EXPERTENKREIS TRANSFORMATION DER AUTOMOBILWIRTSCHAFT

31 October 2024

STANDARDISATION ROADMAP ON BIDIRECTIONAL CHARGING

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1 Executive Summary

Bidirectional charging is the ability of an electric vehicle to feed energy back with a time delay, in addition to the already established function of absorbing energy. As a result, the electric vehicle does not only act as a consumer but is also able to make temporarily stored energy available for different applications as required.

The term bidirectional charging covers a variety of different applications, which require different levels of maturity within the complex, overarching technical system. In addition to regulatory requirements, the further development of norms and standards is necessary for a widespread introduction of bidirectional systems to enable interoperable, manufacturer-independent and safe applications. This standardisation roadmap provides an overview of the current standardisation landscape.

Internationally oriented standardisation work is a central element for the German automotive and electrical engineering industry. It is of strategic importance for accessing global markets. The international standardisation process is perceived as lengthy which arises from the need for consensus-building as a basic prerequisite for broad acceptance of standardisation. The development and codification of national interim solutions seemingly lead to faster results but hinders or even prevents international consensus-building. This may result in proprietary solutions, which harm the export-orientated nation of Germany in the long run. Moreover, the capacities of national experts would be diverted, leaving no resources available for international standardisation processes. As the complexity of the use cases increases, their market launch will require even more time, given that necessary, internationally harmonized system standards for both charging stations and vehicles will not be available until 2027/2028 at the earliest. These standards are essential prerequisites, even for local optimisation.

Interoperable, market-serving and grid-friendly optimisation largely depends on the progress in the development of standards related to energy market and grid integration. The time frame of the standards relevant to electromobility is covered in the following standardisation roadmap. Reference is made to the standardisation roadmap "E-Energy/Smart Grids 2.0" regarding the development of the general standards for the further development of energy supply grids[1]. Electrical safety plays an important role in the context of bidirectional charging. Previous installations are typically not designed for recovery, and accidents could quickly lead to a loss of public acceptance in addition to risks to life and health. The necessary safety concepts are addressed in standardisation and are continuously being developed.

[1] https://www.dke.de/de/arbeitsfelder/energy/deutsche-normungsroadmap-e-energy-smart-grids-2-0

2 Objective / Introductory Chapter

Market-ready systems in the field of electromobility necessitate normative foundations to guarantee recognised electrical safety and interoperability. Due to the international market of manufacturers of charging devices and vehicles, it is particularly important that standardisation takes place at international level. Interim national solutions should be avoided to ensure that international standards remain feasible and can be implemented without complication.

This document aims to provide an overview of the standardisation landscape for bidirectional charging. It introduces existing and ongoing standards, along with their respective timelines. Additionally, gaps are identified and recommendations for action are given. This document only considers conductive applications for bidirectional charging based on the Combined Charging System (CCS). In the future, other types of charging (inductive charging, ERS, MCS) may also be pursued, although no activities have been launched in these areas as of yet.

This document primarily focuses on electromobility-specific standards in within the customer's system and not on the upstream energy supply network. Therefore, the IEC 61850 standard on communication networks and systems for power utility automation, which is relevant for energy supply networks, is not discussed in detail.

3 Definition of technical Use-Cases

3.1 Introduction

The concept of bidirectional charging and its subcategories Vehicle2Home, Vehicle2Building and Vehicle2Grid are not clearly defined. To address this ambiguity, use cases have been developed to illustrate and distinguish the various possibilities of bidirectional charging for users. These use cases typically focus on the point of benefit or value for the users. However, a clear and consistent definition of these use cases across different publications is still not guaranteed.

This section therefore aims to group use cases based on similar normative requirements for components and interfaces. The advantage of this approach is that once the standards and norms for a particular group are established, the various use cases within that group can be applied without needing to assess each use case individually from a normative perspective. As a result, the time horizons developed in later sections of this document provide a clearer estimate of when specific use cases can be normatively mapped and when implementation is possible.

3.2 Overview of the use cases

To aggregate the use cases into groups, the use cases of the final report of the BDL project[2] were adopted. These were no longer sorted according to their revenue location, but according to their objectives. The use cases are briefly described below. For more detailed information on the individual use cases, please refer to

[2] http://ffe.de/wp-content/uploads/2023/03/BDL-Abschlussbericht.pdf

the aforementioned report. In addition, the use cases o*verload intervention by Distribution System Operators (DSO)* and *operation of individual equipment* have been added.

The use case ***operation of individual equipment*** is an exception, as it cannot be assigned to any group according to norms. In this case, the battery of the electric vehicle is used to operate individual equipment directly at the charging port of the electric vehicle (e.g. electric tools or emergency assistance for another electric vehicle). Feed-in into building installations is only permitted through a dedicated, permanently installed bidirectional charging device.

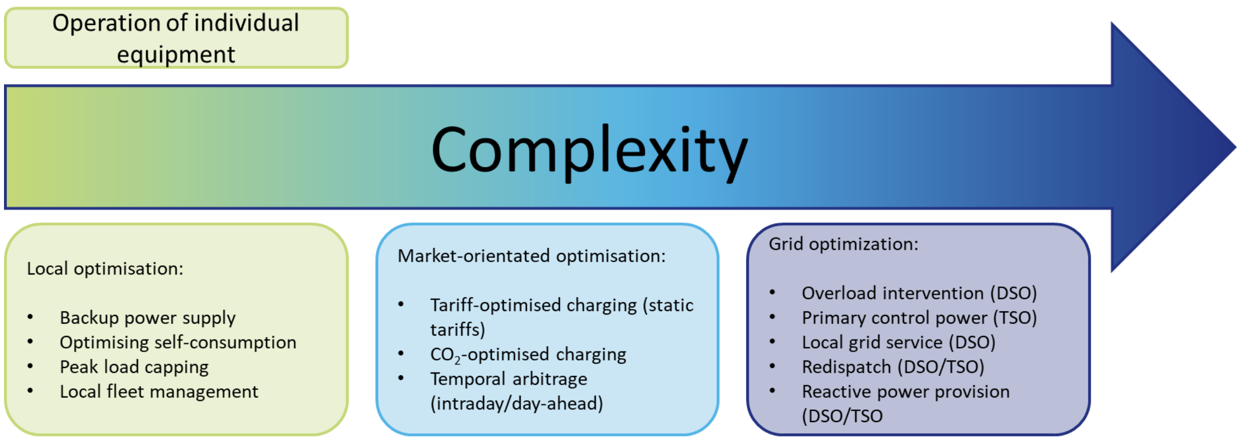


Figure 1: Use cases for bidirectional charging sorted by technical complexity

The first group of use cases as shown in Figure 1 can be summarised under the aspect of local optimisation. It is focussed on the most effective use of self-generated electricity via existing power generation plants (***optimising self-consumption***) or the reduction of peak load to a location, both to reduce costs (***peak load capping***) and to realize the most effective use of the power available at the grid connection point (***local fleet management***). Additionally, providing backup power through the vehicle battery falls under this category. For the implementation of these use cases, communication is limited to the installation up to the grid connection point.

The second group of use cases can be summarised under the objective of market-oriented optimisation. In this context, the controlled charging and discharging of electric vehicles is used to reduce overall costs (***tariff-optimised charging***), to generate profits by participating in the electricity market (***temporal arbitrage***) or to reduce the personal footprint (***CO_2-optimised charging***). This requires communication beyond the grid connection point, implying high levels of complexity compared to local optimisation.

The third group of use cases can be assigned to grid-oriented optimisation. In this group, the focus is on optimising the grid, which can often be financially compensated. Electric vehicles can be utilised to stabilise the grid frequency of the transmission system operator (***primary control power***), to reduce local (***local grid services***) or regional (***redispatch***) grid bottlenecks for the distribution system operator by providing flexibility, or to improve voltage quality through reactive power support (***reactive power provision***). Since various parameters beyond tariffs need to be communicated, the use cases mentioned here involve the highest complexity.

