<b>√</b>	<b>√</b>			
ISO 15118-20	<b>✓</b>	<b>√</b>	<b>√</b>	<b>√</b>	<b>√</b>

Supported charging technologies within ISO 15118-2 and ISO 15118-20

#### 3) Support for different control topologies (scheduled & dynamic control modes)

ISO 15118-20 supports 2 different control modes to reflect who is in charge of the charging schedule, being a "scheduled" and a "dynamic" control mode. The dynamic control mode was added in ISO 15118-20.





In scheduled control mode, the EV is in charge of defining what charging schedule will be executed and thereby how the mobility needs of the driver will be met. The EVSE can only communicate and impose limitations to the charging schedule that should reflect the (local) grid constraints. The process of defining the proper charging schedule by the EV is subject to (re-)negotiation so that the executed charging schedule can always reflect the grid infrastructure constraints. This ensures that the EV will always be charged within the physical local grid limits.

In *dynamic* control mode, control over the charging session is the responsibility of the Charging Station. Mobility needs are exchanged by the EV to the charging station so that the charging station or any external actor such as an EMS, CPO or any other third party can compute a proper charging schedule within the comfort limits of the driver. This mode also provides the option for the Charging Station or any other external actor to update the mobility needs of the driver to the EV if the driver would have indicated or updated other mobility needs in their user interface. Also in dynamic control mode, the EV will use updated mobility needs input to calculate new target values (*EVMinimumEnergy*, *EVTargetEnergy*, *etc*) so that they can also include energy needs related to for example pre-conditioning of the battery.

#### 4) Support for driver mobility needs and battery SoC exchange

While the exchange of mobility needs such as departure time and kWh-needs is sufficient to calculate a charging schedule that satisfies mobility needs of the driver, the lack of access to real-time State-of-Charge information limits actors other than the car manufacturer to develop a good customer experience as driver desire real-time SoC insights.

Although optional, next to the exchange of mobility needs (in kWh), ISO 15118-20 also supports the exchange of battery related information from the EV to the Charging Station such as present SoC and battery capacity size. What still lacks to enable user-centric bidirectional charging as defined in chapter 7, is the exchange of battery state of health or V2X warranty related information.

#### 5) Support for using EV as a backup generator

ISO 15118-2 introduces the *GeneratorMode* parameter. This parameter indicates if the system consisting of EV and EVSE operates as a grid following generator (only injecting active and reactive power) or as a grid forming generator

Generator mode	Description	
Grid Forming	The system is able to control the voltage and frequency of the network and to power wires that would not be powered otherwise in case of interrupted power supply. The <i>GridForming</i> generator mode should be selected, for example, if the system consisting of EV and EVSE is powering up a remote load or the microgrid of a house	
Grid Following	This mode should be used in situations when the system consisting of EV and EVSE is connected to the upstream distribution network, and would not act as one of the main grid forming generators of the network	

In DC energy transfer mode, one could argue that the *GeneratorMode* parameter might not be necessary, as the power electronic unit is located in the EVSE. However, the charging / discharging patterns will be different depending on the generator mode (ramps, depth of discharge, etc.) so the EV should still be informed at the beginning of the charging session in which mode it will be operating.

To deliver these functionalities, the Charging station needs to contain an anti-islanding detection algorithm so that it can switch correctly and timely between the 2 generator modes. Secondly, additional hardware like a UPS battery and Automatic Power Transfer module needs to be installed so that the installation can be safely disconnected from the main grid and the V2X system can continue to receive power in the transition period.

To deliver this functionality to the consumer, an anti-islanding detection algorithm should be situated within the charging station, ideally with a UPS battery system to bridge the gap between interrupted power supply and EV connection. Additionally, an automated transfer switch is needed to disconnect the grid connection safely from the main distribution grid so that electricity flowing out of the EV cannot flow back into the electricity grid for safety reasons.





#### 6) Restart charging after sleeping

An often recurring issue in smart charging using only IEC 61851 for EV – Charging Station communication is that the goes into 'sleep' status during a charging session after a period of time without charging.

This issue limits the potential provided by smart charging for the user as well as the potential to alleviate congestion for the distribution grid as the EV must continue charging at its minimal current (6A as defined in IEC 61851).

ISO 15118 adds the possibility to use a wake-up trigger by both the Charging Station as well as the EV so that charging can be resumed. Secondly, the EV can also go out of standby mode by itself as in ISO 15118, charging schedules are being exchanged instead of current setpoints as is the case with IEC 61851.

#### 7). Strong cyber-security

In ISO 15118-2, the use of Plug & Charge as identification means enforces strong cyber-security on both the transport layer with TLS 1.2 (although not mandatory) with digital XML-based signatures and X.509 certificates. With ISO 15118-20 TLS 1.3 is introduced and now mandatory for all use cases, ensuring very strong cyber-security levels.

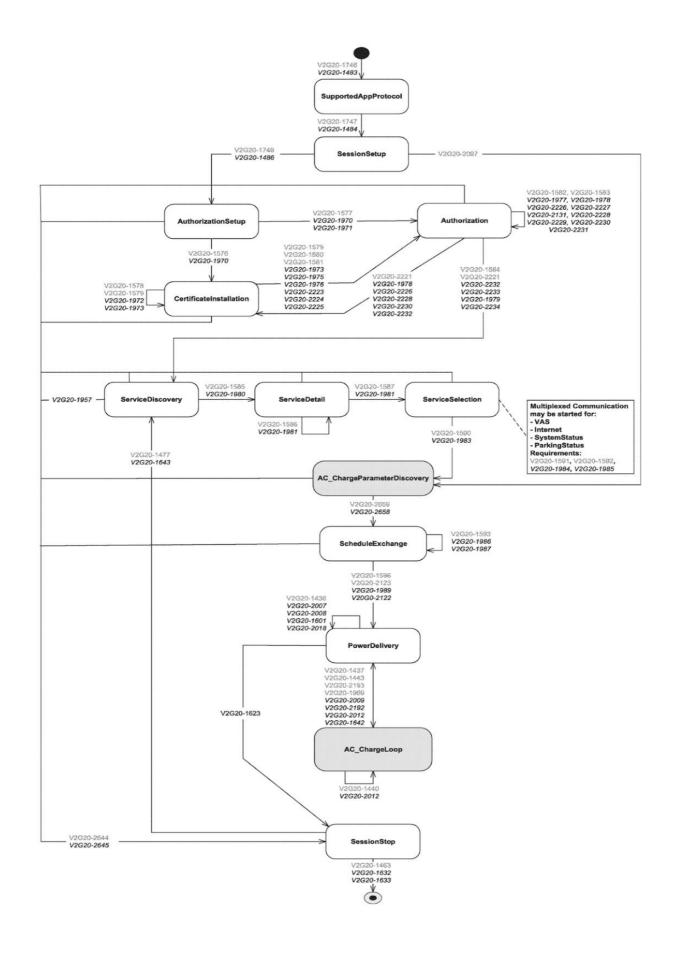
#### 2.1.2.2 Messaging flow

As mentioned before, ISO 15118 complements IEC 61851 by adding high level bidirectional communication capabilities between the EV and the charging station. ISO 15118 is a request – response messaging protocol which means that only the EV can request information directly from the EVSE, who will have to respond within a certain timing to avoid time-outs.

This paragraph will further explain how this communication flow works and describe the different steps and messages that are indicated on the flow chart, which represents the AC messaging flow.









#### 1) supportedAppProtocol:

The EV and the charging station use this request-response message pair to agree upon a protocol version. During this transition phase, it is important that both the EV and charging station speak the same version of ISO 15118. If they are not compatible, it will not be possible to initiate an ISO 15118 charging session.

#### 2) SessionSetup:

Used to assign a unique SessionID for a communication session. The session can be paused and resumed later using the same SessionID. In this case, the previously agreed upon charging parameters will be applied again to ensure charging continues as originally intended by the driver.

#### 3) CertificateInstallation:

In case the EV selects Plug & Charge as an identification method, a valid digital contract certificate must be installed in order for the charging station to automatically authenticate and authorize the driver. If the EV does not yet have this certificate installed or if its existing contract certificate has expired, the EV can use the *CertificateInstallation* message pair to install a new contract certificate from the charging station.

#### 4) Authorization:

The *AuthorizationSetup* message pair is used to negotiate the authentication means and associated services. In both cases, the validity of the authorization mean is verified. If Plug and Charge is selected, a mechanism to avoid a replay attack is used. This is a form of network attack in which a valid data transmission is maliciously or fraudulently repeated in order to gain access to a restricted resource.

#### 5) ServiceDiscovery, ServiceDetail & ServiceSelection:

EV will request the charging station which charging & value-added services as well as identification means it offers through a *ServiceDiscoveryRequest*. These charging services include AC charging (single and three-phase charging), DC, Wireless power Transfer (WPT), Automated Connection Device (ACD) or any bidirectional power transfer service of the mentioned charging technologies. It also includes other value-added services like Internet, ParkingStatus and customServices.

The EV can request more details for each service by using the optional *ServiceDetailRequest* message for one unique *ServiceID*. The EV will respond with a corresponding parameter list of the parameter it supports for the requested *ServiceID*.

The EV will communicate its decision through a *ServiceSelectionRequest* by sending the respective ServiceID and the corresponding *ParameterSetID's*.

#### 6) ChargeParameterDiscovery:

The EV and the charging station mutually exchange their respective technical charging limits by communicating their maximal and minimal allowed voltage levels and amperage through the *ChargeParameterRequest* request and response messages. The EV also informs the charging station on the mobility needs of the driver, such as the amount of energy needed to reach the target State of Charge and the desired departure time as provided by the driver. The exchange of these driver mobility needs is optional in Scheduled control mode, but required in Dynamic control mode so that the charging station or another secondary actor can calculate a charging schedule in the following step.

When the applicable control mode is 'dynamic', the charging station can also update the mobility needs of the driver in the response message so that the EV can update parameters like *EVMaximumEnergy*, *EVMinimumEnergy* & *EVTargetEnergy*.



#### 7) ScheduleExchange:

The SECC will then calculate a charge schedule to propose to the EV. The proposed schedule will include the maximum power with which the EV is allowed to charge while connected to the charging station as well as an optional <code>SalesTariff</code>. The <code>SalesTariff</code> includes schedules that provide information on cost over time, cost in relation to power demand and amount of energy, or a combination of these, aimed at incentivizing the EV to engage in a certain charging behavior.

#### 8) PowerDelivery:

The PowerDelivery message exchange marks the point in time when the EVSE is instructed by the EV to start delivering power. The EV can also transmit the *EVPowerProfile* it will follow in case of scheduled control mode (optional). In Dynamic control mode, the *EVPowerProfile* indicates the fastest charging profile in order to reach the *EVMaximumEnergyRequest* use the *EVPowerProfile*. After receiving the PowerDeliveryReq message, the SECC sends the PowerDeliveryRes message including information if the power will be available.

#### 9) ChargeLoop:

The Charging Status message pair provides sanity checks on the meter readings provided by the SECC. On the basis of the iteratively exchanged Charging Status messages the EV has means to check and validate the power drawn from the EVSE. Also, it allows the SECC to request the EVCC to sign the meter info record included in the ChargingStatusRes message by using the meter receipt message pair.

#### 10) SessionStop:

The communication concludes with the SessionStopReq/-Res message pair. The ChargingSession parameter can be set to either Terminate or Pause. If the charging session is to be paused, certain parameters, like the agreed-upon charging schedule, are temporarily stored by the charging station so it can apply these values when charging resumes.

