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Smart Charging: Status, Drivers & Obstacles to integrate EVs into the electricity grid in the EU

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Executive Summary

With the introduction of bi-directional charging for electric vehicles (EVs), new technical, but especially economic potentials arise. The term “Smart Charging” defines different ways and options of controlled EV charging to avoid peak loads on the local distribution grid, optimize costs, optimize carbon footprint of EV charging or generate additional revenues by trading the bundled EV battery capacity on the electricity market. To enable these options, certain technical conditions and a corresponding market environment need to be established. P3 will provide an overview of the current status, potential drivers and drawbacks as well as future potentials of the technology and underlying business models for the European market.

Smart Charging, V2G (Vehicle2Grid), V2H (Vehicle2Home), Load Management, Intelligent

1 Definition & Use Cases of Smart Charging

Smart Charging comprises different forms of managed and optimized EV charging, in order to save costs for grid expansion and demand charges, or to optimize the electricity bill.

1.1 Evolution of Smart Charging in Three Phases

Smart Charging as shown in this report can be clustered in three major evolution phases [1]:

All forms of “Controlled Charging” are offering potential to statically or dynamically manage and control energy flow to charge the EV to optimize loads and avoid both peak demands and high electricity costs. Technology and services to offer Controlled Charging services are available today and business models are evolving fast in line with growing EV stock in the markets, which requires cost-optimized deployment of charging infrastructure.

With “Bidirectional Charging” (behind the meter), the EV can feed electricity back within the microgrid application to the house, the factory or other EVs to optimise overall consumption schemes within the local system (behind-the-meter). These Bidirectional Charging scenarios are designed to buffer high peak demands or at high energy price periods to optimise the overall electricity costs. The EV battery in these scenarios acts as an (additional) storage, which can also be used to optimize self-consumption from the PV and to storage local renewable energy production for later consumption.

The third evolution phase of Smart Charging “Vehicle Grid Integration” is enabling the exchange of power with the grid. Most of the services require specific smart meter devices. There are unidirectional service potentials such as grid-controlled load management, when local distribution grid operators can access and control charging devices to reduce stress on the grid, or participation in Reserve Control markets with EV battery capacities.

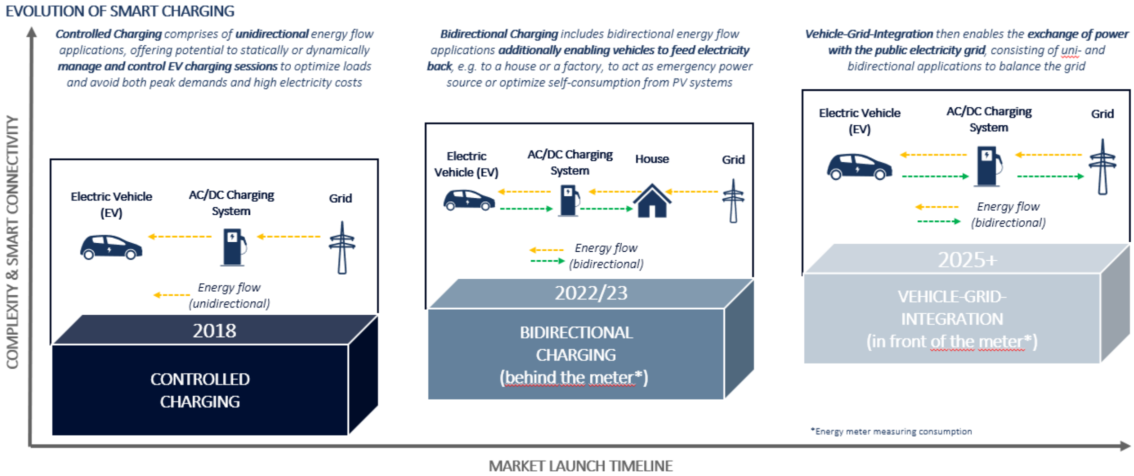

Figure 1: Evolution of Smart Charging based on P3 Definition

More advanced services are centered around Vehicle-to-Grid (V2G) services, where power from EV batteries is fed back into the energy grid (in-front-of-the-meter) to balance the grid. To reach a significant effect and be able to trade the capacities on the energy market, several EV batteries need to be pooled (min. ~1 MW).

For each of the evolutionary steps, different applications and potential business models are applicable.