The use case ***overload intervention by the distribution system operator*** represents a special case, which was not described in the BDL project. Here, the distribution system operator intervenes in the feed-back processes in a grid segment to prevent the grid from being overloaded. Since it is an emergency intervention, it is not compensated and typically does not have a temporal component, which reduces its complexity compared to the other use cases in this group.

Furthermore, many use cases also require normative consideration of ***billing for transferred energy*** across organizations or units. Examples include the use of private cars for *peak load capping* at the workplace and the recovery of electricity charged at the workplace or, conversely, the charging of company cars in the private environment. This consideration is relevant for almost all use cases.

As previously described, the classification of the use cases in the V2X description is not always unambiguous from a technical perspective. Vehicle2Home (V2H) includes the use cases *operation of individual equipment, backup power supply*, *optimising self-consumption* and *tariff-optimised charging*. The abbreviation V2B is not clearly defined, as both the concepts Vehicle2Building and Vehicle2Business can be found in the literature. Here, V2B stands for Vehicle2Building and includes the use cases of *peak load capping*, *local fleet management*, but also *tariff-optimised charging*. All other use cases fall under Vehicle2Grid (V2G).

3.3 Overview of the actors in the context of bidirectional charging from a standardisation perspective

The following chart (Figure 2) provides an overview of the standards available or required for the components and interfaces. The current status, challenges, and the planned timeline will be examined in more detail in the Chapter 4. Due to the international focus of this standardisation roadmap, ISO and IEC standards will be considered first, followed by EN standards, and finally addressing national standards. National special cases resulting from regulatory requirements (e.g. smart meter gateway) are examined where relevant. Norms and standards for components are labelled with capital letters, whereas norms and standards for interfaces are described with numbers. The standardisation roadmap focusses on the area framed in blue, but also considers the outside intersections as far as possible.

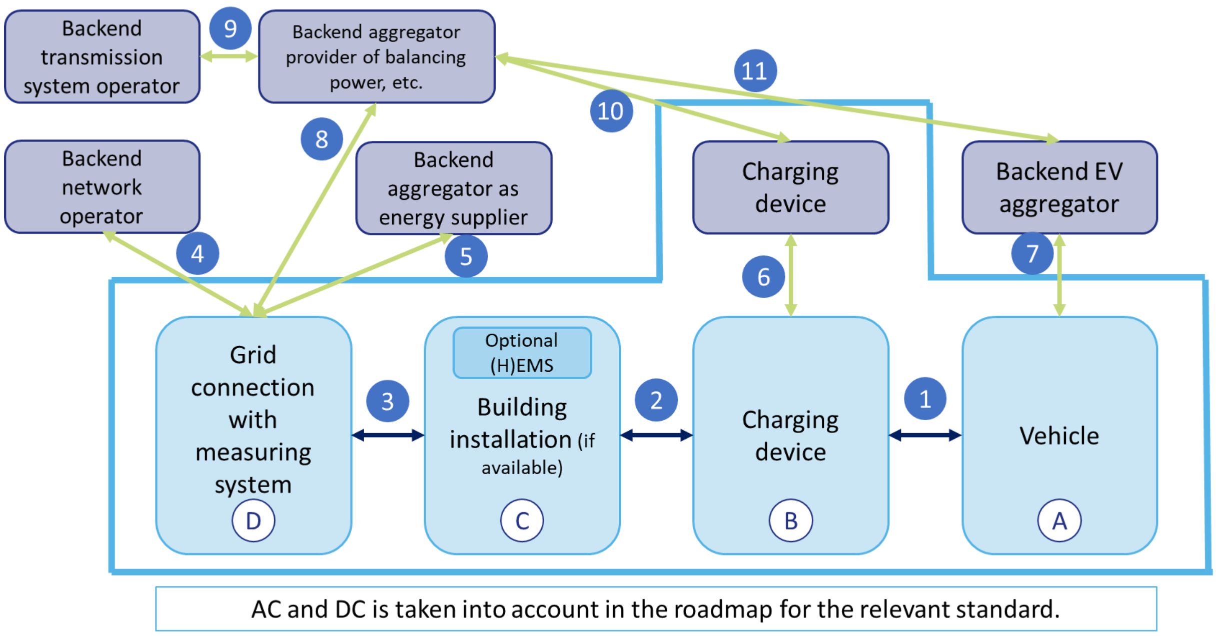


Figure 2: Overview of the actors of bidirectional charging from a standardisation perspective

The necessary components and interfaces are assigned to the use cases described above, see Figure 3 below. Here, the colour green means "mandatory" and blue "optional".

			Component				Interface										
			A	B	C	D	1	2	3	4	5	6	7	8	9	10	11
	1.	Operation of individual equipment (devices, other vehicles) without charging infrastructure	M	M													
Local optimisation	2.	Backup power supply	M	M	O	O	M	M									
	3.	Increase in own consumption	M	M	O	O	M	M									
	4.	Peak load capping	M	M	O	O	M	M				O	O				
	5.	Local fleet management	M	M	O	O	M	M				O	O				
Market-orientated optimisation	6.	Tariff-optimised charging (static tariffs)	M	M	M	M	M	M	M	M		O	O				
	7.	Time-based arbitrage (intraday/day-ahead)	M	M	M	M	M	M	M	M	M	O	O				
	8.	Time-based arbitrage (day-ahead)	M	M	M	M	M	M	M	M	M	O	O				
	9.	CO2-optimised charging "genuine green electricity"	M	M	M	M	M	M	M	M	M	O	O				
Grid optimization	10.	Intervention by the DSO in the event of overload	M	M	M	M	M	M	M	M							
	11.	Primary control power (TSO)	M	M			M	M	M			O	O	M *1	M *1	O *1/2	O *1/2
	12.	Local grid service (DSO)	M	M	M	M	M	M	M	M							
	13.	Redispatch (DSO/TSO)	M	M	M	M	M	M	M	M				M	M	O *1/2	O *1/2
	14.	Provision of reactive power (DSO/TSO)	M	M	M	M	M	M	M	M				O	O	O *1/2	O *1/2