#### 2.1.2.3 Scheduled versus dynamic control mode

Besides the support of bidirectional charging for all charging technologies, the main functional differences related to smart charging functionalities ISO 15118-2 and ISO 15118-20 are linked to the addition of the dynamic control mode in ISO 15118-20. The 2 tables below evaluate impact of both control modes under ISO 15118-20

Outcome impact	Description		
User-centricity	V1G services are being locked in by the car manufacturer as the car manufacturer has a monopoly over the charging schedules, with the Charging Station or secondary actors only capable of setting power limits		
	Mobility needs data exchange is optional		
	Present SoC is not exchanged in AC (not even optional), only in DC		
	<ul> <li>No battery state of health data provided by the EV, so secondary actors cannot provide customer insights into battery degradation</li> </ul>		
Control topology	Control topologies in which another actor than the car manufacturer is in control of the charging schedule for the customer are not supported due to the absence of the dynamic control mode		
Grid impact	EVSE can set power limits for charging to represent grid connection or local distribution grid constraints		



	Cyber-security is not assured as TLS communication (1.2 version) is optional
Energy services	<ul> <li>No real-time active power grid connection measurements can be exchanged via EVSE to EV. This means that the energy services like self-consumption increase, or demand charge reduction cannot be optimally delivered to the site owner.</li> </ul>
	No support for bidirectional charging as this was only added in ISO 15118-20

ISO 15118-2 Ecosystem outcome impact

Outcome impact	Description	
User-centricity	Vehicle-to-Home & Vehicle-to-Building services are being locked in by a secondary actor or EMS as EV lacks real-time active power grid measurements	
	<ul> <li>Present SoC is only optionally exchanged by EV to charging station so secondary actor cannot create the same (mobile app) user experience</li> </ul>	
	No battery state of health data is being exchanged by the EV, so secondary actors cannot provide customer insights into battery degradation	
Control topology	All control options are being supported through combination of scheduled and dynamic mode (if OCPP2.x on EVSE)	
Grid impact	As EVSE or a secondary actor is in control, local grid connection or distribution grid constraints can be taken into account	
·	Improved cyber-security through TLS communication version 1.3	
	All energy services use cases can be delivered by the secondary actor can theoretically be delivered by a secondary actor	
Energy services	<ul> <li>Lack of real-time grid measurement exchange between Charging Station and EV in ISO 15118-20 limits potential V2X services for car manufacturer to grid services only</li> </ul>	

ISO 15118-20 Ecosystem outcome impact

The main missing functionalities in ISO 15118-20 are not linked to the functionalities themselves that the protocol provides, but to lack of information that is exchanged between the EV and the Charging Station. The limitations of this protocol version impact mainly the car manufacturer, as he cannot provide V2H and V2B services to the customer, whereas the impact for the secondary actor is mainly customer experience related.

The ecosystem outcomes are off course not only linked to the supported functionalities under ISO 15118 as this only covers EV - Charging Station communication, but barriers within this communication channel for mainly secondary actors are carried over to other actors and other protocols in the ecosystem.

#### 2.1.2.4 Hardware impact

ISO 15118 implementation creates hardware impact for both the EV and EVSE compared to IEC 61851 communication. These aspects are listed and explained in this section. It is therefore important that EV & EVSE manufacturers take these aspects into consideration for their future electric vehicles and charging stations to ensure that the functional capabilities that ISO 15118 brings about can be unlocked through over-the-air firmware updates.



#### 1) HomePlug Green PHY modem

As ISO 15118 is designed around PLC communication for which the HPGP PLC standard is adopted. This requires that both sides, EV & EVSE need to have a HomePlug Green PHY modem in place to transmit and receive messages over an analogue medium, being the wire inside the charging cable.

#### 2) Memory Space

The Plug & Charge feature is underpinned by a Public Key Infrastructure used to authenticate the driver towards the charger via de EV and vice versa. This requires that both the EV and EVSE have enough memory space to store the necessary certificate chains (up to 4 certificates in a certificate chain). Secondly, ISO 15118-20 is not backwards compatible with ISO 15118-2. This means that the EVSE hardware needs to have sufficient memory space to host the codebase for both protocol versions so that it can charge EVs who support the ISO 15118-2 and ISO 15118-20 language.

#### 3) CPU power

Both ISO 15118-2 and -20 require TLS for encrypted communication, TLS 1.2 and 1.3 respectively, & digital certificates & signatures to ensure the authenticity & integrity of the exchanged messages. Creating and verifying those digital signatures are relatively computational heavy cryptographic operations, thereby impacting the required CPU power. Given also that each ISO 15118 message is assigned a time-out, it is best to ensure that the controller can handle the task before running into time-out.

#### 4) Hardware Security Module (HSM)

ISO 15118 requires that certificates and associated private keys are stored in a secured space in both the EV and EVSE to ensure that no unauthorized third party can access them. This secure storage of digital certificates and private keys could be achieved through a hardware security module.

## 2.2 Charging Station – CPO

#### 2.2.1 OCPP

The Open Charge Point Protocol (OCPP) is an industry initiative managed by the Open Charge Alliance with the purpose of creating an open communocation protocol which allows EV charging stations and central management systems from different vendors to communicate with each other. OCPP acts as the intermediary communication protocol between the charging station and the Charging Station Management System (CSMS) of the CPO.

With OCPP, Charging station owners are less vulnerable to individual system suppliers if a charging station manufacturer ceased to exist as the owner could switch to another OCPP-based CSMS. Giving charging station customers choice and flexibility to use any network on any charging station would encourage charging station manufacturers and network providers to compete on price, service, product features, and innovation. This results in significant benefits to EV drivers as the charging station infrastructure expands.

The dominant OCPP version supported by charging stations and CSMS platforms is OCPP 1.6. OCPP 1.6 was officially released in 2015 and is supported by a certification program since 2019.

#### 2.2.1.1 OCPP 1.6

OCPP 1.6 is the first version of OCPP that provides some support for smart charging by introducing the concept of a *ChargingProfile* within the functional 'Smart Charging' OCPP module. The *ChargingProfile* concept represents the core functionalities to exercise smart charging through OCPP and is extended with additional functionalities in more recent versions of the OCPP protocol. Therefore, the main principles covered within OCPP 1.6 are explained below.

A ChargingProfile holds a Charging Schedule which defines a block of charging power or current limits and can contain a start time and duration applied to a charging station or EVSE. In OCPP 1.6 only the CSMS can send a charging





profile to a charging station and has the possibility to both send a charging profile to a charging station as well as clearing an active charging profile.

A charging profile also has a ChargingProfilePurpose, for which OCPP 1.6 provides 3 options:

ChargingProfilePurpose	Description
ChargingStationMaxProfile	This profile purpose could be used to limit the power or current that can be shared by all EVSE's in a charging station. It can only be set to evseld 0.
DefaultProfile	Default charging schedules that may be used to impose charging policies such as preventing to charge during certain hours of the day
TxProfile	a transaction specific profile that overrules a <i>DefaultProfile</i> for the duration of the transaction only.

Next to a *ChargingProfilePurpose*, OCPP also defines a *ChargingProfileKind* to indicate variations to when the charging schedule should be applied. It includes 3 different options:

ChargingProfileKind	Description
Absolute	use when the charging schedule is relative to an absolute point in time defined in the schedule. This requires that a <i>startSchedule</i> is set to a starting point in time. Could be used to define a charging schedule aligned with dynamic time-of-use prices for example.
Recurring	use when the charging schedule restarts periodically at the first schedule period. A "startSchedule" should be used in combination with a "RecurrencyKind variable (ex.: daily).  Could be used to create a charging schedule in line with a static time-of-Use tariff or DSO connection agreement as explained under chapter 7.4.
Relative	use when the charging schedule period needs to start as soon as the charging profile is activated. No value for <i>StartSchedule</i> should be used.  Could be used when providing grid services and immediate response is desired.

OCPP 1.6 allows to stack profiles of the same *ChargingProfilePurpose* in order to be able to describe more complex calendars or use cases by adding a '*StackLevel*'. When more than one *ChargingProfile* with the same purpose is valid, the *ChargingSchedule* with the highest stack level will overrule the other charging schedules.

This StackLevel functionality allows the CPO for example to implement functionality to prioritize *TxProfile* charging schedules from different actors such as a DSO or Smart Charging Service Provider (see OCPI). It could also be used for charging schedules received by a third party for grid services with a *ChargingProfileKind* 'Relative'.

When several Charging Schedules of different *ChargingProfilePurposes* are valid at a specific point in time, the resulting composite charging schedule will be calculated by the charging station by taking the lowest limit amongst the leading profiles for each interval.

Although already many smart charging use cases can be supported with OCPP 1.6, it certainly still contains many limitations that limits its potential to achieve the desired ecosystem outcomes highlighted in chapter 1.

## 2.2.1.2 OCPP 2.0.1

OCPP 2.0 was officially released in 2018 with a 2.0.1 version released in 2020. The Open Charge Alliance strongly recommends to only use the OCPP 2.0.1 as the 2.0 contained some errors that have been eliminated in the 2.0.1 version. Due to major changes in the messages, OCPP 2.0.1 is not backwards compatible with OCPP 1.6. This means



that a Charging Station that runs OCPP 1.6 will not be able to communicate with a CSMS that only supports OCPP 2.0.1.

Besides new functionalities that provide great benefits for remote asset management to charging point network operators, OCPP 2.0.1 also adds new functionalities that are beneficial for the desired ecosystem outcomes, which are highlighted below.

#### 1) Support for Charging Profiles from a local external control system

The OCPP protocol is originally developed for communication between a CSMS and one or more Charging Stations. As described in the above, this means that a CSMS controls a Charging Station and based on the charging limits of both the EV and the Charging Station, the CSMS determines how fast the EV is charged. However, in some use cases these are not the only 2 factors that could influence the charging speed. Other inputs that determine charging speed could be DSO signals (ex. OpenADR, etc) or signals from a Building / Home Energy Management System (Modbus, Eebus, etc). This assumes that the charging station supports another protocol that an EMS (ex. Modbus) or DSO (ex. OpenADR) could use to communicate locally with the charger and set/clear a charging limit or schedule. This use case is enabled by adding an additional *ChargingProfilePurpose* option to the Charging Profile concept called *'ChargingStationExternalConstraint'*.

When a Charging Station is connected both to the outside world as well as to an Energy Management System (EMS), conflicting signals could exist in certain situations. Such a situation could occur for example when an EMS decides that it's not opportune to charge despite a charging schedule that the EVSE might have received from the CSMS and thereby not behaving as expected. To prevent this, the Charging Station will have to be able to notify the CSMS that it has received a charging schedule from the EMS. This is enabled through a new *NotifyChargingLimit* request that the Charging Station can send to the CSMS.

#### 2) Advanced monitoring

In OCPP 1.6, the transfer of metering values was managed within the 'Metervalues' functional module. This functional module allows for sending clock aligned meter values or based on fixed sampling intervals. OCPP 2.0.1 provides the CSMS with more options for defining triggers for receiving such meter value (or other variables) updates through the Diagnostics module. These new trigger options can be used for different use cases by the CPO.

Monitor options	Description	
Upper Threshold	triggers an event when the actual value of the variable rises above the set value	
Lower Threshold	triggers an event when the actual value of the variable drops below the set value	
Delta	triggers an event when the actual value has changed more than plus or minus the set value	
Periodic	triggers an event every x seconds as configured	
Periodic clock aligned	triggers an event every x seconds after the monitor value was set.	

For example, the *Delta* trigger could be used by the CPO to minimize the amount of data traffic from the charging station to the CSMS while still ensuring that the quality of the value updates is guaranteed.

#### 3) driver needs based smart charging thanks to native ISO 15118-2 support

OCPP 1.6 already provides some basic functionalities for smart charging. But as it doesn't provide support for ISO 15118-2, the information from the EV (i.e. energy amount needed to fully charge the battery, maximum and minimum charging current, departure time of the EV driver,...) cannot be passed on to the EVSE and CSMS. OCPP 2.0.1 adds 2 new messages that allow the charging station to pass through these needs and outcomes to the CSMS.

The "NotifyEVChargingNeeds" message enables the charging station to communicate these driver needs and EV constraints to the CSMS. This allows the CSMS to calculate and propose a charging schedule to the EV via the



Charging Station, which the EV can then consider to do its own charging profile calculation. That profile can either match the CSMS's (or charging station's) proposed profile or deviate from it as long as the EV does not exceed the provided power limits through ISO 15118-2.

Lastly, the CSMS needs to be informed about the EV's calculated charging profile so it can use this information for further charging schedule calculations. This is done through the "NotifyEVChargingSchedule" message. When the CSMS or another external actor decides that it wants to send a new Charging Schedule, it can request a renegotiation of the charging schedule through a "SetChargingProfileRequest" message. Considering that ISO 15118-2 only supports the 'scheduled charging mode', the Charging Profile requests from the CSMS remain a proposal as the EV can decide unilaterally which charging profile it will execute. Therefore, if a driver wishes that his charging sessions are to be optimized by another actor other than his car manufacturer, the combined usage of ISO 15118-2 and OCPP 2.0.1 doesn't allow him/her to do that.

#### 4) Increased cyber-security

OCPP 2.0.1 provides more implementation options through the support of 3 different security profiles for which the following table provides the overview. OCPP 2.0.1 leaves it to market actors to decide which security profile and which TLS version they will implement.

Security profile	CS authorization	CSMS authorization	Security communication
1	HTTP basic authentication	1	1
2	HTTP basic authentication	TLS authentication with certificates	TLS
3	TLS authorization with certificates		TLS

The first security profile does not require the CSMS to authenticate itself to the Charging Station or provide any measures to secure the communication channel. Therefore, the Charging Station has to trust that the server it connects to is indeed the CSMS of the CPO to which it belongs. The use of this security profile is strongly advised against for obvious cyber-security risks and should only be used in private networks with VPN.

