Enabling non-discriminatory bidirectional charging

Recommendations for action by the National Centre for Charging Infrastructure Advisory Board for the implementation of Measure 47 of the Charging Infrastructure Masterplan II

Nationale LEITSTELLE Ladeinfrastruktur

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List of abbreviations

AC	Alternating Current
BiDi	Bidirectional charging
BMWK	Federal Ministry for Economic Affairs and Climate Action
DC	Direct Current
DSO	Distribution System Operators
EEG	Renewable Energies Act (Erneuerbare- Energien- Gesetz)
EnFG	Energy Financing Act (Energiefinanzierungsgesetz)
EnWG	Energy Industry Act (Energiewirtschaftsgesetz)
GNDEW	German Act to Restart the Digitalisation of the Energy Transition (Gesetz zum Neustart der Digitalisierung der Energiewende)
HEMS	Home Energy Management System
ISLa	Interministerial steering group for charging infrastructure (Interministerielle Steuerungsgruppe Ladeinfrastruktur)
MRP	Minute Reserve Power
MsbG	Metering Point Operation Act (Messstellenbetriebsgesetz)
NLL	National Centre for Charging Infrastructure (Nationale Leitstelle Ladeinfrastruktur)
RfG	Requirements for Generators
SMGW	Smart Meter Gateway
SCL	Secondary Control Reserve
TaLS	Taxes, Levies, Surcharges
TCC	Technical Connection Conditions
TCR	Technical Connection Rules
V2B	Vehicle-to-Building
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
V2L	Vehicle-to-Load
V2V	Vehicle-to-Vehicle
V2D	Vehicle-to-Device

Key messages

- Bidirectional charging is a promising additional offer for users of electric vehicles in the future and should be made accessible to them in a simple, safe and non-discriminatory manner.
- Bidirectional charging can also contribute to sector coupling by offering additional flexibility. Opinions differ with regard to its future contribution towards the energy transition and its economic benefits.
- Among the various use cases, V2H will initially establish itself on the market; in the medium term, V2G will develop via aggregators / service providers on the market.
- The members of the National Centre for Charging Infrastructure's Advisory Board have the common goal of enabling all use cases (V2H, V2G, V2B) in a non-discriminatory and competitive manner.
- The number of bidirectional vehicles and charging facilities available on the market is increasing.
    - The systems already available, however, still differ in terms of the use cases supported and, due to a lack of standardised system standards, have so far only operated on a proprietary basis.
    - The Advisory Board expects a significant increase in the number of bidirectional vehicles and charging facilities available on the market.
- The goal is to achieve plug & play solutions. This requires a standardised, interoperable and barrier-free system in which the customer can connect various vehicles with different charging facilities and easily network them with the domestic energy management system.
- In the next two years, proprietary systems will increasingly develop on the market, with interoperable systems expected from 2027/2028.
- Significant legal and technical hurdles still need to be clarified for all use cases.
- Industry and politics must therefore work together to adapt and further develop the international, European and national legal regulations in a timely manner.

Executive summary

Bidirectional charging is a promising and attractive additional product for users of electric vehicles at the interface between the mobility and energy sectors.

In the context of vehicle-to-home (V2H) and vehicle-to-building (V2B) applications, the use of the vehicle battery as buffer storage enables a higher level of self-consumption/self-sufficiency through lower or deferred electricity consumption from the grid and possible cost savings in the domestic system in the home. With vehicle-to-grid (V2G) applications, flexibility can be provided for the energy system with the appropriate price signals, thereby opening up further revenue potential for customers.

In addition, bidirectional charging can contribute to sector coupling by providing additional flexibility. However, opinions differ on the future contribution towards the energy transition and its economic benefits.

From the perspective of the Advisory Board members from the automotive industry, bidirectional charging can make a significant contribution to using renewable energies more efficiently in the future, thereby reducing the economic costs of the energy system and CO_2 emissions. As part of grid and system services, bidirectional charging can also contribute to stabilising the electricity grids in the future.