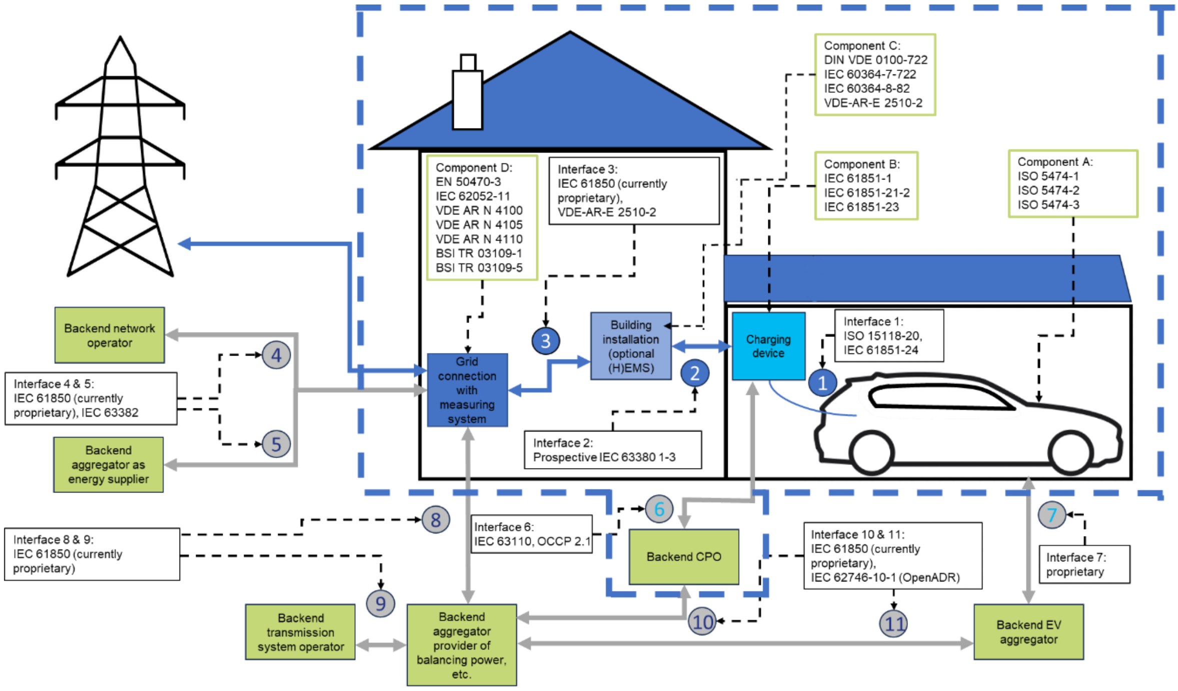
M = mandatory O = optional

*1 Not mandatory if the provision of this service is obligatory for the consumer facility

*2 Only permitted via SMGW in Germany

Figure 3: Necessary components and interfaces for the individual use cases

In this standardisation roadmap, the various communication interfaces for market-oriented integration into the energy system are not considered in detail. Currently, various proprietary systems are used. According to experts in the field of electromobility, the IEC 61850 standard series has the potential to operate all interfaces, however, the necessary data points for the integration of bidirectional charging systems have not yet been sufficiently defined.



Component A: ISO 5474-1 to 3, IEC 61851-21-1

Component B: IEC 61851-1, IEC 61851-21-2, IEC 61851-23

Component C: DIN VDE 0100-722, IEC 60364-7-722, IEC 60364-8-82, VDE-AR-E 2510-2

Component D: EN 50470-3, IEC 62052-11, VDE DE N 4100, VDE DE N 4105, VDE DE N 4110, BSI TR 03109-1, BSI TR 03109-5

Interface 1: ISO 15118-20, IEC 61851-24

Interface 2: IEC 63380-1 to 3

Interface 3: IEC 61850 (currently proprietary)*, VDE-AR-E 2829-6

Interface 4: IEC 61850 (currently proprietary)*

Interface 5: IEC 61850 (currently proprietary)*, IEC 63382

Interface 6: IEC 63110, OCCP 2.1,

Interface 7: Proprietary

Interface 8, 9: IEC 61850 (currently proprietary)*

Interface 10, 11: IEC 61850 (currently proprietary)*, IEC 62746-10-1 (OpenADR)

*not considered in detail in this paper

Figure 4: Overview of standards in the overall system

4 Topics

4.1 Introduction

This chapter provides an overview of standardisation and coordination activities as well as challenges from the standardisation perspective (both European and international) along with timelines. The difficulty in achieving international consensus makes specific statements regarding the publication deadlines of standards difficult, particularly if new revisions have not yet been decided upon. The ecosystem required for bidirectional charging in Germany and the related standards are shown below, both for DC recovery (CCS-Combo II interface) and for AC recovery (CCS type 2 interface).

Both representations exclusively consider the use case where an operator/connection user is assigned to only one subscriber. As regulatory issues arising from more complex operator/connection user and subscriber relationships have yet to be clarified, there may be a need for additional measuring points, e.g. at the regenerative point in the charging facility.

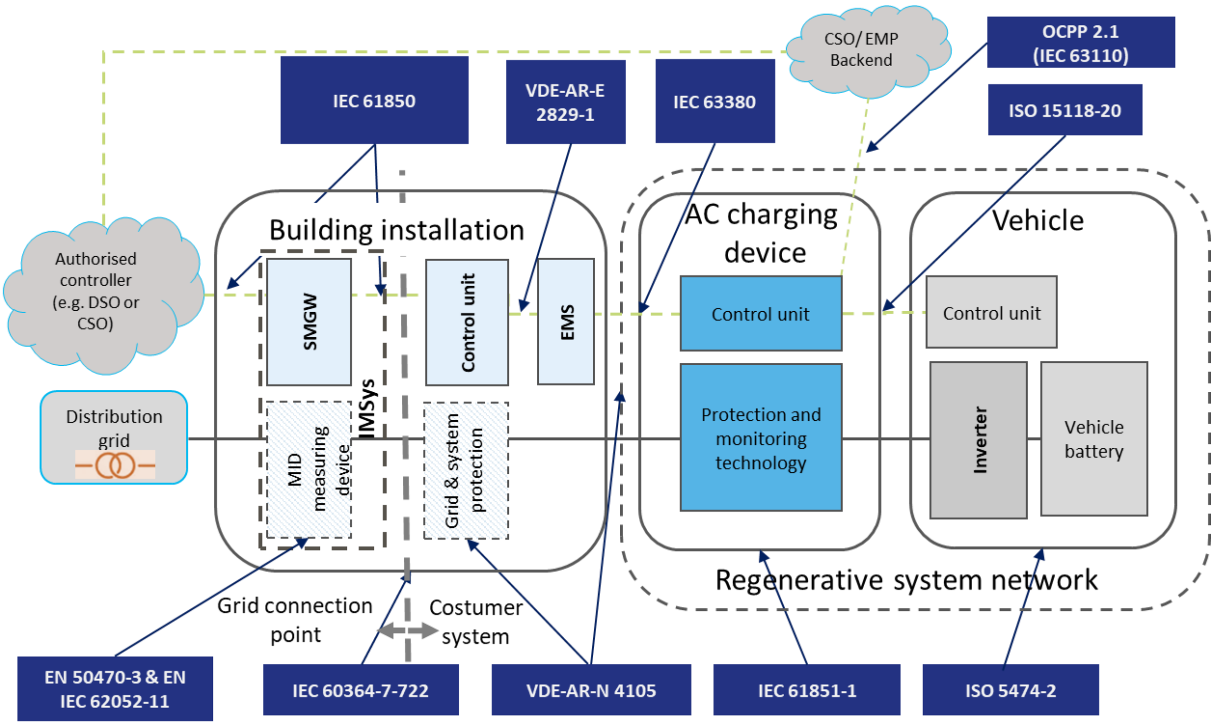


Figure 5: AC recovery (CCS type 2 interface)