With the second security profile, the CSMS is required to authenticate itself making using a TLS server certificate, whereas the Charging Station will still be using HTTP basic authentication.

As TLS is used for securing the data transfer between the Charging Station and the CSMS, the username and password will be sent encrypted, reducing the overall cyber-security risk compared to the first security profile.

With the third security profile, both the Charging Station as well as the CSMS use mutual TLS authentication. This ensures that trust is created in both directions, leading to the highest level of security from all the protocols.

#### 2.2.1.3 OCPP 2.1 additions

A new OCPP 2.1 version is expected to be released in the second half of 2023. Where OCPP 2.0.1 provides native support for ISO 15118-2, OCPP 2.1 aims to accomplish the same for ISO 15118-20, thereby covering bidirectional charging.

The objective of the 2.1 version is to be backwards compatible with existing OCPP 2.0.1 implementations through V2X extensions. These cover additional request-response messages for new functionality and extending some existing messages with additional information. The most anticipated new additions currently covered in the draft version are highlighted below.

#### 1) Support for V2X operation modes

As ISO 15118-20 foresees in a dynamic charging mode in which an actor other than the EV is fully responsible for the charging profile to be executed, the EVSE must be instructed on how it must operate. Therefore, a new data type called *v2XOperationMode* will be introduced into the Charging Profile concept. This will allow the CSMS to instruct a charging





station for a specific bidirectional charging operation. In order to cover the different types of use cases that have their own specific kind of operations, different V2X Operation modes are foreseen that will become part of the ChargingSchedulePeriodType.

In general, 3 different classes of V2X operation modes are foreseen:

- a) Central V2X operation modes: The CSMS of another secondary actor like the eMSP or SCSP is in charge of defining the setpoint to follow in a V2X charging schedule.
- b) External V2X operation modes: an EMS defines the setpoint or charging & discharging limits.
- c) Local V2X operation modes: The Charging Station is instructed to use local data like power-frequency tables, Voltage-Power Factor tables or load balancing thresholds to define the power setpoint.

These different V2X operation modes are explained below.

#### • Charging Only:

This operation mode allows charging only and is the default mode, therefore is not V2X at all. This is also the default V2X operation mode when the field *v2xOperationMode* is missing. It is added especially for Charging Stations that intent to operate in V2X but are unsure during energy service negotiation if the EV and EV user are allowed to operate in V2X at this time and location. It then starts in this operation mode, waiting for authorization of the V2X operation mode. When V2X is authorized, a service negotiation should be performed between EV and Charging Station to start using actual V2X operation modes.

#### • External Setpoint:

This control mode tells the Charging Station that the setpoint parameter is to be determined by some external actor such as an EMS. The CSMS submits the charging profile and leaves the setpoint parameter empty but can use the limit and discharging limit to limit the range of the external setpoint. Its setpoint value should then be received by the Charging Station from the external system through some other means of communication and not via OCPP. How this is done will differ for different applications and is out of scope of OCPP.

When a Charging Station or its controller node supports multiple OCPP connections, then the external system can submit its charging profile directly to the charging station using the SetChargingProfileRequest.

#### • External Limits:

This control mode is similar to External Setpoint with the difference that it is not the *setpoint* that is controlled, but the *limit* and *dischargingLimit* parameters determined by the external actor such as an EMS.

#### • Central Setpoint:

This control mode is used by the CSMS to set a single setpoint or profile for charging and/or discharging, using the *setpoint* parameter. Positive setpoints provide requests for charging, while negative setpoints are for discharging. A single setpoint (when only one entry) or profile might be defined by a secondary actor such as a third party aggregator that relays the message through the CSMS.

Optionally, the parameters *limit* and *dischargeLimit* can be used to limit the charging and discharging overshoots.

#### • Central Frequency:

The setpoint for frequency support is determined by the CSMS or a third party aggregator in the context of frequency containment (FCR or frequency restoration reserves (FRR) delivery. for instance when costly calibrated frequency measurements are to be used that can not be installed in each Charging Station. The CSMS will have to continually update the setpoint when the frequency changes, using the *setpoint* field.



Specifically for FCR, calibrated frequency measurement devices are required by the transmission system operator (TSO) to be allowed as a market party to deliver these services to them. As these measurement devices can be too costly to be installed in each charging station, delivery of such a service through bidirectional charging will rely mainly on central frequency measurements.

Although the control architecture of a 'Central Frequency' V2X operation mode doesn't differ from the 'Central Setpoint' one, other requirements for the delvery of TSO balancing services do exist such as timely and granular measurement data collection as proof of delivery for the TSO.

Therefore, having a separate V2X operation mode for TSO balancing services makes sense.

#### Local Frequency:

In this V2X Operation mode, the power setpoint for frequency support is determined from a power/frequency table, based on the locally measured frequency. The CSMS provides the new power/frequency table might be different for various locations and is therefore provided as a field in ChargingSchedulePeriodType: *v2xPowerFrequencyTable*, which contains a list of at least 27 coordinates, for which the exact power setpoint is determined by the Charging Point through linear interpolation.

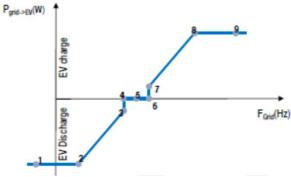


figure: Power/frequency table

This V2X operation mode is particularly useful for FCR services, which usually requires a very fast response rate below 4 s. This can be hard to achieve with the OCPP message delay from a third party aggregator to CSMS to charging station. This mode can also be used to comply with network codes, where output of generators must be decreased when the grid frequency is higher than a certain threshold value.

#### Local Voltage:

The LocalVoltage V2X operation mode allows the V2X system to provide reactive power support to the electricity grid when grid voltage exceeds the normal operating range. The reactive power setpoint for power factor support is determined from a voltage/power-factor (Q(U)) table, based on the locally measured voltage. The voltage/power-factor table might be different for various locations and is therefore provided as a field in ChargingSchedulePeriodType: v2xVoltagePfTable, which contains a list of at least two Voltage-Power factor coordinates. The desired power factor is used by the charging station to calculate the desired reactive power setpoint, which in the case of AC bidirectional charging needs to be sent to the EV.

#### Local Load Balancing:

This V2X operation mode allows an EV to be utilized for load balancing, for example for a building that both consumes energy and produces energy from solar panels. The concept here is that the charging station can read out the grid measurement of the building, enabling the setup of the charging station and EV to influence the resulting load on the grid connection. This is specifically useful for V2H and V2B use cases, where the EV can offset part or all of the power consumption of a home or building.



To make use of this operation mode, the following variables must be set:

Variable	Description	
Upper Threshold	When the measured building load exceeds this limit, the local load balancing mechanism will try to limit the power to a maximum of upper threshold + upper offset	
Lower Threshold	When the measured building load exceeds this limit, the local load balancing mechanism will try to limit the power to a minimum of lower threshold + lower offset	
Upper Offset	An offset value to add to the upper threshold. This allows for some tuning of the upper limit, without changing the threshold value itself	
Lower offset	An offset value to add to the lower threshold. This allows for some tuning of the upper limit, without changing the threshold value itself	

#### • Idle:

This operation mode is used when the EV is neither to charge or discharge for a period of time in order to allow to minimize the energy used by the Charging Station and EV. The field *PreconditioningRequest* is used to indicate if the EV can go to sleep completely or should be on standby. The difference between "sleep" and "on standby" is that when the EV in "sleep" status, it is not expected that it will react quickly on a new schedule, while for on standby, it is expected that the EV can quickly start charging or discharging when for example a new schedule is sent from the CSMS to the Charging Station.

#### 2) Grid code compliance support

When energy is fed back into the grid back through bidirectional charging, the bidirectional system needs to be compliant with the relevant network codes as outlined in 1.4. As already explained in the V2X operation modes section, OCPP 2.1 will foresee Local Frequency and Local Voltage V2X operation modes. These modes and the respective Frequency-Active Power and Voltage-Reactive power tables allow for both DC and AC V2X systems to become compliant with the relevant grid codes.

This is particularly useful for EVs with a bidirectional onboard inverter as the smart inverter functionalities, defining the relevant active & reactive power setpoints can be located within the stationary charging station.

#### 3) Additional 'PriorityCharging' ChargingProfilePurpose

Sometimes, an EV driver just wants to make sure their EV is charged as fast as possible and thereby doesn't want to engage in any smart charging activities for a particular charging session. To facilitate this use case, OCPP 2.1 will add an additional *ChargingProfilePurpose* called '*PriorityCharging*' and defines a *UsePriorityChargingRequest* message. When a user would then indicate via a smartphone app or a button or display on the charger that he/she wants maximum charging power, the *UsePriorityChargingRequest* message would be triggered, applying the '*PriorityCharging*' charging profile purpose on the charger and effectively disabling all other active *Tx* and *TxDefault ChargingProfilePurposes*. How the CSMS can receive a *UsePriorityChargingRequest* message from external actors is considered outside of the scope of OCPP.

#### 2.2.2 IEC 63110

The open protocol IEC 63110 is a standard currently under development with similar functionalities to and based on input from OCPP. The core functionality of IEC 63110 is to standardize the functionalities of OCPP into a de jure standard and to include additional functionalities such as bidirectional power flow. The first version of IEC 63110 is expected to be released in 2024, but it is unclear when IEC 63110 will be finalized and ready for market adoption.



Furthermore, whether the standard will offer significant advantages over OCPP, especially considering the high current market adoption of OCPP within the European Union and given the fact that the standard will cover roughly the same functionalities, remains to be seen.

# 2.3 CPO - third party (eMSP, SCSP,...)

#### 2.3.1 OCPI

While OCPP was designed to manage a single network of chargers by a CPO, EV drivers need access to all charger networks to ensure that they can charge anywhere at any time making use of one single app or RFID card.

Where the CPO manages charging stations, the eMSP manages EV drivers by providing them consolidated access to charging stations operated by different CPO's. The most prominent protocol to enable these EV roaming capabilities is the Open Charge Point Interface (OCPI) protocol, maintained and endorsed by the EVRoaming foundation with the 2.1.1 protocol version as the most widely used version in the market. The OCPI protocol is free to use and can work both peer-to-peer or in combination with roaming hubs such as eClearing.net, Hubject or GIREVE.

With regards to cyber-security, data in transit is protected on the HTTP transport level with SSL and token-based authentication. This mechanism does not require client-side certificates for authentication, only server-side certificates to set up a secure SSL connection. To make a HTTP request to another actor, the credentials token issued by the actor it wants to communicate to needs to be used. SSL is a predecessor of the more secure and less complex TLS used in ISO 15118-20 and OCPP 2.0.1.

The 2.1.1 protocol version has different functional modules which are described below and is the dominant protocol version used in the market.

Mandatory administrative modules:

- OCPI versions: allows the 2 parties, CPO & eMSP, to agree on the protocol version to be used.
- OCPI credentials: Key exchange and authorization verification for securing the communication.

Modules used for basic RFID operations & payment processing:

- OCPI tokens: defines the exchange of tokens (f.e. RFID details) between CPO & eMSP. The MSP will periodically send a list of approved tokens to the CPO who will store this list and use it to authorize charging sessions.
- OCPI CDRs: (Charge Detail Records): Defines the exchange of completed charging session information for billing purposes. When a charging session is completed, a CDR is created by the CPO containing the details of the transaction (cost, duration and amount of energy charged). These CDRs are sent by the CPO to the eMSP who will aggregate all CDRs related to a user into one unified bill.

Modules used by the eMSP for charging session interaction:

- OCPI sessions: Defines the exchange of session related data like energy charged, charging speed and
  socket status. The eMSP can use this data to update the driver in his mobile app with up to date information
  about an ongoing charging session.
   This session object is owned and created by the CPO and pushed to the eMSP. Changes to this session
  object are sent to the eMSP with the updated session info.
- **OCPI commands:** Allows the eMSP to send charging commands to a specific charger such as start and stop a charging session, unlock a stuck connector or reserve a charger.

OCPI 2.1.1 doesn't expose smart charging functionalities via the CPO to third parties other than the eMSP. Such functionalities have been added to the recent OCPP 2.2.1 version.



#### 2.3.1.1 OCPI 2.2.1

With the OCPI 2.2.1 protocol version, the EVRoaming foundation brought big updates to the OCPI protocol. While OCPI 2.0 and 2.1.1 had very strict definition of roles limited to the CPO and eMSP, OCPI 2.2.1 introduced more additional roles & abstracts the role from the OCPI connection itself. In the context of smart charging, the role of the Smart Charging Service Provider (SCSP) was added together with support for additional functionalities related to smart charging, which are explained below.