For the energy and charging industry, bidirectional charging is a building block for the energy transition, together with other options for flexibility. The extent of the flexibility potential depends on a sufficient supply of flexibility from electric vehicles that is competitive with other flexibility solutions.

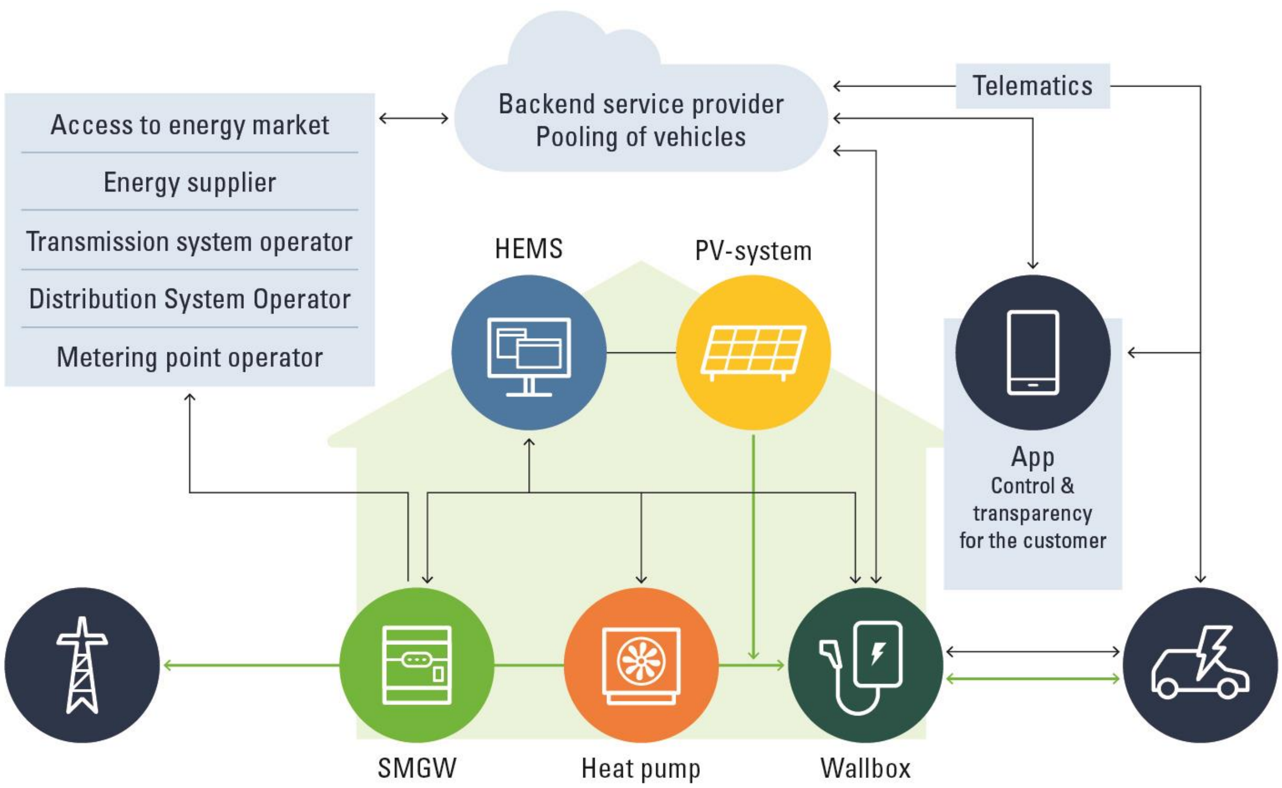

Figure 1: Simplified depiction of bidirectional charging. Source: Based on BDL information.

The potential contribution towards reducing (local) CO_2 emissions and increasing the share of renewable energies, on the other hand, is modest due to the increasing share of renewable electricity in the energy system (80% in 2030). With regard to the distribution grids, it can be assumed that there will be a need for additional grid expansion if bidirectional charging is used intensively.

The members of the National Centre for Charging Infrastructure Advisory Board have the common goal of enabling non-discriminatory bidirectional charging and tapping into the above-mentioned potential, particularly for the users themselves as well as for the energy system.