In the area of “Controlled Charging” this includes local optimization scenarios such as PV-ptimized charging or local load management, as well as the simple cost optimization in relation to the current electricity prices. Price-optimized charging only can be applied in markets with dynamic energy tariffs and sufficient penetration of smart meter gateways to channel actual price information.

For “Bidirectional Charging” several Vehicle-to-Load applications, also in case of emergencies or blackouts (Emergency power) can be realized.

With “Vehicle Grid Integration”, the grid-controlled management of the charging session can support the stabilization of the grid and at the same time make additional revenue pools accessible for EV owners. With the integration of the EVs into the arbitrage business, the loads are feedback into the grid.

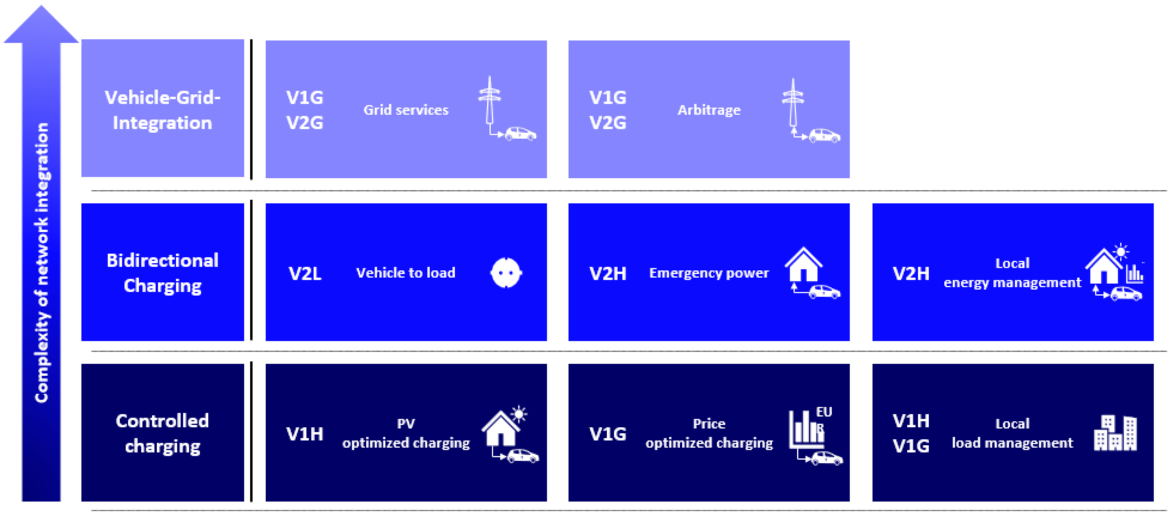

Figure 2: Potential application in Smart Charging

1.2 Ecosystem Overview & Smart Charging Scope

With the ongoing transition towards renewable enegies, EV charging becomes a significant element of a holistic smart energy ecosystem, which needs to deal with fluctuation of renewable energy supply, decentralized production and increasing balancing between supply and demand. [2]

The application of "Controlled Charging" and partly "Bi-directional Charging", esp. for Vehicle-to-Home applications are focused on the local optimization behind the meter and require a very close interaction of EV charging with other consumers, such as local battery storage, PV system, heat pumps or other domestic consumers. The successful integration of EV charging into this ecosystem also is dependent on the availability and technical fit with a home energy management system (HEMS), which is monitoring and balancing the demand and supply behind-the-meter with the goal to optimize the loads and operate this local system as energy self-sufficient as possible or optimize the costs.

When it comes to the integration and interaction of EV charging with the electricity grid, the application also relate to in-front-of-the-meter elements, especially the electricity grid, but also – virtually – the electricity and balancing market. This then also provides an additional level of complexity, especially from grid operator perspective, as numerous local consumers need to be monitored and managed continuously.