#### 1) Addition of a Charging profiles module to support smart charging through third parties

Through the addition of the ChargingProfiles module, parties (SCSPs but also eMSPs) can now send (smart) charging profiles to a Location/EVSE and request the 'ActiveChargingProfile' from a Location/EVSE.

The ChargingProfile concept is similar to the concept of Charging Profiles in OCPP but exposes this functionality to third parties. The data structures are based on OCPP 1.6 & OCPP 2.0.1 to make conversion of messages between OCPI & OCPP easy for the CPO.

Different control topologies are made possible:

- a) eMSP generates a Charging Profile
- b) eMSP delegates smart charging to a SCSP
- c) CPO delegates smart charging to a SCSP
- d) CPO executes smart charging (already covered by OCPP)

The OCPI 2.2.1 ChargingProfiles module supports the following use cases:

- a) eMSP/SCSP sends/updates a charging profile to manipulate a charging session
- b) eMSP/SCSP requests to remove a set charging profile
- c) eMSP/SCSP requests the ActiveChargingProfile
- d) the CPO updates the eMSP/SCSP of changes to an ActiveChargingProfile

Within OCPI 2.2.1, the eMSP & SCSP can only send a charging profile for an active charging session, thereby relying on the session module to be informed about a new charging session.

To support smart & bidirectional charging over OCPI, the CPO must therefore have implemented the ChargingProfile module within OCPP to be able to send the received charging profile to the EVSE. Secondly, the Charging Station must also support the same Charging Profile module of OCPP. When both the CSMS of the CPO and the Charging Station support the OCPP 2.0.1 version and a lower local charging limit is received by the EVSE (from an EMS or DSO), the local limit will always prevail. This stems from the fact that both are considered to have a different ChargingProfilePurpose, a concept explained under the OCPP 1.6 section in paragraph 2.2.1.1.

In practice, this could cause conflicts when a SCSP or eMSP applies the charging profiles in the context of a TSO grid balancing service and wants to apply a charging power higher than the local limit. This could be solved by the eMSP/SCSP by requesting the *ActiveChargingProfile* to get insights on what the actual available charging limit is over a certain period to determine beforehand what the actual available power on charging session level for grid balancing services.

#### 2) Support for driver needs input

To execute smart charging without harming the mobility needs of the driver additional driver, input is needed. OCPI 2.2.1 therefore supports the possibility to add a charging preferences object to a session object. This can be done both by the eMSP, SCSP or CPO. Changes in charging preferences will always result in an updated session message sent by the CPO to an eMSP or SCSP to ensure that the party executing smart charging will always be informed as soon as possible about changes in driver needs and can compute a new Charging Profile.

The addition of the charging preferences object also allows the CPO to forward changes in the charging preferences made in the EVs infotainment system or mobile app if both the EV and the Charging Station support ISO 15118 and the Charging Station and CSMS support OCPP 2.0.1.



Charging Preferences property	Description
Profile Type	This represents the type of charging profile selected by the driver and provides the option to indicate the objectives of the driver in the context of smart charging. Possible values could be CHEAP, GREEN, FAST and REGULAR for when the driver has no special preference, or the options are not provided to them.
Departure time	represents the expected departure time of the driver
Energy need	represents the requested amount of energy by the driver by departure time expressed in kWh. This property has the same meaning than the 'TargetEnergyRequest' used in ISO 15118. To satisfy the driver needs, this value needs to be smaller or equal to zero by the end of the charging session.
Discharging allowed	Indicates whether the driver allows their EV to be discharged. This property should be default indicated as 'False' to represent the opt-in choice for the driver in the context of bidirectional charging at a given location.

Charging preferences can only be used when the 'EVSE Capabilities' contain "Charging Preferences Capable". Also, when a given profile type is chosen, a specific Tariff must be provided by the CPO which can be the default tariff.

Although the Charging Preferences property options supported by OCPI 2.2.1 are different from the *MobilityNeeds* property options that ISO 15118 supports, the desired functionalities from a driver needs perspective could be produced.

To deal with these differences, the following workaround could be used to make OCPI 2.2.1 compatible with ISO 15118 with regards to fulfilling the mobility needs of the driver: When the MinRequiredEnergy variable under ISO 15118 is larger than 0 kWh, the CPO should put the Profile Type to FAST and change it to REGULAR when it is equal or smaller than 0 kWh. Only when the profile type is not FAST, the eMSP or SCSP should set a charging profile.

## 2.3.1.2 OCPI 3.0

OCPI 3.0 will contain major changes, including changes to infrastructure to improve efficiency of OCPI. Therefore, OCPI 3.0 will not be backwards compatible with older OCPI version implementations. In November 2021 the Business Use Cases were published that will form the basis for OCPI 3.0, expected to be released in December 2023.

Although details of the targeted functionalities are not known at the time of writing, based on the high level business use case descriptions, the following use cases are considered relevant for the desired system outcomes of chapter 7:

#### 1) native ISO 15118-20 support for smart & bidirectional charging

Derived from the business use case descriptions, OCPI 3.0 is aiming to provide support for ISO 15118-20. Although it remains to be seen what functionalities exactly will be covered and how they can be used, from the descriptions the following functionalities are targeted to be covered:

- Allowing the SCSP to send charging schedules to an ongoing charging session for bidirectional charging
- Allow a user to give and revoke permission to use bidirectional charging
- Allow the SCSP to be informed when other (local) systems are influencing the charging session
- Allow for priority charging to take place on behalf of the driver when he/she needs to leave as soon as possible

#### 2) Support for sending meter values to grid operators by CPO's

This business use case aims to provide a solution to use cases where the grid operator would like to receive metering information for validation purposes near real-time. This meter values could be energy consumed, active power, frequency etc. taken from the charging station or any other local metering device external from a charging station.







These targeted set of functionalities would be able to advance the desired system outcomes for both the third party control topology as well as the need for grid operators to get access to independent validation data streams for TSO grid balancing and DSO congestion management services.

#### 2.3.2 IEC 63119

IEC 63119 is a standard currently under development aimed at harmonizing roaming communication. The standard will describe the technical specifications and make it possible for CPOs and eMSPs to exchange data across Member States through roaming hubs or on a peer-to-peer basis (European Commission, 2021). As it is unlikely that existing roaming protocols will be harmonisation by the market itself given the fact that harmonisation will lead to financial disadvantages for protocol developers, a top-down approach via the IEC – and possibly European legislation - can push market participants towards standardisation to some extent.

It is, however, currently unclear whether IEC 63119 will appeal to market participants across the entire European Union and whether it will support smart & bidirectional charging use cases for third party actors similar like OCPI.





# 3 Software requirements and recommendations

# 3.1 User centricity

#### 1) Fulfilling the driver needs should always be prioritized

First and foremost, the mobility needs of the driver need to be able to be exchanged across the different protocols to ensure the mobility needs can be fulfilled when applying smart or bidirectional charging. With ISO15118-20 & OCPP 2.0.1, the mobility needs from the driver can be exchanged from the EV, over the charging station to the CSMS and vice versa through the *NotifyEVChargingNeeds* message. The mobility needs variables that are supported across these 2 protocols cover both the energy needs (minimum, target and maximum energy) as well as the departure time of the driver. When ISO 15118-20 is combined with the future OCPP 2.1, additional driver and vehicle limits related to the discharging of the EV could also be exchanged.

When a third party actor other than the EV or the CSMS would be responsible for smart or bidirectional charging and thereby ensuring that the mobility needs are met, other protocols are impacted. To ensure these mobility needs can be received by a third party, OCPI 2.2.1 is needed. With OCPI 2.2.1, the addition of the *ChargingPreferences* property allows the departure time and target energy needs to be passed on to a third party actor like the eMSP and SCSP.

OCPI 2.2.1 also allows for certain mobility needs to be updated by the eMSP or SCSP to the CSMS but are limited to the departure time and target energy needs. Without access to SoC information on the other hand, these energy needs expressed in kWh will be difficult to determine for them.

With ISO 15118-20, up-to-date mobility needs are always calculated by the EV so that auxiliary energy needs like for example required for preconditioning of the EV can also be accounted for. This can be done by updating the Minimum, Target and Maximum SoC variables towards the EV. To better match these functionalities in ISO 15118-20, OCPI should extend the charging preferences properties to include these different SoC variables.

To ensure the EV can be charged with maximum available power when the driver would decide not to engage in any smart or bidirectional charging for a given session, an additional *PriorityCharging* Charging Profile Purpose and *UsePriorityChargingRequest* message is defined in the upcoming OCPP 2.1. Based on the business use case description of OCPI 3.0, some priority charging functionalities are also considered in scope of this future protocol update.

Some gaps still exist to fulfil the related desired outcomes. These are translated into the following recommendations for the different protocols which are listed below.

ID	Recommendation	Explanation
1-1	Extend the charging preferences properties in OCPI to ensure compatibility with ISO 151118-20 and OCPP 2.1	Variables such as Min, Max & Target SoC should be added so that a third party can update these towards the CSMS when a driver would have updated these
1-2	Make Present SoC value exchange to the Charging Station mandatory for the EV in AC charging when dynamic control mode is used under ISO 15118-20	To ensure that a driver can make optimal decisions on their charging preferences in a user-friendly way, real-time SoC information should be present in the same GUI. For third party actors other than the EV to be able to provide such a user experience, present SoC values should be available to them.  This requires that the Present SoC variable is made mandatory to exchange instead of optional for AC charging.
1-3	Add Present SoC values to OCPI	To make sure the CSMS can pass through present SoC values to a third party actor for an ongoing charging session, the CSMS will need to be able to add SoC values to a OCPI session object. This is currently not covered within the latest OCPI protocol version



1-4	Add the UsePriorityChargingRequest in OCPI	Although that it is mentioned somewhere in de business use case descriptions of the future OCPI 3.0 protocol update, it is worthwhile to explicitly list it in these requirements.
1-5	Automatically switch to priority charging when <i>RemainingTimetoTargetSoC</i> in ISO 15118-20 equals or is less than the remaining time until time of departure	When the third party fails to manage the charging session within the mobility needs constraints, the charging session should be able to switch to priority charging automatically. This can be derived from the <i>RemainingTimeToTargetSoC</i> value which is optionally exchanged under ISO15118-20 between the EV and the EVSE. How this mechanism should work and which actor will become responsible for it, should be determined by the ISO 15118 standardization body.

#### 2) Freedom of smart charging service provider choice without vendor lock-in

When combining ISO 15118-20, OCPP 2.x and OCPP 2.2.1 the different actors like EV, EMS, CPO, eMSP or SCSP can theoretically exert control over the charging session. Still, some lock-ins continue to exist within the ecosystem when making use of the latest protocol versions.

As explained, when ISO 15118-20 is used for EV – Charging Station communication, the EV can always unilaterally decide whether it allows external actors to define the charging schedule for the charging session by selecting the dynamic control mode. This requires that the driver should be able to clearly indicate to the EV through a GUI that it wants to give the responsibility to optimize his charging session to another actor within the system.

With OCPI 2.2.1, the different supported control topologies allow for the eMSP to post a charging schedule for an ongoing charging session on behalf of the driver without explicit consent of the driver or CSMS. For the SCSP to be able to do the same on behalf of the driver, it requires that control is explicitly delegated by the eMSP or CPO. This creates lock-in by the eMSP or CPO on who will be able to optimize smart and bidirectional charging for the driver.

To eliminate these lock-ins, the following recommendations were defined at this stage.

ID	Recommendation	Explanation
2-1	Clear and transparent instructions for the driver in the EV GUI on how it can allow to switch from scheduled to dynamic control mode under ISO 15118-20	To avoid EV lock-in on smart & bidirectional charging
2-2	Allow the EV driver to delegate smart or bidirectional charging to an eMSP, CPO or SCSP under OCPI	To avoid that only the CPO or eMSP assign smart or bidirectional charging to an SCSP as supported under OCPI 2.2.1
2-3	Active registry management of SCSP's	To make sure that the driver can decide which SCSP is allowed to manage the flexibility from his charging sessions and not the eMSP or CPO, we foresee the requirement of an active registry for SCSP's managed by an independent party in the ecosystem.
		The concept could be similar to the registry of active energy suppliers and BRP's for a grid connection point in the energy sector. This concept could also provide the foundation to facilitate consumer processes like switching etc.