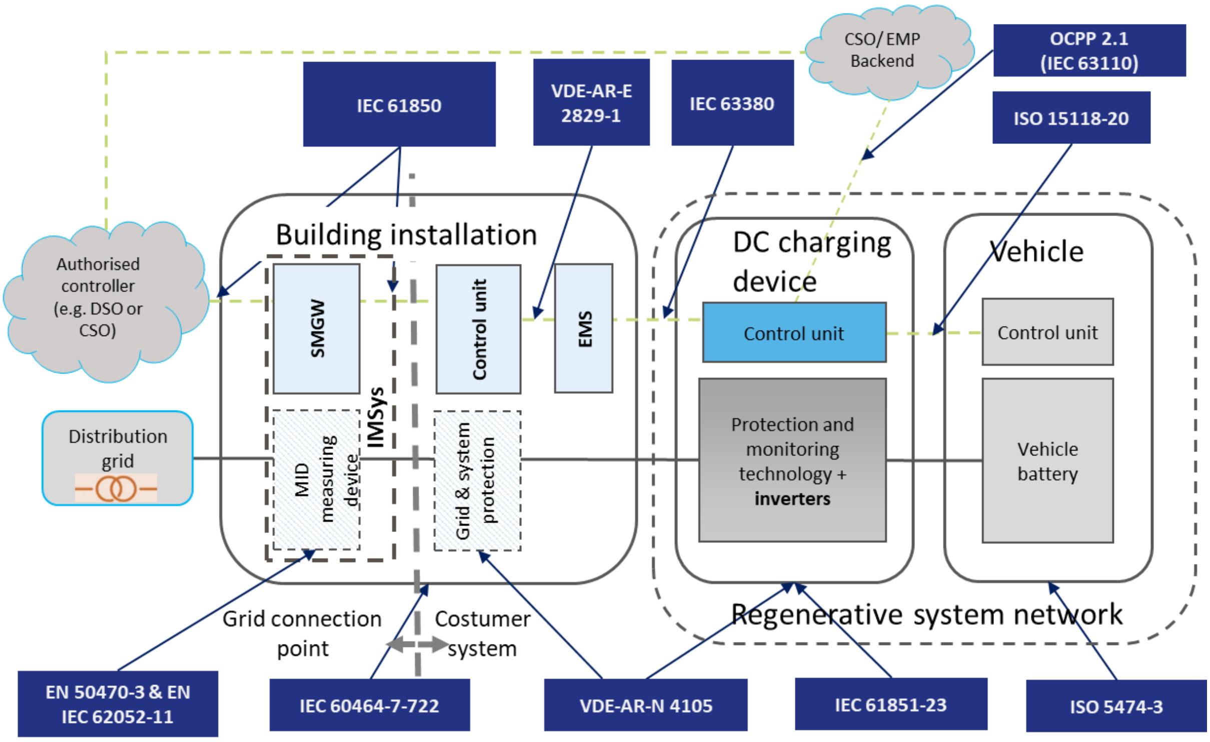


Figure 6: DC recovery (CCS-Combo II interface)

For a better classification of the standards listed in the following chapters, it makes sense to distinguish between the following areas:

- **Electrical safety** and **interoperability** between **grid connection point, charging device and vehicle**
- **Grid Connection Guidelines**
- **Communication protocols** for control and digital market integration
- Requirements for the use of legally compliant **billing systems**
- Electromagnetic compatibility **requirements**

The following chapter examines individual subject areas in greater detail: First, the respective topic area is introduced, its central challenges are described, and the status quo of standardisation is presented. Furthermore, the recommendations for action for future standardisation process are derived. Finally, expectations on the schedule of the respective standardisation are presented. As described in the introduction, the international consensus process may lead to deviations from the timeline presented here.

4.2 Electrical safety and interoperability between grid connection point, charging device and vehicle

4.2.1 Outline and current challenges

It must be noted that with the advent of electromobility, electrical safety has gained a new application area within the automotive sector. Electromobility is the only application where laymen in electrical engineering interact with the interface between vehicle and charging station, over which power in the multi-kilowatt range is transferred. Accordingly, current safety concepts, e.g. concerning photovoltaics and mobile power generators, are not directly transferable.

As of today, neither national nor international standardisation offers a comprehensive concept for electrical safety, covering the entire path from the energy provider, through the electrical installation and charging station, to the vehicle battery for either AC feed-back via the CCS Type 2 interface or DC feed-back via the CCS Combo 2 interface. Therefore, it is necessary to define additional requirements for all use cases in which energy is fed back into a fixed installation, regardless of whether they are coupled to the public distribution grid. Based on current knowledge, a software update presumably will not be sufficient on both the vehicle and infrastructure side to enable products currently on the market to support bidirectional operation in accordance with the latest published standards.

Before electrically safe interoperable solutions can be put into circulation, relevant product and installation standards (IEC 61851, ISO 5474, VDE 0100 series, DIN VDE 0100-722/ IEC 60364-7-722) for bidirectional charging must be expanded. As the development of the standards is partly quite advanced, the necessary requirements for bidirectional charging can no longer be included in the current revisions.

Unresolved questions in the field of electrical safety are, among others:

1. How can the vehicle be safely electrically disconnected in the event of a fault?
2. How can the low-voltage installation behind the regenerative network be safeguarded in the case of single and multiple feed-ins, such as those involving photovoltaic systems and stationary storage systems? How can it be ensured that electrical energy from the vehicle is not fed into a building installation and possibly further into the distribution network, which is not designed for this purpose?
3. How can electrical safety be ensured when combining different vehicles and installations?

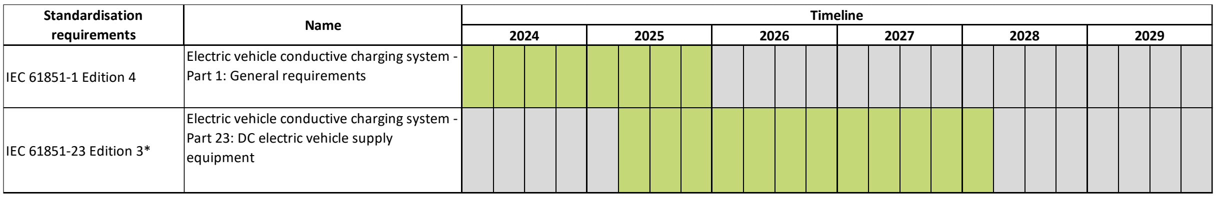
The statements made above do not fully apply to the use case ***operation of individual equipment*** (Vehicle2Load, V2L) that allows the *operation of individual equipment* via household or industrial plugs to the vehicle's HV on-board system. ISO 5474-2 already provides a rudimentary protection concept for V2L with Edition 1 from March 2024. However, the necessary counterpart of a V2L adapter for connection to the CCS Type 2 inlet still needs to be standardized, for which Germany has submitted a corresponding standardisation proposal at the international level.

Concerning electrical safety, it is crucial that technical solutions defined for supplying individual equipment is limited to the V2L use case. In this case, individual equipment is fed from the traction battery via household or industrial sockets. Supplying an entire building from one of these sockets is not intended.

4.2.2 Current and already planned norms and standards

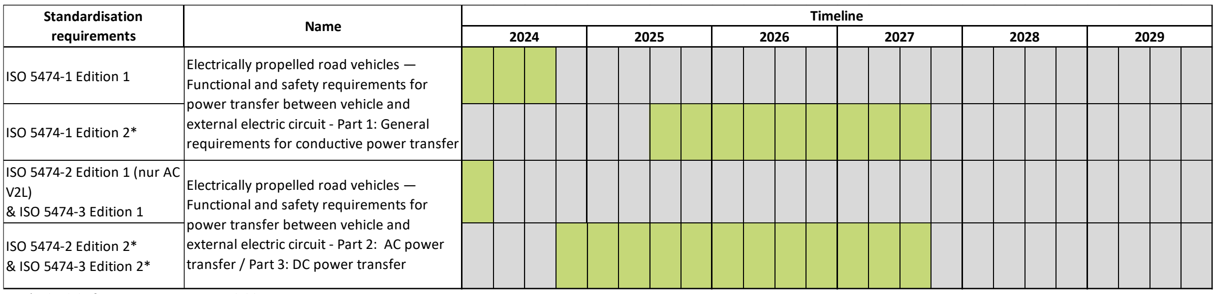
- **Product standard for a regenerative AC charging device:** Development of requirements as part of the ongoing revision of IEC 61851-1 Edition 4, with anticipated publication in 2026.
- **Product standard for a regenerative DC charging device:** Development of requirements as part of the forthcoming revision of Edition 3 of IEC 61851-23 that has yet to be initiated. A timeline for Edition 3 of IEC 61851-23 is not yet available.
- **Product standards for the vehicle interface (AC+DC):** Development of the requirements as part of the forthcoming revision of Edition 2 of the ISO 5474 series or parts 1-3, which are crucial for conductive charging. The revision has not been started yet. Edition 1 of ISO 5474-1/-2/-3 only describes the use case *operation of individual equipment* (V2L) via the AC charging interface. A timeline for Edition 2 of ISO 5474 is not yet available.
- **Communication standard between vehicle and charging device:** Edition 1 of the communication standard between vehicle and charging device, ISO 15118-20, allows for recovery in DC. An amendment to Edition 1 that is currently being developed will make recovery in AC possible. Various research projects indicate a need to increase the maturity level of ISO 15118-20 Edition 1. Fault-free, interoperable communication will develop over time and be verified through to-be-defined test standards.
- **Installation standards:** Although recovery is included in the published edition of VDE 0100-722:2018, some questions remain unanswered. These are to be addressed in Edition 2, whose development began internationally in Q1/2024 (IEC 60364-7-722). Particularly, for systems with multiple charging points with a dynamic load management system for unidirectional charging, the maximum expected regenerative currents of the cable installation must undergo a review. Currently, this is not yet addressed normatively. It is also important to examine the extent to which the IEC 60364-8-82 standard and the VDE application rule VDE-AR-E 2510-2 can be used in the context of electromobility. The published version of the latter application rule, which specifies requirements for stand-alone grid operation, explicitly excludes the connection of e-mobility systems. The IEC 60364-8-82 standard mentions electric vehicle and charging equipment as part of the Prosumer Electrical Installation (PEI) but does not specify any detailed requirements for them.