Based on the very high interdependencies between EV charging and multiple other smart energy elements, the success of the implementation of the described services is very depending on the successful integration of all system elements and requires open/available technical interfaces, which enable the communication and interaction between these elements (for details see Chapter 2 – Technology Requirements). [3]

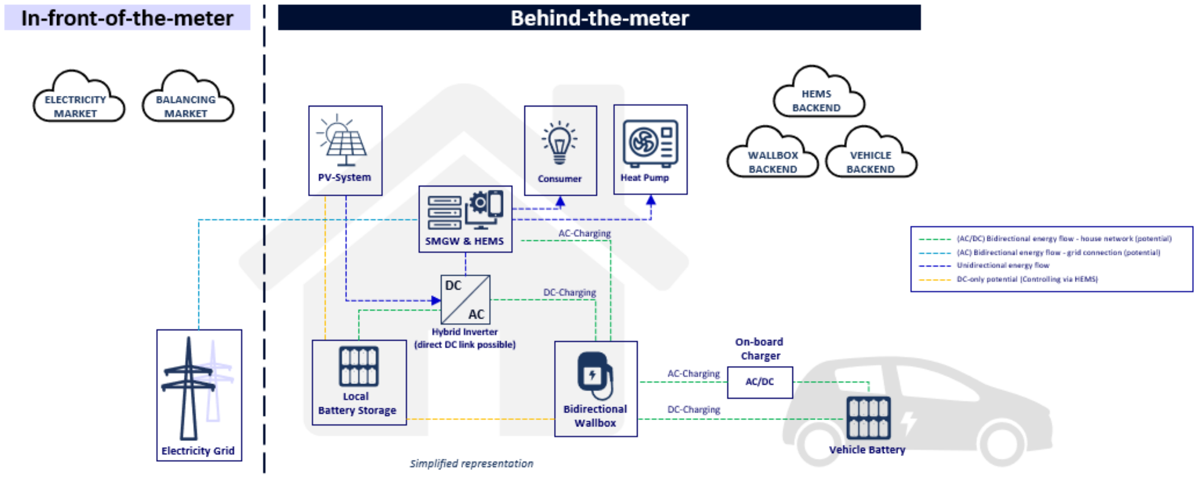

Figure 3: Smart Energy Ecosystem Behind- and In-front-of-the-meter

1.3 Baseline EV growth in EU until 2035

With the ongoing market penetration of EVs in Europe, the potential to implement smart charging scenario will grow further. In 2022, the market share of EV new registrations in the passenger car segment for EU was at 23% (9% BEV). European key markets, such as Germany had an EV registration share of 31% (18% BEV). This highlights, that the relevance of smart charging will also increase further.

Very ambitious zero-emission targets from industry players, require twofold forecast on the market: 1) based on CO2 compliance standard from EU (trend scenario) 2) based on industry announcements (progressive scenario).

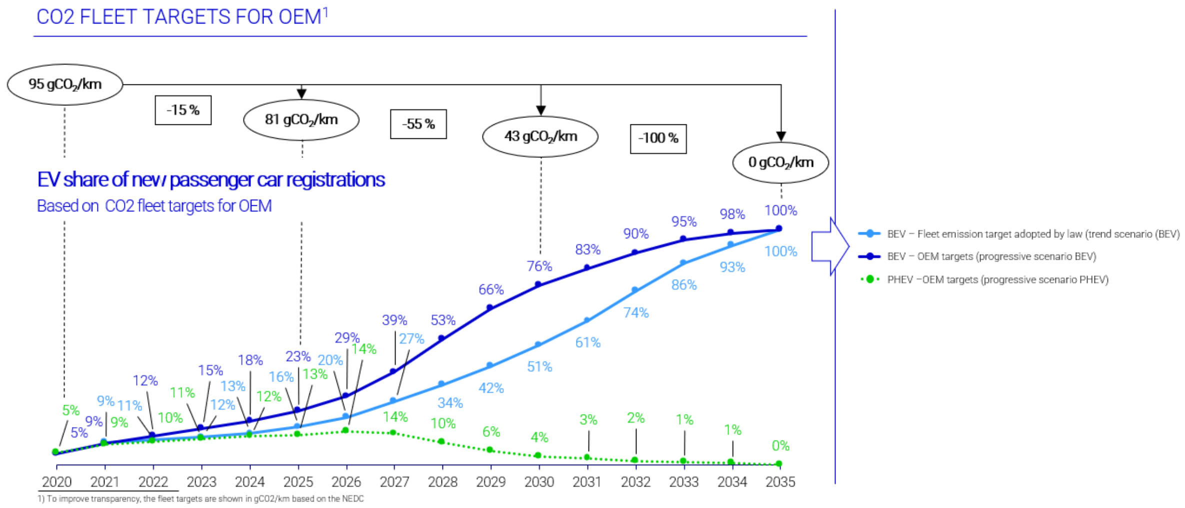

Figure 4: EV Ramp-Up in EU until 2035 based on P3 Market Model (2023)