# 3) Smart and Bidirectional charging can only be executed within the technical limits of the EV battery so that the warranty of the vehicle will not be impacted for the consumer

To avoid that the execution of smart or bidirectional charging would violate the technical and operational limitations imposed by the EV, the relevant technical constraints of the EV should be known to the external actor. ISO 15118-20 allows to exchange such variables to the charging station through the *ChargeParameterDiscoveryReq* message. To





allow an external actor other than the EV, Charging Station or CPO to determine a proper charging schedule that doesn't violate these EV constraints, such variables need to be communicated over OCPI to a third party, which is currently not covered with the latest OCPP 2.2.1 version nor the future 3.0 version based on the available descriptions of the targeted business use cases.

Although ISO 15118-20 already covers some technical EV constraints related to charging and discharging, some required or desired variables are not yet exchanged such as round-trip efficiency coordinates or vehicle V2X warranty limitations imposed by the EV.

If the current draft of the Renewable Energy Directive and more specifically Article 20a would be enforced as is foreseen later in 2023, exchange of some of the missing data would already be enforced through government mandates. This Paragraph states that non-discriminatory, free and real-time access to SoC, state of health, battery capacity size, etc must be provided to third party actors based on explicit consent of the user and compliant with GDPR.

The bidirectional communication means of ISO 15118-20 provide a possible pathway to exchange such information to such third party actors if the following identified gaps and recommendations would be covered.

ID	Recommendation	Explanation
3-1	Mandatory exchange of energy storage capacity of the EV to the charging station when dynamic control mode is selected under ISO 15118-20	To allow to comply with Article 20a of the draft Renewable Energy Directive.
3-2	Add a EV round-trip efficiency table to the <i>ChargeDiscoveryParameterReq</i> message in ISO 15118-20	Similar to for example the Power/Frequency table under the draft OCPP 2.1, a EV round-trip efficiency table could be used by the EV to specify towards an external actor who efficient it is able to charge or discharge electricity at different input and output power target values.  This information could be used by an external actor to account for efficiency losses when defining the optimal charging schedule.
3-3	Add State of Health information related to V2X warranty limitations to the <i>ChargeDiscoveryParameterReq</i> message in ISO 15118-20	In order to make sure that discharging will not affect the warranty of the EV and that the optimization of charging schedules can minimize the V2X warranty impact as additional objective, information about the V2X warranty constraints should be known.  It should be targeted to aim for a limited set (ideally even just one) of possible parameters that would reflect V2X battery state of health as this would otherwise potentially require separate optimization strategies per different unique or combination of V2X warranty parameters.
3-4	Ensure that the variables contained in the ISO 15118-20 ChargeDiscoveryParametersReq message can be exchanged over OCPP and OCPI to a CSMS or another third-party service provider	To ensure that an external actor other than the EV can determine an optimal charging schedule within the operational and technical limits of the EV.  This requirement thereby would cover all updated changes to ChargeDiscoveryParametersReq message by the other listed requirements.

# 3.2 Control topology agnostic for the different energy services

#### 4) Control topology agnostic

As described under chapter 1.2, the ecosystem architecture should provide the capabilities for different actors to influence the charging speed and the direction for smart and bidirectional charging respectively. Through the functional



analysis of the different protocol versions, the following conclusions can be drawn regarding support for the different control topologies with respect to smart and bidirectional charging.

Actor	Smart charging	Bidirectional charging
Car manufacturer	ISO 15118-2	ISO 15118-20
СРО	OCPP 1.6	OCPP 2.1 (draft)
EMS	OCPP 2.0.1	OCPP 2.1 (draft)
Other Third party	OCPI 2.2.1	Not covered yet in OCPI

As these conclusions show, OCPP 2.1 promises to facilitate both a CPO as well as an EMS to exert control over a charging session for bidirectional charging energy services. This will be achieved by the addition a new *V2XOperationMode* data type that needs to be added to the *ChargingSchedulePeriod* within a *ChargingProfile*. The 9 different supported V2X Operation Modes are more in detail explained before.

Although support for bidirectional charging is mentioned in the business use case descriptions of OCPI 3.0, the V2X related functionalities of OCPP 2.1 are possibly not yet on the radar of OCPI for inclusion within the future 3.0 version as the EVRoaming Foundation which manages the OCPI protocol is not an official member of OCA, the organisation that manages the OCPP protocol.

To make sure that OCPI will provide backwards compatibility with OCPP 2.1, the same approach could be applied that OCPI 2.2.1 took with regards to the addition of the Charging Profiles module. The most obvious route for adoption is therefore to adopt the same functionalities and messages in OCPI that OCPP 2.1 will provide to the CSMS with regards to bidirectional charging and its different V2X operation modes.

This results in the following recommendations:

ID	Recommendation	Explanation
4-1	Adopt the V2XOperationMode concept as additional data type for a ChargingSchedulePeriod within a Charging Profile to OCPI	To ensure that third parties can deliver bidirectional charging services to a driver
4-2	Define clear rules and responsibilities in OCPP and OCPI with regards to V2X operation Mode switching initiated by different actors	To avoid conflicts when different actors want to change the V2X operation mode, for example when a SCSP is requested by a grid operator to deliver grid balancing services

### 5) Energy services agnostic

Paragraph 1.2 already provided a description of the different behind-the-meter services that are targeted within SCALE and explained the input data requirements that the delivery of each energy service relies upon for smart and bidirectional charging. For several energy services IEC 61851, the current dominant protocol for EV – EVSE communication is not considered future proof due to 4 main reasons:

- It doesn't support bidirectional charging
- It doesn't allow to exchange battery related information from the EV over to the EVSE
- It doesn't allow to exchange mobility needs by the EV to the EVSE on behalf of the driver
- It doesn't allow for delayed charging as the EVSE cannot request the EV to go out of a 'sleep' or 'stand-by' state which would be required to optimally deliver several energy services as explained in paragraph 1.2

ISO 15118-20 is therefore considered the only future-proof protocol for energy services, both for smart and bidirectional charging. As generic input data related to mobility needs and battery related information has already been





covered under the user-centricity conclusions, this section focusses on conclusions and recommendations related to grid measurements and tariff information required for behind-the-meter energy services for the different control topologies.

These conclusions and recommendations do not include the required input data for the back-up power energy service from bidirectional charging. By making use of the related functionalities covered by ISO 15118-20 combined with the upcoming OCPP 2.1 version, all functionalities and input data would be available locally to deliver on this use case, not considering additional hardware impact.

#### · Grid measurements:

The most recently published versions of the protocols covered in the analysis do not support the exchange of real-time grid measurements between different actors in a standardized way. Although the flexible device model of OCPP 2.0.1 could be used by CPO's to allow the CSMS to collect external meter values like grid measurements, such an implementation should be considered proprietary.

This is a major interoperability gap with regards to the delivery of different energy services through the different control topologies. Both OCPP 2.1 and OCPI 3.0 promise to fill in the gap by allowing to exchange values related to external meters not tight the charging infrastructure. This could provide a starting point to allow the same variables to be exchanged over ISO 15118-20 from the EVSE to the EV.

#### • Tariff information:

Although an in-depth analysis of supported tariff structures was not provided within the context of this report, ISO 15118-20, OCPP and OCPI support some sort of tariff data model and corresponding messages.

To support the different energy services, the different components that could be represented in the electricity bill should be able to be covered with the underlying electricity tariff data model so that smart and bidirectional charging energy services could achieve the most optimal financial and ecological benefits for the user.

As the supported tariff models by the different protocols are first and foremost focussed on the settlement of energy charged to an EV, it currently only covers time variations of volumetric energy charges (€/kWh).

In order to better reflect both capacity based and feed-in tariff structure use cases, the tariff models covered by the different protocols should be updated and ideally harmonised across protocols to make message conversion over the different protocols easier for actors like a CSMS. How the input is gathered on the applicable tariff at a given site is considered out of scope of this report. This could for example be through a manual entry from the site owner in any GUI provided by an actor.

The following recommendations summarize gaps to be overcome in order to achieve the desired outcomes with regards to energy services support through the different control topologies for grid measurements and tariff information.

ID	Recommendation	Explanation
5-1	Add real-time grid measurements in OCPI for third party control purposes	The business use case description of OCPI 3.0 related to collecting grid measurements only mentions the grid operator's perspective.  As real-time grid measurements are a key input for behind-themeter energy services, the SCSP should also be allowed to request and receive them.  Porting the functionality provided by OCPP 2.1 on collection of external measurements to OCPI would allow real-time grid measurements to be collected as input data by third party actors in order to optimally determine a proper charging schedule.
5-2	Ensure message compatibility related to grid measurements between OCPP and OCPI	To make message conversion related to grid measurements easier for the CSMS, it should be aimed for that messages and data structures are the same across OCPP and OCPI.  This would make the implementation for the CPO easier.
5-3	Avoid any artificial delay from the CSMS when exchanging (grid) meter value updates to third parties over OCPI	The effectiveness of certain energy services is determined by their ability to react fast to changing conditions.





		It is therefore important that a third party can adapt their charging schedule in a timely manner when for example the amount of electricity that is consumed or injected at a given site changes.
5-4	Real-time grid measurement exchange from EVSE to EV under scheduled control mode in ISO 15118-20	To ensure that car manufacturers can also offer (all) smart & bidirectional charging services at a given site (V2Home & V2Building).
5-5	Add support for capacity based grid tariffs under the different protocols	To be able to support the demand charge reduction energy service by the different control topologies
5-6	Add support for feed-in tariffs under the different protocols	Currently, tariff information can only contain one volumetric price per timeslot whereas a site could be exposed to 2 different tariffs for respectively injection and consumption of electricity. This requires a change in the tariff data model of the different protocols
5-7	Harmonisation of tariff data models across the different protocols	The different protocols rely on different underlying tariff data models. This makes conversion of such information towards different protocols difficult and error prone.  To achieve this level of semantic and technical interoperability across the different protocols, collaboration and alignment between the different standardization organizations will be required.

# 3.3 Provide independent validation data streams to the grid operator

Both OCPP 2.1 and OCPI 3.0 promise to include functionalities that could enable grid operators to receive meter values from both the charging station as well as external meters such as local grid measurements. In this set-up, the CPO would act as Validation Data Provider (VDP) for the grid operator. To minimize the data traffic that the CPO would need to accommodate for acting as a VDP towards a grid operator, several functionalities included in OCPP 2.0.1 and 2.1 could be used.

Through the advanced monitoring capabilities that OCPP 2.0.1 provides to the CPO, different triggers could be used to fulfill in the needs of the grid operator as well as reducing the amount of data traffic between the charging station and the CSMS.

It could for example configure the periodicity if meter values to second level to provide the grid operator with highly granular measurement data and ensure that they are clock-aligned. To reduce the amount of data traffic and therefore network costs, delta values could as well be configured so that the charging station will only send a meter value update message to the CSMS when the underlying value of the variable has changed with more than plus or minus a set value.

Specifically for bidirectional charging, the foreseen addition of the 'Central Frequency' and 'Local Frequency' *V2XOperationMode* in OCPP 2.1 would allow CPOs to make sure that the charging station only sends highly granular and timely measurement data to the CSMS when they would be participating in balancing services. This anticipated functionality would allow them to reduce the data traffic even further within their potential role of VDP towards the grid operator.

As validation data requirements could be different for each balancing service, CPOs should be able to configure the triggers differently. To do this, the current V2X Operation Modes should allow the CPO or charging station to make a distinction between the different balancing services nor DSO congestion management services.

For the digital and physical e-mobility ecosystem to provide the independent validation data stream to grid operators, the following recommendations are provided:





ID	Recommendation	Explanation
6-1	Further breakdown V2X Operation Modes in OCPP	To better reflect the different TSO and DSO grid services and their unique validation data requirements, a CPO should be able to configure the different monitoring triggers differently and know to which grid operator (TSO or DSO) it needs to send the data to
6-2	Avoid any artificial delay from the CSMS when exchanging grid measurement variable updates to grid operators over OCPI	As certain grid services require access to real-time measurements, no artificial delays in the CSMS can take place between the collection of the measurement data from the charging station to sending the measurements to the grid operator
6-3	ADD unique grid connection point identifier as additional variable to OCPP and OCPI	As grid users are represented by unique grid connection point identifiers, these identifiers are used to communicate customer related data over different actors in the electricity domain. These identifiers will need to be used to register sites and devices towards the grid operator and exchange meter values for

## 3.4 Minimize impact on the distribution grid

### 7) Power quality and network code compliance

With regards to bidirectional charging hardware technology choices by car manufacturers, different strategies can be observed. From the different product announcements, it can be observed that some OEMs stick to the existing unidirectional onboard inverter technology while others will equip the electric vehicle with bidirectional onboard inverter technologies. This impacts whether an AC and/or DC V2G ecosystem can be created with the electric vehicle and consequently will determine whether an AC or DC bidirectional charger will need to be adopted.