4.2.3 Schedule for planned norms and standards



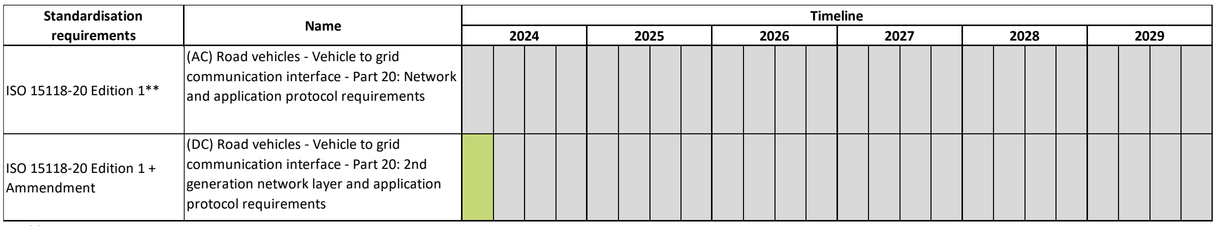
*Schedule for revision not yet available

Figure 7: Product standards for loading equipment



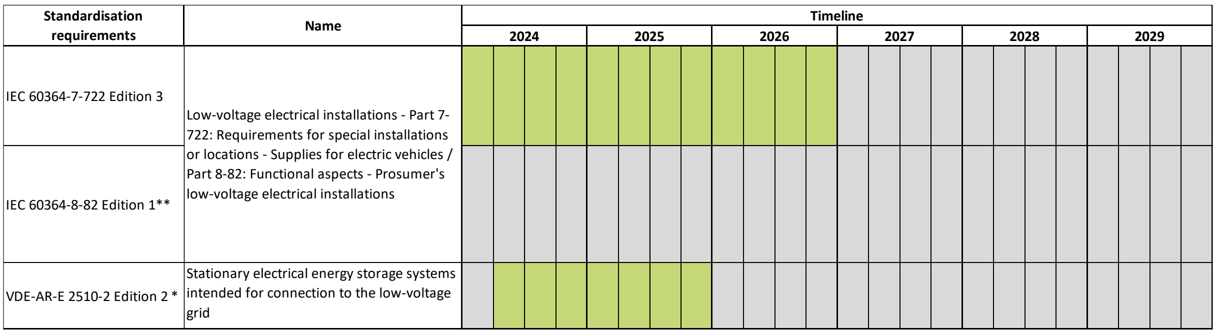
*Schedule for revision not yet available

Figure 8: Vehicle product standards



**Published norm

Figure 9: Communication standard between vehicle and loading device



*Schedule for revision not yet available
**Published norm

Figure 10: Installation standards

4.3 Grid Connection Guidelines

4.3.1 Outline Outline and current challenges

From an electrical engineering perspective, recovery with and without coupling to the public grid must be distinguished. Most applications of local optimisation, such as increase in or optimisation of consumption, are also linked to the public grid, meaning that technically, the grid connection guidelines defined by VDE FNN must also be followed. For all applications, regardless of whether the inverter is located in the vehicle or in the infrastructure, the regenerative overall system consisting of vehicle and charging device must comply with the corresponding requirements of the upstream installation and grid connection.

As the use case of DC recovery via the CCS Combo 2 interface with a stationary inverter is very similar to the feed-in from the photovoltaic sector, analogous considerations can be applied for this case. In the case of AC recovery, inversion takes place in the vehicle. Regarding the requirements of the grid connection guidelines, the pending standardisation must clearly assign the functionalities between vehicle and charging device. For both feed-back variants, the locally valid grid connection parameters must be stored locally, i.e. in the charging device. For AC feed-back, these parameters must be transferred to the vehicle via the mandatory ISO 15118-20 protocol. An amendment to this standard is currently being prepared and scheduled for publication in Q1/2024.

Regardless of whether bidirectional AC or DC charging infrastructure is integrated into existing electrical installations or large charging hubs are created, both VDE-AR-N 4105 (applicable to a medium-voltage connections) and application rule VDE-AR-N 4105 (applicable to a low-voltage connections) must be considered.

In addition to the mentioned VDE application rules for generation plants, the possibility of controllability must also be defined for bidirectional charging, currently specified in VDE-AR-N 4100 for the reference case. The 2025 revision of VDE-AR-N 4100 calls for a digital, bidirectional communication interface and a protocol defined in accordance with the "FNN Specification for Control Box". The VDE-AR-E 2829-6 series of standards and the IEC 63380 standard, which was specially developed for the domain of electromobility, already provides guidance for case of bidirectional charging.

Finally, it should be noted that revising the grid connection guidelines for supply and generation plants at European level will necessitate adjustments to the requirements framework for grid-connected recovery.

4.3.2 Current and already planned norms and standards

The draft published in VDE-FNN on the "Implementation of the proof of the technical requirements of VDE-AR-N 4105 for bidirectional charging of electric vehicles" of 02/2024 is referenced in the current revision of VDE-AR-N 4105, planned for 2025, and summarizes the requirements for the certification of regenerative systems in a consolidated manner. Based on the experience gained in the low-voltage range, the FNN project group on VDE-AR-N-4110 will discuss how medium-voltage connections can be covered in the future. Generally, the current consultation with ACER regarding the grid codes at European level which will influence the further development of Technical Connection Rules (TCR) must be taken into account.

4.3.3 Timeline of standardisation

Standardisation requirements	Name	Timeline					
		2024	2025	2026	2027	2028	2029
VDE-AR-N 4105	Requirements for low voltage grid connection of generators						
VDE-AR-N 4110	Technical rules for the connection and operation of customer installations to the medium-voltage grid (TCR medium voltage)						

Figure 11: Grid Connection Guidelines

4.4 Communication protocols for control and digital market connection

4.4.1 Outline and current challenges

ISO 15118-20 and OCPP 2.1 (expected to be replaced by IEC 63110 in the future) as well as IEC 63380 are indispensable as digital communication standards for the control and digital market connection of bidirectional charging, both for AC and DC. Besides implementation in the customer system such as the charging device and vehicle products, they require deployment on the part of the grid and charging station operator backends.

As introduced in chapter 4.3, both a digital, bidirectional communication interface and a protocol in the "FNN requirement specification for control boxes" are required for control in the unidirectional reference case. The VDE-AR-E 2829-6 series of standards and IEC 63380, which was specially developed for the domain of electromobility, will be extended to include bidirectional charging. The use cases described in Part 1 of the VDE-AR-E 2829-6 series of standards are also undergoing international standardisation in the IEC TR 62746-2 project, which is currently being revised.