EU policy requires -15% emissions in 2025 (compared to 95g CO2/km). As proposed EU legislation, a further reduction of fleet emissions of -55% by 2030 (trend scenario) – the European Parliament has already agreed to stricter requirements (previously it was a reduction of -37.5%). [4]

This requires electrification rates across all automotive manufacturers of approx. 51% for BEV and 8% for PHEV (trend scenario) in 2030 and also aims towards the planned EU initiative that all newly registered passenger cars must be emission-free from 2035 onwards. [5]

Most automotive manufacturers have already announced even more ambitious targets (e.g., 70% EV share from VW, 100% BEV share from Ford, Daimler, Stellantis, Volvo and Renault by 2030) – if these targets are reached, the EV share in new registrations will already reach ~80% in 2030. [6]

Based on this industry-target-oriented scenario (announcements from automotive industry on their zero-emission roadmap), the ramp-up of electric vehicles runs ahead the regulatory requirements with new registrations reaching 5.7 million in 2025 and 13.2 million in 2030. The target of 100% electric new registrations by 2035 remains, thus there are 17.3 million new registrations in 2035 to be expected. The stock of EVs in the market is accordingly increasing to 72 million passenger cars by 2030 and 152 million by 2035 – this represents a market share of 27% (2030) and more than half (58%) by 2035. Regarding the EV stock, the progressive scenario leads to 58% EVs in the market by 2035 – which means that more than every 2nd passenger car has an electric drivetrain by then. In absolute figures, the stock will grow to 152m EVs.

2 Technology Requirements & Status of Standardization

As of today, not all smart charging applications, esp. regarding Bidirectional Charging or Vehicle-Grid-Integration, are not yet available on a large scale, but rather are tested in selected pilot projects.

The successful implementation of Smart Charging applications in the mass-market, does not only require an open and flexible collaboration of multiple stakeholders involved along the Smart Charging Ecosystem, but also the (further) development and definition of technical standards that enable different competitors to participate in the market.

2.1 Stakeholder Overview

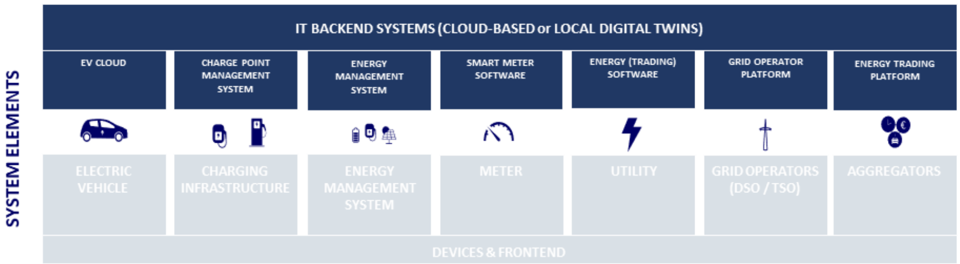

Figure 5: Ecosystem & Stakeholders in Smart Charging

The successful implementation of viable business models with Smart Charging requires the involvement and active empowerment of substantially different stakeholders from different "domains" across the whole value chain. For example, Smart Charging requires constant access to vehicle data ("State of charge") which is within the "domain" of the automotive manufacturers ("OEMs") and requires authorization and open technical "interfaces".

The challenge is, that most of those stakeholders along the smart charging value chain have their own strategy and (often clashing) economic interest in mastering the "value add" from those services. So, there is for example a "natural" conflict of interests between the OEMs and the charging point operators (CPOs), to keep control of the customer and keep the "ownership" of all involved data, as those will be a future potential additional value creator. And that is even more true if the grid / energy providers come into the game.

Another challenge for companies might be the pure total number of acting stakeholders. For example, in countries like Germany, the DSO landscape is extremely scattered and local (mostly “municipal utilities”, >800). VGI players need to build individual cross stakeholder “win-win” business models, but probably some native stakeholders (e.g., DSOs) will build protectable “local-only” Smart Charging services. We also see a higher probability, that some cross regional players (e. g. utilities, OEMs) might consolidate the Smart Charging market with highly vertical integrated market approaches. [7]

2.2 Technical Enablers & Status of Standardization

Two major building blocks enable the implementation of Smart Charging services up to Vehicle-Grid Integration. The first mandatory precondition is the provision of Connected Charging infrastructure and the availability of standardised data interfaces to exchange information and manage the charging sessions. Next to that, all involved hardware elements need to be enabled for bidirectional usage, especially the EV itself, the charging device, and the grid connection with the specific meter.