With the upcoming OCPP 2.1 version, the addition of the 'Local Frequency' and 'Local Voltage' V2X Operation Modes, network code compliance can be delivered from the charging station so that a V2X system comprising of both the electric vehicle and charging station can become compliant with the different network codes.

For DC V2X, the inverter sits within the charging station. It is therefore very clear that the relevant network codes only apply to the charging station. For AC V2G on the other hand, applying OCPP 2.1 and ISO 15118-20 in dynamic control mode would allow for the charging station to deliver 'smart inverter' functionalities to the EV by sending the proper active or reactive power commands to the EV. This AC V2G use case is currently not well covered in regulation with regards to requirements for network code compliance and more specifically the requirements and standards the EV and the Charging Station respectively need to comply with and therefore be tested against.

To create a level playing field between the different OEMs and their respective hardware & software choices related to V2X, regional, national and international regulators should come up with clear requirements & conformance testing procedures for AC V2G that are applicable to both the electric vehicle and the charging station.

The following recommendations have been formulated:





ID	Recommendation	Explanation
7-1	Clear requirements for AC V2G systems	To create a level playing field for the different OEMs with regards to V2G customer propositions
7-2	Harmonization of requirements for EVs and charging stations (AC & DC) across regional, national and international levels	To make it easier for EV and charging station to bring V2G products in the market across different geographies, thereby shortening time-to-market and reducing product costs for V2G
7-3	Provide machine readable Volt/Var and Power/Frequency tables for the market to ensure network code compliance for bidirectional charging	Network code requirements like requirements for generators can differ on a regional and national level.  Secondly, the information on how generators are expected to respond in certain voltage and frequency conditions is written down in often difficult to retrieve documentation in the specific official languages of that country.  This slows down market adoption of network code compliant bidirectional charging technologies.  Providing market access to such information in machine readable formats, ideally centralized available could effectively speed up the uptake of network code compliant bidirectional charging technologies

### 8) Indirect or direct control by the DSO over charging sessions

To evaluate how the current and future e-mobility ecosystem could accomplish the different DSO use cases related to non-wired alternatives, the structure of the different type of instruments from chapter 1.4 will be used.

### • Smart tariffs & connection agreements

OCPP 1.6, the dominant OCPP protocol version adopted by the market already provide required functionalities in the 'Smart Charging' module to accommodate for some connection agreement use cases.

The *DefaultProfile* as *ChargingProfilePurpose* with a 'recurring *ChargingProfileKind*' could be used by the CPO and Charging Station if the regulation would impose a limited charging speed for certain recurring time periods.

Making use of this *ChargingProfilePurpose* in OCPP 1.6 would still allow the driver to overrule the default limited charging speed with OCPP 1.6 if another *TxDefaultProfile* would be imposed or if the *DefaultProfile* would temporarily be removed. For this specific use case, future OCPP 2.1 and OCPI 3.0 releases promise an easier implementation when a *DefaultProfile* would be active as an additional *PriorityCharging ChargingProfilePurpose* is foreseen to be added

With regards to Smart capacity-based tariffs, the different current and future protocol versions do not cover capacity-based tariff components within their tariff model. Related recommendations to solve this gap are already covered with 5-5 and 5-7.

#### Market solutions

It is assumed that market based DSO congestion management services are provided by an aggregator market party that is already assigned by the driver to optimize their charging sessions through one of the different control topologies. How the activation request will be received from the DSO by the aggregator is considered out-of-scope of this report.

In order to validate the correct delivery of congestion management services, DSOs could rely ex-post on the meter values that it collects from smart meters. If more real-time meter values could be required by the DSO for validation purposes, the recommendations provide under 6-1, 6-2 and 6-3 are valid tor these use cases.

#### Interventions

Through OCPP 2.0.1, local direct control over the charging session by the DSO is supported through a new addition of new *ChargingStationExternalConstraint ChargingProfilePurpose*. Through which possible communication protocols the





charging station receives such a charging profile is left out-of-scope of this report, but at least one should be able to be supported. If a DSO wishes to apply direct local control over a charging station, it should specify requirements for the local interface to the market.

DSO interventions related to charging limits via the cloud could be realized through different options such as the OpenADR protocol. The current and future OCPI 2.2.1 and 3.0 versions don't foresee that a DSO is allowed to send charging profiles to a CPO over OCPI for an active charging session.

If such a OCPI and OCPP use case would be targeted to cover in a future OCPP or OCPI update, it is important that regulation exist that would define the conditions in which a DSO is allowed to exert direct control over a charging session so that the driver impact is minimized.

This results in the following recommendations:

ID	Recommendation	Explanation
8-1	Machine-Machine readable digital interfaces for smart grid tariffs	In most EU countries, many DSO's operate within the national territory. Often each of them apply their own grid tariffs (tariff structure and/or costs) for customers located at different voltage levels of the grid.  To make it easier for the smart charging service provider to take these grid tariffs into the optimization, grid tariffs should be known to the algorithm.  Having access digitally to the grid tariffs that apply per grid connection point would both help the consumer forward as well as the service provider
8-2	Harmonize requirements across geographies related to local interfaces for DSO's	If every DSO or region would come up with its own requirements, potentially different charging stations need to be built. This would impact product standardization, negatively impacting end-consumer charging station prices
8-3	Allow DSO's to also send a charging profile to an active charging session over OCPI	This would allow interventions by the DSO to take place
8-4	Add additional ChargingProfilePurpose for DSO charging profiles in OCPP and OCPI	To make sure that a DSO intervention is effective, possible conflicts with other active charging profiles should be avoided. Adding an additional ChargingProfilePurpose for DSO charging profiles would allow to avoid such conflicts
8-5	Regulation that defines the operational situations in which a DSO is allowed to directly intervene with a charging speed limitation	To avoid that DSO control would be too frequently applied or even misused, regulation is needed to avoid excessive impact on the driver needs

### 9) High levels of cybersecurity

As explained under in paragraph 1.4, for a system to be considered cyber-secure, the system needs to satisfy data confidentiality, data integrity and authenticity criteria. This means that all the different used protocols must meet the same criteria so that weak links are avoided and end-to-end security can be guaranteed.

For data confidentiality, it is important that data in transit is protected and cannot be tampered with. Only ISO 15118-20 imposes a minimum TLS version, being TLS 1.3 which was released in 2018. OCPP provides 3 security profiles that market parties can use. Only 2 require TLS for secure communication without specifying which the minimum version that needs to be used. OCPI on the other hand still proposes SSL to be used for secure communication, the predecessor of TLS. It is therefore recommended that all protocols make use of the best available technology for data confidentiality and adapt to the mandatory TLS 1.3 requirements from ISO 15118-20.

While detailed requirements for data integrity will be analysed under task 2.2, OCPP 2.0.1 already provides some functionalities that would ensure a high level of data integrity between the charging station and the CSMS. For authentication means, different technologies are used by the different protocols. While ISO15118-20 makes use of client – server certificates, the use of certificates is only required with the 3<sup>rd</sup> and highest security profile in OCPP 2.0.1.







OCPI doesn't make use of certificates but instead relies on credential tokens. To ensure high levels of authenticity, it is recommended that all actors interacting with one another across rely on certificate based authentication.

This results in the following proposed recommendations. More in depth analysis of cyber-security requirements will be executed under task 2.2.

ID	Recommendation	Explanation
9-1	Mandatory use of the third security profile for future OCPP 2.x or higher implementations	As OCPP 2.0.1 leaves it open to market actors to decide which security profile it will implement, this optionality should ideally be removed in future protocol updates.
9-2	Mandatory use of TLS 1.3 for securing Charging Station - CSMS communication in OCPP 2.x	As OCPP 2.0.1 doesn't specify the minimum TLS version to be supported, by making this more explicit to the market, cybersecurity levels could become on par with ISO 15118-20. This would lead to a higher level of end-to-end security
9-3	Mandatory use of TLS 1.3 in OCPI 3.0	To secure data in transit over OCPI, more recent available protocols should be used for transport layer security than the old SSL to bring cyber-security to a higher standard, definitely when OCPI would be used more and more for smart and bidirectional charging purposes
9-4	Two-factor authentication for internal personnel across the different market parties for application interfacing GUI's	To improve cyber-security of internal IT systems from hacking of username and passwords.



# 4 Hardware requirements

To ensure that only the physical e-mobility infrastructure is interoperable with each other and can be used in a safe way by the driver, different international standards have been defined. This chapter provides an overview of these different standards and explains what hardware components they cover and what they regulate. The covered standards under this chapter are also listed within chapter 6 with regards to the smart and bidirectional charging requirements. This chapter therefore provides the reader additional background information on these standards.

### 4.1 IEC 61851

Electrical safety is of paramount importance to avoid short-circuits, overheating and electric shocks. To ensure safe charging of electric vehicles, IEC 61851 is a standard for electric vehicle conductive charging systems covering the operating conditions of the EVSE, safety requirements for AC & DC charging and the necessary low-level communication between the EVSE and EV.

Visual representation	Description
AC STATE OF THE ST	In <b>Mode 1</b> charging, an EV is charged through a regular household socket with a simple extender cable without any safety devices in between.  This charging mode is considered unsafe for EV charging and is more intended to charge electric bikes & scooters
AC Communication	The <b>Mode 2</b> is similar to Mode 1, but makes use of a dedicated charging cable with an integrated control & protection device that mostly comes supplied with the EV. This mode is much safer than mode 1, however the charging capacity is limited to the max rating of the outlet.
AC Control & Communication	Mode 3 involves the use of a dedicated charging station.  In this mode, there is communication between the car and the charging station and voltage will only pass throught the socket once a suitable charging current has been determined by the ca
AC DC Control & Communication Cable connected to charger	<b>Mode 4</b> charging refers to DC charging where DC current is supplied to the EV by an off-board charger and a fixed charging cable, bypassing the onboard converter.

The IEC 61851 part 21, gives requirements for conductive connection of an electric vehicle (EV) to an AC or DC supply. It applies only to on-board charging units either tested on the complete vehicle or tested on the charging system component level. The IEC 61851-21 covers the electromagnetic compatibility (EMC) requirements for electrically propelled vehicles in any charging mode while connected to the mains supply. Part 21-2 defines the EMC requirements for any off-board components or equipment of such systems used to supply or charge electric vehicles with electric power by conductive power transfer (CPT), with a rated input voltage, according to IEC 60038:2009, up to 1 000 V AC or 1 500 V DC and an output voltage up to 1000 V AC or 1 500 V DC. This document covers off-board charging equipment for mode 1, mode 2, mode 3 and mode 4 charging as defined in IEC 61851-1.



### 4.2 IEC 62196

The IEC 62196 standards series currently comprises three parts.

IEC 62196-1 provides general requirements for the interface between an electric vehicle and a charging station as well as general mechanical and electrical requirements and tests for plugs, socket-outlets, vehicle connectors and vehicle inlets that are intended to be used for EV charging. It does not describe specific designs, which can be found in the IEC 621196-2 and IEC 62196-3.

IEC 62196-2 defines 3 types of connectors for AC power supply whereby the type 2 connector, otherwise known as the 'Mennekes' connector is the standard for AC power supply with an EVSE adopted in Europe. This type 2 connector has 5 power pins, one for neutral, one for protective earth and 3 AC line phases, allowing for both single- as well as 3-phase charging.

The most used technology for fast charging EVs is to supply the EV with direct current from the EVSE effectively bypassing the on-board converter (OBC) in the EV. IEC 62196-3 defines the requirements for DC charging which allows fast charging, both for DC connector as well as Combo connector which combine AC & DC in- and outlets. The CCS type 2 variant is by far the most widely adopted connector by EV brands and models in Europe. This connector unites AC & DC charging into a single connector combining the type 2 connector with 2 DC charging pins.

The relevance of IEC 62196 regarding interoperability related to smart charging is limited to physical specifications in terms of signaling pins and connector compatibility between vehicles and charging stations.

#### 4.3 FN 50620

This standard specifies design, dimensions and test requirements for halogen-free cables with extruded insulation and sheath having a voltage rating of up to and including 450/750 V for flexible applications under severe condition for the power supply between the electricity supply point or the charging station and the electric vehicle (EV).

The EV charging cable is intended to supply power and if needed communication (details see EN 61851-1 and the EN 62196 series) to an electric vehicle. The charging cables are applicable for charging modes 1-3 of EN 61851-1. The cables in this standard with rated voltage 300/500 V are only permitted for charging mode 1 of EN 61851-1. The maximum conductor operating temperatures for the cables in this standard is 90 °C.