4.4.2 Current and already planned norms and standards

OCPP 2.1 will fundamentally support interaction with ISO 15118-20 and, thus, bidirectional charging. At this stage, it is not foreseeable whether the specifications made in OCPP 2.1 will be incorporated into IEC 63110. Depending on the ongoing discussions about transferring OCA activities into IEC 63110, it is expected that bidirectional charging based on ISO 15118-20 will be supported. However, due to the unresolved discussions between OCA and IEC, a timeline is not foreseeable.

The communication protocol described in VDE-AR-E 2829-6 Series Edition 2 for the exchange of information at the interface to the property is already includes an extension for bidirectional charging. IEC 63380, which is specific to electromobility, is currently discussed internationally. Germany is significantly advancing the standard.

4.4.3 Schedule for planned norms and standards

Standardisation requirements	Name	Timeline					
		2024	2025	2026	2027	2028	2029
IEC 63110 (OCPP 2.1/2.2)	Protokoll for management of electric vehicles charging and discharging infrastructures						
IEC 63380 Edition 1***	Local charging station management systems and local energy management systems network connectivity and information exchange						
IEC TR 62746-2	Systems interface between customer energy management system and the power management system - Part 2: Use cases and requirements						

***Part 1: 12/2024; Part 2: 01/2025; Part 3: 01/2025

Figure 12: Communication protocols for control and digital market connection

4.5 Requirements for the use of legally compliant billing systems

4.5.1 Outline and current challenges

The initial applications expected to use bidirectional charging do not require novel measurement systems. This is the case, for example, when the owner of the vehicle is also the operator of the charging station (e.g. in the use case ***optimising self-consumption***). The balancing billing required at the grid connection point can performed with conformity-assessed solutions based on the EN 50470-3 and IEC 62052-11 standards. These have been covering bidirectional energy flow for years.

However, it is anticipated that business models will emerge requiring the billing of energy fed back from the vehicle between the vehicle owner and the charging station operator. An example would be feeding energy from an employee's vehicle back to the employer in the ***peak load capping*** use case or from a company car in a private setting.

For billing in this kind of business models, there is currently no suitable standard for charging station metering systems. EN50732, which will cover this case, is currently being worked on. Before its release, the use of simplified or flat-rate billing procedures on a transitional basis is desirable.

The central challenge concerning billing is the lack of regulation. It impedes the definition of measurement concepts and thus technical standardisation and development of corresponding systems. To address gaps in the body of standards and the product range in this area, answering the following question is crucial: Is either the energy from the vehicle battery or the energy that is withdrawn and fed in by the customer system at the grid connection point relevant to billing, or should both types of energy be considered simultaneously?

Based on regulatory requirements, it can be determined, for example, whether two-way DC meters need to be standardised and economically viable for industry to market.

4.5.2 Schedule for planned norms and standards

Standardisation requirements	Name	Timeline					
		2024	2025	2026	2027	2028	2029
EN 50732	Billing at the charge/feedback point						
EN 50470-3**	(Billing at the grid connection point) Electricity metering equipment Particular requirements. Static meters for AC active energy (class indexes A, B and C)						
EN IEC 62052-11**	(Billing at the grid connection point) Electricity metering equipment. General requirements, tests and test conditions - Metering equipment						

***Published norm*

Figure 13: Requirements for the use of legally compliant billing systems

4.6 Electromagnetic Compatibility (EMC) Requirements

4.6.1 Outline and current challenges

Electromagnetic compatibility (EMC) refers to the ability of an electrical device to emit only acceptable levels electromagnetic interference while also being immune to such interference. In the case of charging infrastructure for electromobility, good EMC properties are crucial: They ensure that no conducted or radiated electromagnetic interference occurs that could affect other devices or systems, both during the charging process and during feed-back

While the requirements for charging infrastructure are being further developed through the IEC 61851-21-2 standard, revisions are also underway on the vehicle side with the IEC 61851-21-1 standard. For vehicle homologation (type approval / e-mark), the internationally recognized ECE R 10 standard on "Electromagnetic Compatibility" is applied.

The current version of ECE R10, Edition 6 from 2019, does not include any requirements for bidirectional charging. Edition 7, which is expected for 2024, will not mention any specific requirements in this regard either. However, both standards reference the usual EMC requirements for consumers in the public energy supply network as outlined in the IEC 61000-3-X series of standards.

Generally, the product standards' EMC requirements are derived from the overarching basic standards (EN 61000-6-X series), which are to be used as horizontal standards for various electronic products.

As a result, it is challenging for manufacturers of charging equipment and electric vehicles when additional and stricter requirements are imposed within the grid connection directives that have not yet been unanimously adopted in the basic standards or product standards.

There is ongoing discussion regarding the extent to which potential grid connection requirements for charging electric vehicles with a phase current exceeding 75 A should be normatively considered. Until now, for such connection capacities, it has always been necessary to contact the operator of the public low-voltage supply network in advance to coordinate the technical conditions of the grid connection with the product manufacturer and the operator.

4.6.2 Current and already planned norms and standards

Both relevant parts of the IEC 61851-21 series are currently being revised. It is planned to adopt the limit values established for the "charging" operating mode. These are already used in the current IEC basic standards for the "refeeding" operating mode.

4.6.3 Schedule for planned norms and standards

Standardisation requirements	Name	Timeline					
		2024	2025	2026	2027	2028	2029
IEC 61851-21-1 edition 2	Electric vehicle conductive charging system - Part 21-1: Electric vehicle on-board charger EMC requirements for conductive connection to an AC/DC supply						
IEC 61851-21-2 edition 2	Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems						

Figure 14: Electromagnetic Compatibility (EMC) Requirements

4.7 Summary and conclusion

While most of the standards for AC and DC charging currently exhibit a high degree of maturity, there are no normative requirements for the case of feed-back allowing interoperable AC or DC recovery, both technically and commercially, at this time.

The availability of interoperable products, i.e. products that are compatible across manufacturers, cannot be mapped by a single set of rules, but must have a defined degree of maturity as an overall system across all stakeholders.

The analysis of the maturity levels of technical regulations indicates that comprehensive solutions will take a longer time to develop. Nevertheless, approaching this goal, a step-by-step model based on defined intermediate statuses allowing a certain extent of bidirectional applications can be developed. Presumably, the use cases for local optimisation will be available in a first step as soon as the required product standards for required infrastructure and vehicles have been expanded to include requirements for bidirectional charging, which will not happen before 2027/2028. For the use cases of market-oriented and grid-serving optimisation, the availability of consistent communication protocols will also be necessary.

No compromises can be made regarding electrical safety, which must be fully ensured from the grid connection point to the traction battery across all installation variants. It is important to note that installing a bidirectional charging device always constitutes an intervention in the electrical system. It must be reported to and approved by the grid operator and carried out by an installation company registered in an installer directory in accordance with Section 13 of the German Energy Industry Act (NAV). Particularly in the case of systems with several charging points with a dynamic load management system for unidirectional charging, the cable installation must be checked regarding the maximum expected regenerative currents.

5 Consideration of the positive and negative effects of bidirectional charging on the technical energy system

As a successor to conductive charging or inductive charging, bidirectional charging is not a new charging technology, nor does charging occur in two directions, as the name suggests. Bidirectional charging means that, in addition to the familiar functionality of being able to be charged, the vehicle also has the capability to release energy, i.e. to feed it back into the grid. The electric vehicle is no longer charged exclusively with energy for driving, but is connected to the customer's system and, if necessary, also to the power grid as a (mobile) storage system. Thus, it can make temporarily stored energy available for other applications as needed.