One of many possible solutions to the described complexity is the development and broad implementation of open standards. Standards like ISO 15118-20, OpenADR (IEC 62746-10-1) are under development and several players work on a bilateral implementation of the relevant interfaces and protocols. However, the current set of standards, highly individual implementation efforts and required cooperation prevent the fast large-scale roll-out of Smart Charging and grid-related services. In addition, regulators/governments need to take action by supporting the implementation of open standards / interfaces but also with specific de-regulating legislation, to “free-up” more flexible value creating business models (e.g., flexible cross-system electricity tariffs w/o tax burdens).

Based on expert interviews with relevant stakeholders and market evaluations, P3 developed a data model to provide an overview of available and applied protocols and data interfaces as a baseline for services related to Controlled Charging, Bidirectional Charging and Vehicle-Grid-Integration. This model illustrates on the one hand that there is a great variety of different interfaces and protocols in the market. Based on the evaluation, several protocols show a high market relevance and are applied by different players, which prevents the market from a standardised mass-market launch of these future services. [8]

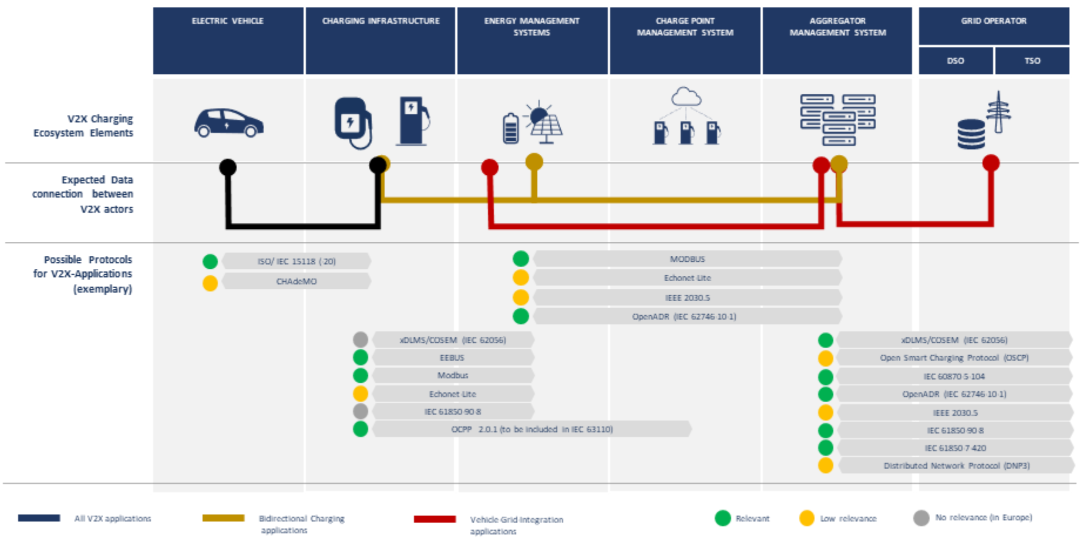

Figure 6: Status of Standards and Interfaces to realize Smart Charging

There is a clear trend towards a more standardized market approach. The key enablers for this are selected protocols, which will become more and more disseminated in the market:

Table 1: Status of Standardization for Smart Charging

Protocols	Purpose	Status
Type 2 & CCS – Combo 2	Plug types are being widely used and defined as the main standard in the EU market for AC (Type 2) and DC (CCS – Combo 2) charging. Other than the Japanese fast-charging standard, the European plug types were not designed for bidirectional charging from the very beginning, although, the standardisation is ongoing with ISO 15118-20. First proprietary implementations from selected players, oriented on the future standard or on current ISO 15118-2, which requires high implementation efforts, are available.	Bidirectional Charging currently only via ISO 15118-2 with high implementation efforts. New ISO 15118-20 under development, to be published 2022/23. [9]
ISO 15118(-20)	Enable smart communication between EV and charging station to transmit status information and enable controlled charging. Basic versions of ISO 15118 are already available and high importance is already recognised by automotive and charging device manufacturers. However, ISO 15118-20, which enables bidirectional charging, is still under development and forms crucial enabler for Bidirectional Charging and Vehicle-Grid-Integration.	Under development, to be published 2022/23. [10]
OCPP / IEC 63110	De-facto standard Open Charge Point Protocol is constantly further developed to include additional features and manage the data exchange between charging devices and the software systems. With version OCPP 2.0.1, which is expected to be available from 2022 on, bidirectional charging is supported. The increasing importance of OCPP based on additional features, which become available, including the connection with energy management systems may become a feasible alternative for Modbus, which requires highly individualised onboarding processes.	Under development, to be published 2022/23. [11]