The cables may be:

- a) an integral part of the vehicle (case A of EN 61851-1);
- b) a detachable cable assembly with a vehicle connector and AC supply connection to a socket outlet (Case B of EN 61851-1)
- c) permanently attached to a fixed charging point (case C of EN 61851-1)

#### 4.4 ISO 17409

ISO 17409 specifies electric safety requirements for conductive connections of electrically propelled road vehicles to an external electric power supply using a plug or vehicle inlet. It applies to electrically propelled road vehicles with voltage class B electric circuits.

It applies only to vehicle power supply circuits. It applies also to dedicated power supply control functions used for the connection of the vehicle to an external electric power supply. It does not provide requirements regarding the connection to a non-isolated DC charging station. The requirements when the vehicle is not connected to the external electric power supply are specified in ISO 6469-3.





# 5 Power quality requirements

Charging and discharging an electric vehicle can affect the quality of the electricity in the grid, and at its turn the power grid can also influence the charging behavior. While charging or discharging, a vehicle can affect the voltage of the power grid, while the quality of the voltage has an influence on the quality of the power that the vehicle consumes. The power quality of an electrical network is usually investigated in terms of voltage and frequency fluctuations, power losses, phase unbalance. The following standards related to power quality apply to the EV as well as the Charging Station. Requirements for the EV or charging station related to power quality will be listed separately as additional requirements under chapter 6.

### 5.1 EN 50160

This European Standard defines, describes and specifies the main quality characteristics of the voltage at a network user's supply terminals in public low voltage, medium and high voltage AC electricity networks under normal operating conditions. These characteristics include the frequency, magnitude, wave form & symmetry of the 3 phase voltages. All the hardware used in a V2X system should therefore be able to deal with and operate normally under the characteristics specified in this standard.

#### 5.2 EN 50549-1

EN 50549-1 is a European standard specifying the technical requirements for the protection functions and the operational capabilities for generating plants intended to operate in parallel with low voltage distribution grids. It thereby is only applicable to bidirectional charging.

The standard is written to be compliant with the Commission regulation 2016/631 network code (RfG, requirements for generators) but goes beyond the scope of RfG, which leaves member states flexibility for implementation. It thereby is advised to member states to reference this standard towards manufacturers of EVs and bidirectional capable charging stations.

The standard gives detailed description of functions to be implemented and supported by these assets. examples include:

- what the normal voltage operating ranges are
- · reactive power capabilities
- interface protection & anti-islanding operation
- definition of response to over- & under voltage & frequency events



# 6 Smart & bidirectional charging requirements

The smart & bidirectional charging requirements are divided into five modules that can be applied independently or in addition to each other and will be described under the different paragraphs within this chapter.

### • Smart Charging Basics (MODULE 1 and 2):

The basic conditions for smart charging for every electric vehicle (MODULE 1) and for every charging point (MODULE 2)

### Smart Charging – Private and Semi-public (MODULE 3A)

Additional requirements for Smart Charging at Private and Semi-Public charging points

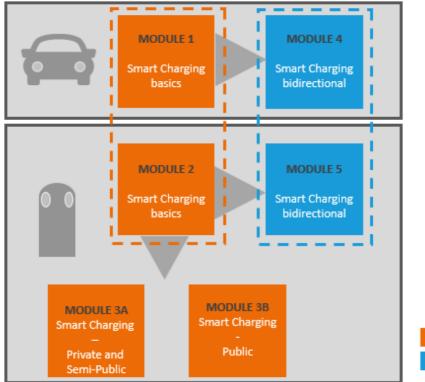
### • Smart Charging - Public (MODULE 3B)

The additional basic conditions for smart charging for charging points in the public space, with additional protocol support

### Bidirectional Charging (MODULE 4 and 5)

The additional conditions for every electric vehicle and for every charging point, with the option of discharging the vehicle battery (Vehicle-to-Anything)

The illustration below shows how the modules relate to each other. The conditions in MODULES 1 and 2 are the mandatory basic requirements for Smart Charging. The conditions in MODULE 3 are only mandatory in public environment. The conditions in MODULES 4 and 5 are optional and recommended when using bidirectional charging.







# 6.1 Smart charging basics - EV

Applicable for: Electric Vehicles

Module 1 forms the basis for Smart Charging and is mandatory for all charging points and electric vehicles within the scope of the Smart Charging Requirements. The guidelines described relate to the vehicle, the charging cable and the charging point.

Many different standards apply to (electric) vehicles. The part that has to do with charging is relevant for Smart Charging: the On Board Charger and the charging control capabilities of the vehicle. The requirements below relate to properties of this charger, such as the technical specifications, the options for Smart Charging and the Power Quality properties as well as charging control in general where the OBC is not per se used. These requirements apply to manufacturers of vehicles and / or on-board chargers and are outside the sphere of influence of the charging station manufacturer. Note. in case of DC charging, the On Board Charger is not used. The standards also apply to DC charging and charging control is also applicable if the OBC is not used.

### 6.1.1 Standards for EVs and charging cables

The vehicle and charging cable comply with the applicable standards for electric vehicles and their charging systems below.

ID	Requirement	Explanation
1-1	IEC 61851-1:2017; Electric vehicle conductive charging system - Part 1: General requirements  For communication with EVSE: Annex A 'Control pilot function through a control pilot circuit using a PWM signal and a control pilot wire'	This standard describes, among other things, how a current [A] value can be communicated to an electric vehicle from a charging point. This is the basic principle behind Smart Charging.  Scope: AC Charging  For more detailed information, see paragraph 4.1.
1-2	IEC 61851-21-1, -23 and -24 DC Charging (Mode 4)	For DC charging, the vehicle complies with the applicable IEC standard For more detailed information, see paragraph 4.1
1-3	ISO 17409:2020; Electrically propelled road vehicles — Conductive power transfer — Safety requirements	Contains requirements for, among other things, inrush peaks and Power Factor, essential for the reliability of the electricity grid.  For more detailed information, see paragraph 4.4
1-4	The vehicle is equipped with at least 1 of the following plugs / contact points as described in the IEC 62196 -1,2,3 The vehicle always uses the Type 2 female connector for AC charging.	Standardization of the charging plug is important for uniformity in smart charging. For more detailed information, see paragraph 4.2
1-5	UN-ECE R10 – Electromagnetic Compatibility	The vehicle must be immune to EMC and must not cause any disturbances itself
1-6	IEC 62196 series; Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles	Contains Requirements for the standard charging plugs. For more detailed information, see paragraph 4.2
1-7	The supply voltage of the charging point is within the limits of EN 50160; the vehicle must charge stably at least within the limits of this standard	Dealing with full spectrum of supply voltages. For more detailed information, see paragraph 5.1
1-8	EN 50620:2017; Electric cables - Charging cables for electric vehicles	Contains Requirements for charging cables for electric vehicles. For more detailed information, see paragraph 10.3





# 6.1.2 EV Communication protocols

The foundation needed for smart charging protocols to work.

ID	Requirement	Explanation
1-10	For EV – EVSE communication, ISO 15118-20 must be supported before end of 2024	To be able to allow for bidirectional communication capabilities between the EV and EVSE so that for example SoC information can be exchanged
1-11	Mandatory exchange of present SoC values to the EVSE in dynamic control mode under ISO 15118 -20	To allow a secondary actor to provide the user with real-time SoC information in a GUI and to anticipate compliance with Article 20a of the draft Renewable Energy Directive. For further explanation, see recommendation 1-3 under paragraph 3.1
1-12	Clear and transparent instructions in the EV GUI for the driver to enable control by other actors	In order to switch the default control mode to 'Dynamic' under ISO 15118-20. For further explanation see recommendation 2-1 under paragraph 3.1
1-13	Mandatory exchange of energy storage capacity to the EVSE when dynamic control mode is used	To anticipate compliance with Article 20a of the draft Renewable Energy Directive

# 6.1.3 Charging Power and -control of EV

The vehicle must support charge control, and it is also important to set a framework for the charging currents that must be supported, as this is sometimes insufficient in the standards.

ID	Requirement	Explanation
1-14	The minimum charging speed at which the vehicle must be able to be charged is 1x6A	The minimum charging current as specified in IEC 61851-1, but not yet supported by all electric vehicles.  Note that this charging current is rarely used due to the low efficiency of the OBC, but falls within the effective range of the Mode 3 PWM signal NB. During a charging break (PWM 100%) the vehicle "charges" with 0A.
1-15	The vehicle can handle the charging currents that are communicated from the charging station.  Specifically, the vehicle must be able to handle the following situations:  • Frequent changes of maximum charging current, alternating with charging pauses (PWM 100%); it must be possible to resume charging after an indefinite pause. (This can occur several times within the same charging session)  • Dealing with current / power variations between the Pmax and Pmin of the vehicle  • Delayed charging: after connecting to the charging station, a delayed start takes place (indefinite time) before charging starts (PWM 100% = 0A).	Although this falls within the Mode 3 spectrum of the IEC 61851-1, not all electric vehicles support it well This also concerns longer waiting times by the vehicle, for example when it is in 'deep sleep' mode.
1-16	The maximum charging current as indicated by the charging point always indicates the maximum permissible charging current, regardless of any other charging speeds programmed in the vehicle or received via Connected Car telematics	Vehicle settings or charge control via, for example, "connected car" may never exceed the current offered by the charging point. This is also secured by the charging point



## 6.1.4 Power Quality EV

Charging and discharging an electric vehicle can affect the quality of the electricity in the grid, and at its turn the power grid can also influence the charging behavior. When charging, a vehicle can affect the voltage of the power grid, while the quality of the voltage has an influence on the quality of the power that the vehicle consumes.

ID	Requirement	Explanation
1-12	With regards to EMC, the vehicle must also be tested for non-rated (lower) charging currents (<16A).	Lower charging currents (<16A) are used regularly. EMC is important in these bandwidths as well.
1-13	To avoid supra-harmonic disturbances, the switching behavior of the inverter must be adjusted to the highest possible frequency.  No disturbances may be injected into the charging point from the vehicle.	A high frequency produces less disturbance
1-14	No disturbances, such as Supra-Harmonic Currents (between 2 kHz and 150 kHz) may be injected into the charging point from the vehicle. Supra-Harmonic emissions, usually caused by the switching frequency of the AC / DC converter in the Onboard Charger, must be prevented, for example by using a filter, using other power electronics or changes in the switching behavior.	Supra-harmonic disturbances are not yet sufficiently included in standards

# 6.2 Smart charging basics - Charge Point

Applicable for: all charge points (private, semi-public and public)

This Module describes the standards for charging points and the aspects where further clarification or addition on standards is necessary. The additions are subdivided by theme. The scope is Smart Charging; only those requirements that are relevant within the theme of Smart Charging are included.

### 6.2.1 Standards for Charge Points

Standards that a charging point must meet to make Smart Charging possible.

ID	Requirement	Explanation
2-1	IEC 61851-1:2017; Electric vehicle conductive charging system	Basic standard for EVs and Charging points
2-2	EN 50160 - Voltage characteristics of electricity supplied by public distribution systems	The charging point must be able to handle the voltage spectrum described in this standard.
2-3	EN 1010 - Safety provisions for low voltage installations	For a safe installation
2-4	Power electronic converters with a nominal power greater than 5 kW (> 1-phase 22A, () are generally connected to three phases.*  *Subject to selectivity limits	In accordance with the Electricity Network Code (October 2020) article 2.33 paragraph 5 Note: In Germany the following requirement is applied: The asymmetrical load on the grid connection point is limited to 4.6kVA (between the phases)
2-5	The protection of electrical installations and parts thereof is selective with the protection that the network operator applies in the connection of the electrical installation or in the supply network.	In accordance with the prevailing Grid Code Electricity (October 2020)



# 6.2.2 Charging Station communication protocols

The foundation needed for smart charging protocols to work.