Corresponding business models are currently being developed, trialled and will be launched on the market in the coming years.

Among the various use cases, V2H/V2B will initially establish itself on the market; in the medium term, V2G will also develop on the market via aggregators and service providers.

It can therefore be assumed that V2H and V2B use cases such as increasing self-consumption, tariff-optimised charging and discharging of electric vehicles or load management for commercial users will be the first use cases to be represented on the market in the coming years. V2G use cases such as participation in electricity markets (intraday, day-ahead) and the provision of ancillary services (balancing energy, re-dispatch) will gradually establish themselves on the market.

The Advisory Board members agree that all use cases must be implemented in a non-discriminatory, standardised and competitive environment.

The availability of suitable bidirectional vehicles and charging facilities as well as their interoperability – from the vehicle to the charging facility and on to the grid connection point – are key to the successful nationwide introduction of bidirectional charging.

The increasing digitalisation of grids, including the spread of smart metering systems and pragmatic metering concepts, as well as improved mobile phone coverage, also play a key role in this.

Overall, the number of bidirectional vehicles and charging systems available on the market is increasing. However, the systems already available still differ in terms of the use cases they support and, due to a lack of standardised system norms, have so far only operated on a proprietary basis.

In the coming years, the Advisory Board anticipates a significant increase in the number of bidirectional vehicles and charging systems available on the market. The goal is plug & play solutions, i.e. standardised, interoperable and barrier-free systems in which the customer can connect various vehicles with different charging facilities and easily network them with the domestic energy management system in the home.

With increasing market penetration, bidirectional charging in the distribution grids is leading to changes in load and feed-in curves. How this affects the utilisation of the respective electricity grid depends, among other things, on which bidirectional use cases are offered and actually used by customers.

Nevertheless, the Advisory Board members from the energy industry assume that bidirectional charging, when used intensively as an option for flexibility in the electricity system (i.e. energy and balancing energy market), is accompanied by an additional need for grid expansion in the distribution grid. Only the application of Section 14a of the German Energy Industry Act (EnWG) can temporarily reduce the need for grid expansion independently of bidirectional charging.

The automotive industry is of the opinion that V2H (optimisation of self-consumption) and the market-oriented use cases of V2G (participation in electricity markets) offer the greatest benefits for users and the energy system. In addition to the position of the energy industry, the automotive industry points out that the grids must be comprehensively expanded and digitalised due to the electrification of heating and mobility.

With a realistic mix of use cases and the right framework conditions (time-variable grid charges, Section 14c EnWG), bidirectional charging may have a positive impact on the need to expand the grid, for example in comparison to scenarios with high proportions of price-controlled unidirectional charging applications.

In order to implement bidirectional charging, a suitable technical and regulatory framework must be created for all use cases.

To enable bidirectional charging to establish itself on the mass market, the Advisory Board believes that the following technical and regulatory measures in particular are required.

Setting the technical course:

From a technical perspective, internationally applicable and interoperable plug & play solutions are the goal and key success factor for a nationwide market launch in Germany.

In the following relevant standardisation areas, far-reaching enhancements are required for bidirectional charging:

Electrical safety: Adjustment or expansion of the existing safety parameters for the electrical connection between the charging device and the vehicle.

Grid connection: Adjustment of the parameters for connecting alternating mobile storage (e-vehicles) to different grid connection points (in contrast to purely stationary applications such as home storage).

Digital communication: Transfer of the now established and almost fully developed standards for linking the individual components of the overall system "vehicle – charging facility – backend" to the application phase.

Measurement, control, digitalisation: Necessary sets of rules for linking the digital communication "vehicle – charging facility – backend" to measurement and control applications.

Standardisation in the field of bidirectional charging is largely based on projects at ISO and IEC level. The international orientation of these standardisation projects ensures that largely uniform requirements are placed on the overall system worldwide.

The expansion of the various international standards for the use of all applications has been initiated and is to be largely implemented in the years 2025 to 2027.