3 Economic Potential

For the assessment of the market size for Smart Charging, only revenue potential has been considered from a private setting (single homes and multi-unit dwellings) and from workplace charging. Those revenue streams are from one-off sales (incl. hardware for home energy management and bidirectional charging), recurring revenues (incl. subscription fees for energy management, bidirectional charging services or compensations), and trading (for vehicle-grid-integration). Additional value could also be generated from cost savings resulting from smart charging applications but are not considered in this market valuation.

The key drivers of the market volume are:

- the increasing stock of both unidirectional and bidirectional charge points (derived as demand of the growing number of electric vehicles)
- the take rate of charging services

The European market for Smart Charging as defined above has a value of EUR 29mn in 2021 which is almost solely based on revenues from Controlled Charging. The market will increase to up to more than EUR 914mn in 2025, with a significant increase of the revenues from Controlled Charging as well as with the emergence of Bidirectional Charging and Vehicle-Grid-Integration on the market. In 2025 already, Bidirectional Charging will be responsible for the largest share of revenue potential. The market will further almost triple until 2030 to a total value of EUR 5bn with growth across all segments, however Bidirectional Charging will remain the major driver with a share of more than 46%.

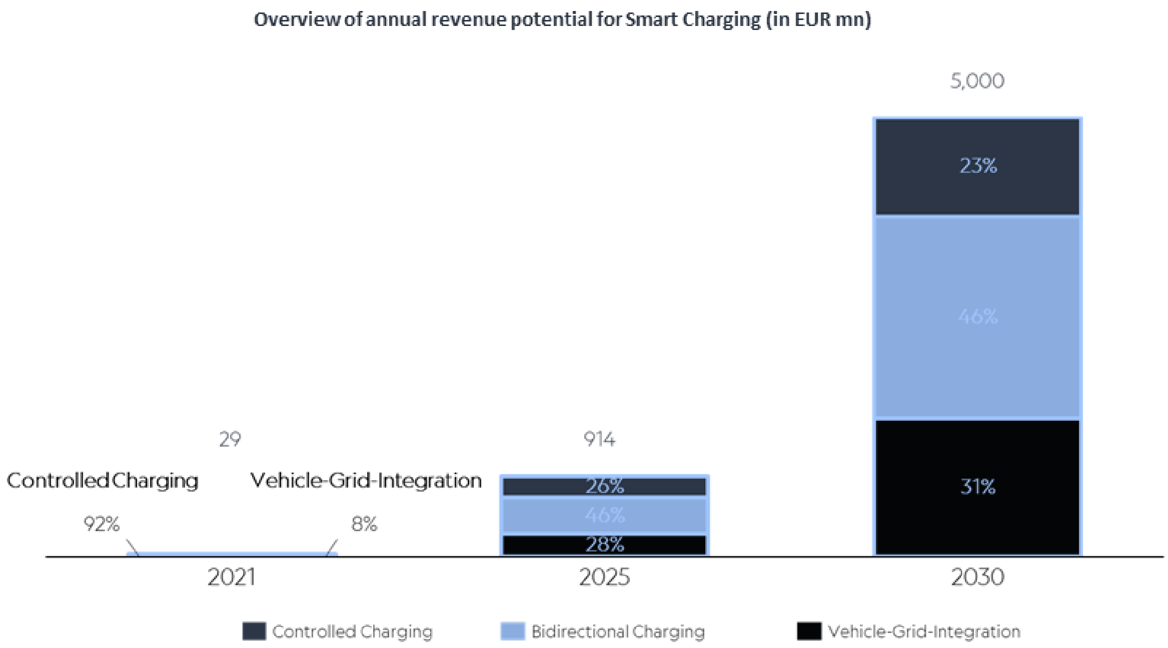

Figure 7: Economic Potentials from Smart Charging in the EU based on P3 Analysis

Revenues for Controlled Charging will increase almost tenfold from EUR 26mn in 2021 to EUR 240mn in 2025, and even fortyfold until 2030 to a total value of more than EUR 1.13bn. In 2021, the most valuable use case is Local Load Management with a share of more than 65% of revenues related to Controlled Charging. While all use cases will show significant growth over time, Optimised Charging has the highest increase and will transform from the smallest (17% in 2021) to the largest use case (49% in 2030) in terms of revenue potential, making up for almost half of 2030's revenues.