ID	Requirement	Explanation
2-7	New official published versions of all mentioned protocols will be implemented within the following period:  Larger structural changes (normally indicated by a shift in the first number of a version, for example from v1.0 to v2.0) will be implemented within 2 years after publication.  Smaller incremental changes (normally indicated by a shift in the second number of a version, for example from v1.0 to v1.1) will be implemented within one year from the date of publication.	So that the charging points are up to date asap, within the capabilities of the manufacturer.  This ensures that new functionalities supported by more recent protocol versions can be delivered by the charging station.
2-8	All charging points have a telecommunication module	European regulations in the field of the European internal energy market state that an end customer must be enabled to become "active" in the energy market. There is an essential role for the end customer in realizing more flexibility in the electricity system, for example through its EV.
2-9	Telecommunications connections are online and connected at least 98% of the time	This is important to send and receive Smart Charging signals
2-10	The charging point and the communication connections used comply with the most recent Cyber Security Requirements for EV Charging Stations  Current version: EV-301-2016	Secure communication is essential for smart charging
	Current version. Ev-301-2010	Charging Station – EV communication
2-10	The communication between the charging station and EV can be established through ISO 15118-20	With ISO 15118-20 as high-level communication on top of IEC 61851, advanced bidirectional communication means between the EV and EVSE are supported such as the exchange of SoC information.
2-11	The communication between charging station and CSMS is in conformity with OCPP 2.0.1.  The goal for Open Charge Point Protocol (OCPP) is to offer a uniform solution for the method of communication between charge point and central system.	Charging Station - Control System communication  With OCPP it is possible to connect any central system with any charge point, regardless of the vendor. A uniform standard prevents all kinds of coordination problems and is therefore an advantage for the whole electric vehicle market.
2-12	Mandatory use of the highest security profile of OCPP 2.0.1	To increase cybersecurity levels. For further information, see recommendation 9-3 under chapter 3.4
2-13	Mandatory use of TLS 1.3 for secure Charging Station – CSMS communication	To ensure OCPP achieves the same data confidentiality cyber-security criteria as ISO 15118-20. For further information, see recommendation 9-2 under chapter 3.4





# 6.3 Smart charging - Private and semi-public

Applicable for: private and semi-public charge points, in addition to Module 2: Smart Charging Basics - Charge Point.

This Module contains additional requirements for Smart Charging that are only applicable for Private and Semi-Public Charge Points.

Note: the requirements in Module 2 are thus also applicable for Private and Semi-Public Charge Points.

### 6.3.1 Private and semi-public charge point - communication protocols

ID	Requirement	Explanation
3A-1	The charging station can communicate with an Energy Management System (EMS) via an open protocol such as EEBus, EN50491-12,	Charge Point - Control System communication For communication between EVSE and Energy Management System
3A-2	The charging station can communicate with the meter in the Grid Connection if this meter supports local connection possibilities.	Charge Point - Control System communication For communication between EVSE and Energy Management System and/or Power Grid Management System

# 6.4 Smart charging - Public

Applicable for: Public Charge Points.

This module is mandatory for public charging points and is an addition to Module 2: Smart Charging Basics – Charging Station. This module focuses on communication from the CPO with Third Parties and thus external options for charge control. Additional guidelines with regards to metering equipment apply to public charging points.

## 6.4.1 Standards Public Charge Point

Standards that a public charging point must meet for Smart Charging (in addition to the basic standards from Module 2: Smart Charging Basics - Charging point).

ID	Requirement	Explanation
3B-1	The charging point complies with the Connection Requirements for charging objects with an integrated grid connection.	Contains requirements from Dutch network operators on how a connection to the electricity network must be realized in a charging station.
3B-2	The connection is used in accordance with the Grid Code Electricity.	Decision of the Netherlands Authority for Consumers and Markets of April 21, 2016, reference ACM / DE / 2016/202151, establishing the conditions as referred to in Article 31 of the Electricity Act 1998 (Grid Code Electricity).





## 6.4.2 Smart charging public charge point

ID	Requirement	Explanation
3B-3	When Smart Charging is active, regardless of the Smart Charging profile, charging is always started for a short period (for example, 30 seconds). Then any charging profile is executed.	So that the user knows that his vehicle is properly connected.
3B-4	All charging points, regardless of power, must be remotely controlled, whereby the power can be adjusted in time (read charging speed) "near real-time" (NRT; within 1 minute), within the capabilities of the communication link.	To enable Smart Charging.
3B-5	With single phase charging, the power is limited to 3.7 kW (16A)	Necessary to avoid phase imbalance.

## 6.4.3 CPO communication protocols

These are communication protocols that a CPO uses to approach Third Parties. These protocols apply to the backend in which (groups of) charge points are managed.

ID	Requirement	Explanation
3B-6	To enable data sharing with other market parties and - roles or delegate smart charging to a third party, the Open Charge Point Interface (OCPI) v2.2.1 is used.	Control System – Third Party System communication  Open Charge Point Interface (OCPI) - Supports connections between Mobility Service Providers who have EV drivers as customers, and Charge Point Operators who manage charge stations.
3B-7	To enable Smart Charging based on actual grid load, IEC 62746-10:2018 (OpenADR) OR the Open Smart Charging Protocol (OSCP) is used.	No choice has yet been made regarding the protocol standard for this purpose. Support of one of these protocols is done in consultation with the client and is only applicable when Smart Charging use cases in which charge control takes place on the basis of DSO signals are used.
3B-8	No artificial delay can take place when exchanges meter value updates to other market parties	To make sure that the SCSP can adapt the charging schedule fast enough to changes in the environment on behalf of the customer.

## 6.4.4 Measuring device Public Charge Point

Requirements for the metering device of the charge point. Note: This concerns the meters on the sockets. Guideline 3B-1 describes the requirements for connection to the electricity grid, where another dedicated meter is used. The meter from the Connection Specifications prescribed in Guideline 3B-1 is always a Smart (DSMR) Meter, owned by the grid operator.

ID	Requirement	Explanation
3B-8	Any charging point that is measured uses an accountable MID meter.	Measuring instrument directive; this meter may then be used for billing.
3B-9	The technology and protocols implemented in the charge point and backend are suitable to provide the driver with insight into the charged kWh and the price for it at any time.	Technology should not be an obstacle to this. Specific details of how the user gains this insight is up to the CPO and eMSP.





# 6.5 Smart charging - Bidirectional Charging - EV

### Applicable for: electric vehicles supporting Bidirectional Charging/V2X

This module is mandatory for vehicles that support bidirectional charging / V2X. To make V2X possible, both the vehicle and the charging station must support this technology. This Module concerns the requirements for the EV. Since the technology (AC or DC) is not determined, some requirements also apply to the charging point. These are therefore included in Module 5.

# 6.5.1 V2X Standards and protocols

Standards and Protocols that an EV must meet when bidirectional charging is supported.

ID	Requirement	Explanation
4-1	EN 50549-1:2019 Requirements for generating plants to be connected in parallel with distribution networks Part 1: Connection to a LV distribution network Generating plants up to and including Type B	Standard for distribution units
4-2	VDE-AR-N 4105 Power Generating Plants in the Low Voltage Grid	Standard for distribution units applicable in Germany
4-3	The Grid Code Electricity (October 2020) and the Requirements for Generators (RfG) incorporated therein	Particularly Chapter 3 applies to distribution units.
4-4	The protocols used for V2X is ISO 15118-20 for both DC V2G as well as AC V2G .	As Chademo is not used anymore for new EVs

### 6.5.2 Functional requirements V2X Vehicle

ID	Requirements	Explanation
4-5	The vehicle must be capable of bidirectional charging using AC and / or DC technology; In the case of AC:  • Minimum with 1.4 kW (AC 1x6A)  • Maximum 22 kW (AC 3x32A).  • With single phase feed-in, the power is limited to 3.7 kW (16A). In the case of DC:  • At least 5kW; maximum 20kW	As whether or not the vehicle supports V2X is beyond the control of the charging station manufacturer, this is an optional module. Even if it is decided to prepare the infrastructure for V2X, non-bidirectional vehicles must be able to use the infrastructure.
4-6	It must be possible to start bidirectional charging from 100% SOC, even if this 100% SOC has been applicable for a longer period of time.	So that V2X is possible if the battery has been fully charged for a longer period of time. See further information, see also ID 1-10 under chapter 3.4



# 6.6 Bidirectional Charging - Charge Point

**Applicable for:** private, semi-public and public charge points that support V2X/Bidirectional Charging. This module is mandatory for charging points that support bidirectional charging / V2X. To make V2X possible, both the vehicle and the charging station must support this technology. This Module concerns the requirements for the charge point. Since the technology (AC or DC) is not determined, some requirements also apply to the EV. These are therefore included in Module 4.

### 6.6.1 V2X Standards and protocols

Standards that a charging point must meet when bidirectional charging is supported.

ID	Requirements	Description
5-1	NEN-EN 50549-1:2019 Requirements for generating plants to be connected in parallel with distribution networks Part 1: Connection to a LV distribution network Generating plants up to and including Type B	Standard for distribution units
5-2	VDE-AR-N 4105 Power Generating Plants in the Low Voltage Grid	Standard for distribution units
5-3	The Grid Code Electricity (October 2020) and the Requirements for Generators (RfG) incorporated therein	Particularly Chapter 3 applies to distribution units.
5-4	The protocols used for V2X are:  CHAdeMO ISO 15118-20 (draft, expected in 2021) In case of DC V2G, the charge point supports at least one of these protocols. In case of AC V2G, the charge point supports at least ISO 15118-20.	Depending on the choice of AC or DC V2G; CHAdeMO can only be used for DC V2G. Support of CHAdeMO depends on the expected types / brands of vehicles at the bidirectional charge point.
5-5	OCPP v2.1 as Charging Station – CSMS communication protocol	As the upcoming OCPP 2.1 is in its final stages and therefore expected to be officially released in the later in 2023. For detailed explanation on the additional functionalities that OCPP 2.1 promises to deliver, see paragraph 2.2.1.3

### 6.6.2 Physical requirements V2X charge point

Requirements for the appearance of bidirectional charge points.

ID	Requirement	Explanation
5-6	At/on charge point it is clearly visible that the charge point is suitable for bidirectional charging	So that the e-driver knows whether bidirectional is possible at the charge point.
5-7	The status indicator of the charge point provides an indication when the vehicle (via the charge point) supplies energy to the grid. This indication can be clearly distinguished from the regular indicators	So that the chare points' status is visible

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# 6.6.3 Functional requirements V2X charge point

Requirements for the operation of bidirectional charge points.

ID	Requirement	Explanation
5-8	The system is suitable for both loading and return delivery. The current status must be visible in the backend.	Both charging and discharging should be possible
5-9	It must be possible to both charge and supply within the same transaction	So that the transaction remains active when charging is complete, and the user can get the supplied energy billed/rewarded
5-10	The supplied and returned energy is registered on separate counters/registers of the MID meter. Both registered must be readable in the backend.	The charged energy may have a different rate/price than the energy supplied from the vehicle.
5-11	The system is equipped with a mechanism that automatically disconnects the charge point from the grid in case of power failure (anti-islanding). It is allowed to use the relay for this disconnection.	For safety during work during a power failure.





# 7 Conclusions

Already with the use of existing dominant protocols versions some level of smart charging can be performed. But to truly unlock the potential benefits from smart and bidirectional charging for both the consumer as well as the wider electricity system requires new capabilities and functionalities from the communication infrastructure.

Through desktop research on the functionalities of the different protocols and their respective version, we conclude that the latest or soon to be released protocol versions of OCPP & OCPI allow for most desired outcomes to be achieved by a V2X ecosystem.

Nevertheless, it relies heavily on information availability from the EV to fulfil on the user-centricity guiding principles. With regards to EV - Charging station communication, the current dominant protocol for both AC as well as DC charging is IEC 61851. This protocol is not considered future proof due to several reasons such as it lack of support for bidirectional charging, absence of high level communications means with the EVSE.

In general, we can conclude that if ISO 15118-20 combined with the upcoming OCPP 2.1 and OCPI protocol versions would be supported by the different actors in the e-mobility ecosystem, many of the desired outcomes of chapter 1 could already be achieved. Different tasks of Work Package 2 will build further upon the software requirements and recommendations provided by this report in chapter 3.

Unfortunately, we also need to conclude that market adoption of the latest protocol versions tends to go very slow. This leads to a market which is lagging behind on unlocking the smart & bidirectional charging capabilities that would otherwise be possible if the market be adopting new protocol versions much sooner.

Governments, (inter)national and local, could play a key role in consumer adoption of V2X technologies and related services by pushing for faster protocol adoption through public tendering requirements and point-of-purchase subsidies. For this audience, chapter 6 provides a list of requirements to be used for public tendering of point of purchase subsidies or tax credits for the e-mobility infrastructure that it covers. This way governments can be ensured that this smart and bidirectional charging hardware and software infrastructure will be able to deliver the desired smart and bidirectional charging system outcomes based on what is possible with the latest available communication protocols and hardware standards.

By including the requirement for minimum lead times for implementation of newer protocol versions, governments would be able to play a key role in speeding up the adoption of newer protocol versions, bringing us closer to a user-friendly, cyber-secure smart and bidirectional charging physical and digital ecosystem that can operate within the limits of the distribution grid while paving the way for faster adoption and higher penetration rates of renewable energy.



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