ISO 15118-20 is essential for standardised communication between the vehicle and the charging system. According to statements made by vehicle manufacturers in the NLL's Cleanroom[1] Talks, the standard will be implemented by all manufacturers surveyed from 2025..

Setting the regulatory course:

In order to tap into the potential of bidirectional charging for all use cases (V2G and V2H), the existing obstacles or disadvantages for electricity storage or electricity fed back into the grid under the current legal framework with regard to the obligation to pay fees, charges and levies must be removed in their entirety. This must be provided for regardless of the type of storage facility. An overarching legal framework must be created for this in the near future.

In addition, there is currently a lack of standardised regulations across Europe on how the user can access the data and make it available to aggregators and service providers, particularly with regard to data availability from the vehicle.

The following points in particular must be promptly adjusted by the federal government in the legal framework:

[1] Most of the participants in the 2023 update of the Cleanroom Talks were German and European manufacturers, whose market share in the passenger car sector is just under 80 %

- The current classification of intermediate storage of kilowatt hours drawn from the grid as "final consumption" with regard to the obligation to pay grid charges, levies and surcharges systematically penalises electricity storage, as the electricity stored temporarily is charged with ancillary electricity costs both in the context of intermediate storage and in the actual final consumption – and thus twice.

- In order to prevent this kind of double burden, electricity storage must not incur any grid charges, levies or surcharges. This does not constitute preferential treatment, as it merely avoids the imposition of a double burden. All grid fees, levies and surcharges are ultimately paid at the time of final consumption.

- Intermediately stored "green" electricity must retain its designated status and continue to be supported and marketed as green electricity under the EEG, even if it is temporarily stored in a storage facility that also contains grey electricity from the grid. The storage-related exclusivity principle in accordance with Sections 3 No. 1, HS 2, 19 (3) EEG must therefore be adapted.

- In principle, bidirectional charging requires a pragmatic and practicable metering concept that allows for the differentiation of temporarily stored grey and green electricity as well as the quantities of electricity fed back into the public grid.

- The implementation and revision of the relevant European regulations is essential so that the user can access the data required for bidirectional charging from the vehicle or transfer it to third parties for further services. The European requirements on the energy and power data from the vehicle required for bidirectional charging (e.g. usable energy quantity, charging and discharging power), for example in Article 20a, paragraph 3 of RED III, must therefore be incorporated into national law. It is important to ensure that data access is automated and standardised.

Based on existing preliminary work (BDEW paper PG Data, VDA paper PG Charging), the automotive and energy industries, together with the responsible authorities, ADAC and consumer associations, are setting up an expert dialogue on the energy and power data required for bidirectional charging and its exchange, and are developing a list of the necessary data points for digital communication. The Advisory Board is defining a clear and comprehensive roadmap to pave the way for the widespread introduction of bidirectional charging. According to this, marketable – still proprietary – vehicle-to-home applications can be expected from 2025, with the first proprietary V2G solutions likely to enter the market with a short time lag.

From 2027/2028, there may be a ramp-up of interoperable, standardised solutions for V2H and V2G, which will facilitate the most important use cases once the corresponding standards are in place. The necessary regulatory and technical foundations should have been laid by then. Legislators must therefore take action at European and national level as soon as possible. At the same time, the internationally applicable technical standards must be successively developed further.

The introduction of bidirectional charging should be flanked by comprehensive and transparent consumer information measures throughout the entire process. The companies involved, consumer advocacy centres and automobile clubs have a particular responsibility in this regard. The National Centre for Charging Infrastructure's Advisory Board will continue to provide ongoing constructive support for the process in the future.