The effects of bidirectional charging on the energy system are therefore multifaceted and will particularly depend on the acceptance and consequently the dissemination of the use cases presented in Chapter 3.2. When examining these impacts, it is important to differentiate between the effects on customers, the grid and the energy market.

The use cases for local optimisation, such as *optimising self-consumption* or *peak load capping*, can relieve the grid in both energy flow directions as both, the customer's purchase from the grid and the feed-in into the grid, are reduced. Nevertheless, the grid must be designed for the nominal output required by the customer so that charging can still be carried out in the event of unavailable self-generation and that any surplus can be fed into the grid if the vehicle battery is already full.

In the use cases of market-oriented optimisation, the aggregators optimise charging and regenerative processing depending on energy availability and market price. Since the energy market in Germany is unified, these use cases place a high simultaneous demand on the grid for both procurement and for recovery due to the coordinated behaviour.

Accordingly, control options for the DSO should be provided for feed-back as well as for energy consumption. According to §14a EnWG (effective from 01.01.2024), the load on controllable consumers, such as electric vehicles and heat pumps, must be reduced to prevent peak loads in the event of grid bottlenecks in the low-voltage grid. This should also apply to recovery. From a technical point of view, therefore, only part of the theoretical total regenerative power of all electric vehicles connected to the grid can be retrieved. In addition, the revision of the European Network Codes, especially the Requirements for Generators (RfC) including bidirectional charging, will enable faster control mechanisms to ensure grid stability.

However, the V2G use cases of grid-supportive optimisation can also be interesting beyond the proactive balancing of supply and demand on the energy market, if the vehicles are used in conjunction with the charging infrastructure to provide balancing energy and other ancillary services in the future. In this case, energy is provided by the vehicles in a system-supportive manner on demand by the transmission system operator (TSO), who balances energy supply and demand within their control area, or on demand by the DSO to counteract local grid bottlenecks. It should be noted that the location of the feed-in of the balancing energy is technically relevant for the TSO and, with the decentralised and virtually unknown distribution of the vehicles, has different effects than the targeted use of individual high-performance balancing energy sources.

A more detailed examination of the positive and possibly also negative effects of bidirectional charging on the electrical energy system and the energy market, both with regard to the capacity requirements for charging and recovery, as well as for the system-serving use of the electric vehicle fleet for grid stability, is provided in the FNN note "Bidirectional charging - charging and refeeding of electric vehicles from the perspective of the power grid"[3]. The document is currently being developed and is scheduled for publication in February 2024.

6 Implementations and boundary conditions from practice (experiences from pilot projects)

The technical feasibility of charging bidirectionally has been demonstrated multiple times on prototypes as part of funding projects. An overview of known funded projects is shown in Table 1 in the appendix.

[3] https://www.vde.com/de/vde-fnn-hinweis-bidi-laden

Electrical systems today are not designed for bidirectional operation

Existing electrical systems must be tested for bidirectional operation and, if necessary, upgraded. There is a need for qualification in the planning, construction and commissioning of electrical systems with multiple variable power sources as well as in-field troubleshooting. The use case of energy recovery results in an additional power source with significant power transmission capacities (depending on the number of connected vehicles), which must be included into the protective measures. Problems arise from the presence of multiple power sources, such as the electric vehicle, PV systems, etc. (protection against electric shock, overcurrent protection, and neutral protection). In multi-family residential buildings/homeowner associations and commercial use, the complexity further increases.

7 Recommendations

Further accelerating activities at international level

As outlined in the roadmap, the timing is subject to fixed rules. This is due to the underlying processes of international standardisation for bidirectional charging infrastructure, electric vehicles and communication standards. In addition, the stakeholders of automotive and charging infrastructure manufacturers operate in an international (including European) environment. A departure from international standardisation and an increased focus on developing national standards or norms to possibly realise short-term solutions complicate the international consensus process and do not necessarily lead to interoperable solutions in the long run. Furthermore, this weakens the position of the German economy in the global context, ties up the capacities of experts due to parallel work, and leads to additional costs and potential misinvestments for both industry and consumers.

The national position must be consolidated as effectively as possible within the established standardisation committees of DIN and DKE, ensuring a broad presence of national experts in international standardisation. Topics that cannot be addressed internationally, such as payment systems and calibration law, should initially be addressed in a European context. A commitment to standardisation in the established standardisation committees of DKE and DIN from both industry and politics would ensure a focus of standardisation efforts and further increase acceptance.

Focusing and prioritising future standardisation projects in all relevant use cases

The technical requirements on the vehicle side are defined by the international ISO 5474 series of standards. Parts 1-3 specifically address the conductive AC or DC energy transfer between vehicle and charging infrastructure. After the release of the first edition, a timely revision is recommended. For the revision, the use cases Vehicle-2-Grid (V2G) in Grid-following-mode and Vehicle-2-Home (V2H) in Grid-forming mode should be prioritized. The Vehicle-2-Load (V2L) use case has already been addressed in the first edition.

In the ongoing revision of IEC 61851-1 for AC charging equipment, energy return is already being considered, with a focus on the V2G and V2H use cases.

For the recently released IEC 61851-23, Edition 2 for DC charging equipment, Edition 3 is already in development, in which the requirements for bidirectional charging will be addressed.

Increasing Germany's presence in international standardisation by supporting experts

In the area of bidirectional charging, international standardisation aligned with German interests can be further promoted, as many international standardisation activities are currently initiated and advanced by Germany. It is crucial that national delegates assume international activities as well as project management positions. This affects content and temporal stringency of standardisation work most strongly and should be financially supported. The resulting benefits extend to all national stakeholders, even those not directly involved in the standardisation process.

There is also a need for a solution to financially support nationally active, internationally engaged experts. This could be done, among other things, by expanding the Act on Tax Incentives for Research and Development (Research Allowance Act – FZulG), encouraging standardisation work analogue to research and development activities.

Greater integration of the results of publicly funded research projects into standardisation

It must be ensured that results from application-oriented research projects funded with public funds are incorporated into standardisation work. This requires an initial alignment with ongoing standardisation activities by the funded projects to build upon the current state of the art. Participation in standardisation activities should also be examined, whereby long-term participation must be ensured even beyond the project period. During the entire duration of the project, it should be ensured that findings and usable results relevant for standardisation are transferred into tangible standardisation proposals.

Stringent alignment of application-oriented research projects with cross-manufacturer- testing in a real-world environment

Research results from funded projects show that bidirectional charging is possible under laboratory conditions and that prototypes are available. So far, the technical design and testing under real-world conditions, for example through large-scale installation in the broad existing infrastructure, is still lacking. While previous funded projects have focused on technical feasibility, subsequent research projects should focus on testing interoperable systems across manufacturers. As previously mentioned, early transfer of insights is essential.

Timely adoption of requirements in vehicle homologation regulations

Since electric vehicles are not subject to the generally applicable European directives (Low Voltage, EMC Directive) and the associated "CE" marking, the requirements necessary for grid integration, for example regarding electrical safety and electromagnetic compatibility when fed into the power grid, must be proven by appropriate certification procedures or covered within the framework of vehicle approval (homologation regulations).

Support for specialist planning and trades through targeted qualifications and early publications

A central challenge in practical implementation is that specialist planners and electricians lack expertise in the design and installation of system networks capable of bidirectional charging in accordance with the generally accepted rules of technology. Therefore, qualification of the specialist planners and electricians is required. While revising recognized technical standards, parallel efforts should be made to create guidance addressing the practical implementation of normative requirements. In addition, training and further education offerings should be established to enable the trades to offer these new technologies to customers more quickly, as well as to install and maintain solutions. The development of tools and support for troubleshooting and fault resolution should involve the trades more closely in standardisation and research projects to enable proactive collaboration on solutions and ensure application-oriented results.