The largest market segment of Smart Charging services is Bidirectional Charging, though it is not suitable for the mass market yet. It will make up for 46% of the Smart Charging market both in 2025 and in 2030, though its revenue potential will increase from about EUR 418mn in 2025 to about EUR 2.3bn in 2030.

Applications for Vehicle-Grid-Integration are expected to be ready for mass-market by 2025 onwards and are by far the smallest segment in terms of revenue potential until 2030. The segment is valued at more than EUR 257mn in 2025, which is mostly based on revenues from Reserve Control (~79%). With a major increase to an annual revenue potential of EUR 1.58bn in 2030, the share of revenues related to Reserve Control drops to only 41% as the Vehicle-to-Grid application, as well as Grid-Controlled Load Management, become more and more important.

In 2025, the trading value for a charge point both at home or at work is estimated at EUR 270 with energy trading potentials from reserve control and Vehicle-to-Grid, with the majority of the value coming especially from Vehicle-to-Grid. Despite increasing revenue potentials in each segment, higher participation rates will lead to a moderate decline of the trading value per charge point over time as more and more charging points will be available to be used as operating reserve.

A high share of the revenue potential until 2030 is hardware-driven, such as the sale of bidirectional wallboxes which will enter the market, and which will be quite expensive in the upcoming years. However, several developments will cause the Smart Charging market to change after 2030. The price per unit of bidirectional hardware will become cheaper, while flexibilities in the energy market become bigger, and energy services will generally carry more weight in terms of revenue potential. [12]

4 Conclusion & Outlook

Relaization and offer of Smart Charging applications will become a necessity short-term to contribute to the overall energy transition and make EV charging an integral component of this new system.

Different stakeholders along the Smart Charging ecosystem need to shape their product portfolio accordingly, prepare suitable collaborations with other players and open their communication interfaces to ensure a good and future-proof customer experience. With the expected progress in standardization and unified interfaces, the market entry barriers to participate in the market will become lower, which then will bring additional momentum to the market and will lead to a rapid growth.

From a customer and demand perspective, the application of Smart Charging and integration into a wider smart energy ecosystem is already there and further fueled by the ongoing energy crisis. In the first step, optimization, cost-saving and efficiency measures will play a major role, but the expected availability of additional revenue streams, which can be addressed with Smart Charging applications can be addressed from 2025 onwards.

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Presenter Biography

As Managing Partner, Johanna Heckmann is responsible for all EV charging-related topics at P3 in the business unit of e-mobility.

Since Johanna joined P3 in 2015 she gained extensive experience along the entire value chain of EV charging – from standardization and product development up to the development of market entry and partnering strategies in EV charging. Her current focus is on strategic technology consulting in EV charging for clients from automotive, energy industry and financial economy.

Before joining P3 she started to work in the area of e-mobility in 2012 as member of the project management center for the funding project „Schaufenster Elektromobilität" in the state of Baden-Württemberg on behalf of e-mobil BW.

Johanna holds a Master's degree from the University for Applied Sciences in Konstanz in Business Management.

Lukas Schriewer leads the Charging Technology & Network Operations team at P3 Group. For more than 8 years he has gained in-depth expertise in the areas of product development for charging hardware and software solutions, interoperability testing of charging infrastructure (EV – EVSE – Backend) and operational excellence for network operators. During this period he worked with automotive OEMs, HW manufacturers, CPOs, MSPs and utility companies. His daily work also focuses on the design of technology roadmaps, the development of smart maintenance models and the strategic supplier evaluation for charging infrastructure products and services. Before joining P3, he has studied industrial engineering at RWTH Aachen University (Germany) and Polytechnic University of Turin (Italy).

Falko Bartnik works as Senior Consultant E-Mobility for P3, specializing in the field of charging infrastructure for electrc vehicles.

He accompanies market analysis and strategy consulting projects with automotive manufacturers, energy suppliers and charging hardware manufacturers.

Before joining P3, Falko attained his Master's degree in International Management at the University of Applied Sciences Bochum.