Making full use of existing opportunities for international standardisation

While unilateral national efforts seem of limited value in the standardisation of bidirectional charging technology, all available avenues for international standardization should be used as needed. For example, new requirements on specific topics, such as bidirectional charging, can be introduced into the existing standards by creating amendments as supplementary additions.

Additionally, it is recommended that new technologies, where a broad consensus has not yet been reached, should initially be described in quicker-to-implement, less binding standardisation formats, such as PAS (Publicly Available Specification) or TS (Technical Specification). The aim should be a subsequent swift transition into international standards, enabling international standardisation to proceed more efficiently and, if necessary, at a faster pace.

8 Further recommendations for action outside of standardisation

The above recommendations provide an outlook on the standardisation activities that should be prioritized in the future. However, at this point, the Expert Group Transformation of the Automotive Industry (ETA) also makes recommendations about regulatory activities.

- **Regulating calibration law and payment systems at European level**
  Equally relevant for the implementation of bidirectional charging is the clarification of the calibration law and of payment systems that are as standardised as possible. It is recommended to address these issues as quickly as possible at the European level to enable uniform solutions for the European market.
- **Creating incentives through tax advantages**
  Currently, it is still challenging to offer vehicle owners (= end customers) sufficient economic incentives. Therefore, it should be examined to what extent financial incentives for users and end customers can be used in the launch phase. These might contain subsidies, tax advantages or repayments that promote attractiveness, dissemination and acceptance of systems capable of bidirectional charging.
- **Clarifying the cost discussion between OEM and infrastructure**
  Bidirectional charging entails considerable investments and additional costs for OEMs, operators of charging infrastructure, distribution system operators and owners of properties (especially for apartment buildings). All parties must ensure that their investments are covered and that their business models are economically viable. The unresolved questions surrounding this must be addressed to avoid excessive cost structures for consumers. Ultimately, bidirectional charging must be economically attractive and sustainable for users. Since this functionality incurs additional costs, whether on the vehicle or infrastructure side, bidirectional charging will only become economically appealing for end customers once the revenues generated through leveraging energy price spreads exceed these additional costs.

Glossary and list of abbreviations

A - Ampere

AC - Alternating Current

ACER - Agency for the Cooperation of Energy Regulators

AR - Application Rule

BDL - Bidirectional Charging Management

BSI - Federal Office for Information Security

CE - Conformité Européenne (European Conformity)

CCS - Combined Charging System

CPO - Charge Point Operator

CSO - Charging Station Owner

CO_2 - Carbon dioxide

DC - Direct Current

DIN - German Institute for Standardisation

DKE - German Commission for Electrotechnical, Electronic, and Information Technologies of DIN and VDE

DSO - Distribution System Operator

ECE - Economic Commission for Europe

EMS - Energy Management System

EMC - Electromagnetic Compatibility

EN - European Norm

ENwG – Energiewirtschaftsgesetz (Energy Industry Act)

ERS - Electric Road Systems

EV - Electric Vehicle

FNN - Network Technology/Network Operation Forum

FZulG - Forschungszulagengesetz (Research Allowance Act)

HEMS - Home Energy Management System

IEC - International Electrotechnical Commission

ISO - International Standards Organization

MCS - Megawatt Charging System

GCP - Grid connection point

NAV - Niederspannungs-Anschlussverordnung (Low Voltage Connection Ordinance)

OCCP - Open Charge Point Protocol

PEI - Prosumer Electrical Installation

SMGW - Smart Meter Gateway

TCR - Technical Connection Rules

TR - Technical Rules

TSO - Transmission System Operator

V2B - Vehicle2Business/Building

V2G - Vehicle2Grid

V2H - Vehicle2Home

V2L - Vehicle2Load

VDE - Association for Electrical, Electronic & Information Technologies

RfC - Requirements for Generators

Appendix

Project	Information	Description
V2G plant at Mirafio	https://www.media.stellantis.com/em-en/e-mobility/press/the-vehicle-to-grid-pilot-project-has-been-inaugurated-at-mirafiori	In phase one, 64 pre-series vehicles of the all-electric "Cinquecento" are being used as test models to demonstrate how a large number of electric cars can communicate with the public power grid and enhance grid stability through power feed-back. In the further course of the project, up to 700 e-cars are to be integrated bidirectionally. **However, little information has been published about the project.**
Bidirektionales Lademanagement (BDL, Bidirectional Charging Management)	https://www.ffe.de/projekte/bdl/	For this project, 50 standard BMW i3s were expanded to include a regenerative function and connected via CCS-Combo II via DC wallboxes 11 kW from Kostal. **In various user-oriented field trials, the V2G network integration was tested in the commercial and private sectors.** The project was completed in 2023.
UNITE² - Reallabor für vernetzte E-Mobilität (Real-world laboratory for networked e-mobility)	https://unit-e2.de/	In 4 sub-projects, the interaction of grid, buildings and e-vehicle are tested. Transfer from research to practice. **In the heav-E sub-project, grid-friendly charging and communication standards are tested.** Project duration 2021 to 2024
GaN4moBiL – Bidirektionales Laden (Bidirectional Charging)	https://www.iaf.fraunhofer.de/de/medien/pressemitteilungen/projektstart-von-gan4emobil.html	The aim of the consortium is to demonstrate an **intelligent and cost-effective bidirectional charging system** with new semiconductor devices, component concepts and system components.
V2X Suisse	https://novatlantis.ch/projekte/v2x-suisse/	40 locations were equipped with 50 Honda e Mobility electric cars with bidirectional capabilities up to max. +/- 20kW. **The aim is to gather insights into stabilising the electricity grid and optimising self-consumption.** Project duration 09/2021 to 06/2024
eMobiGrid	https://www.now-gmbh.de/projektfinder/emobigrid/	The overall goal of the project is the scalable, flexible and **bidirectional integration of electric vehicles** into the stationary commercial or municipal electrical infrastructure **through DC coupling and cross-sectoral information technology**. Project duration: 01.01.2023 to 31.12.2025
FlexFleet	https://www.now-gmbh.de/projektfinder/flexfleet/	Research, into how **bidirectional and intelligent charging** via energy management can contribute to reducing the peak load of the fleet of partner Regionetz, is conducted. **Due to the insufficient project amount, it is not clear yet whether application-oriented implementation will be considered.** Project duration: 01.08.2022-31.07.2025
ELSTA	www.elsta-mobilitaet.de	Project to promote electromobility through standardisation, coordination and strengthening of public perception. **The bidirectional energy flow is one of the focal points of the project.** Project duration 01.07.2020 to 30.06.2024

Table 1

About the Expert Group

The Expert Group Transformation of the Automotive Industry (ETA) is an independent advisory body of the Federal Ministry of Economic Affairs and Climate Action (BMWK). The Expert Group develops target and recipient-based recommendations for action for politicians, business and society in general, which can be used to successfully shape long-term structural change in the industry. The overarching goal is to achieve climate neutrality, in addition to securing value creation, jobs and apprenticeships in Germany as an automotive location.

The ETA consists of 13 people from the scientific community, business and society who were appointed by Federal Minister Dr. Robert Habeck for the 20th legislative period. Other experts, in addition to relevant institutions and stakeholders, are involved in the work of the ETA via flexible and agile work formats. The members receive no remuneration or expense allowance for their involvement in the ETA. The group of Experts is supported by a process and scientific monitoring team commissioned by the BMWK. The ETA has a sister body, the Expert Advisory Council on Climate Action in Mobility (EKM) at the Federal Ministry for Digital and Transport (BMDV). Both bodies are integrated into the Federal Government's Transformation of the Automotive and Mobility Industry Strategy Platform (STAM).

The ETA is responsible for the content. It develops statements, position papers and reports partly in its working groups, then deliberates and decides on them in plenary session, and subsequently publishes them under its own responsibility.

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