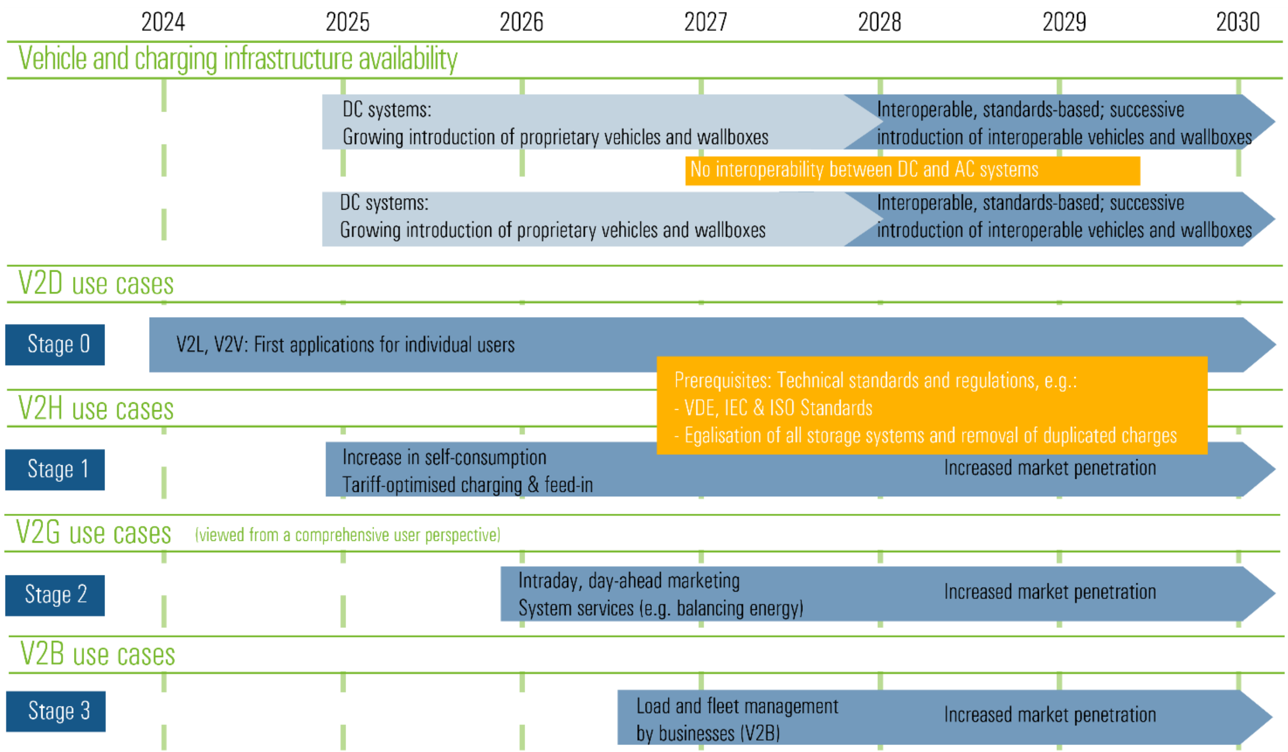

Figure 2: Bidirectional charging roadmap; Source: Own depiction

Working group results

1 Introduction

In its coalition agreement, the German government made it clear that the energy transition must be accelerated in order to achieve the Paris climate target. It was against this backdrop that the coalition agreement explicitly formulated the objective of "enabling bidirectional charging". As a result, Measure 47 was defined in the Charging Infrastructure Masterplan II, also taking into account the industrial policy relevance for international competitiveness.

The National Centre for Charging Infrastructure's (NLL) Advisory Board has drawn up this document together with experts at the request of the NLL and the Interministerial Steering Group Charging Infrastructure (ISLa – Interministerielle Steuerungsgruppe Ladeinfrastruktur) in order to provide industry and stakeholders with recommendations for the practical implementation of Measure 47. Based on an analysis of the status quo and possible use cases, the document describes a concrete roadmap with recommendations for action to enable non-discriminatory and user-friendly bidirectional charging. It is essentially based on the results of existing studies as well as projects and experiences gained in practice.

Bidirectional charging, i.e. the optimised charging of vehicle batteries as well as their re-feeding into a home network (vehicle-to-home, V2H) or building network (vehicle-to-building, V2B), along with effective re-feeding into the upstream energy system (vehicle-to-grid, V2G), represents an example of energy storage-based flexibility.

This creates opportunities for users of electric vehicles to optimise their energy consumption as well as additional applications and revenue opportunities. Bidirectional charging is therefore an attractive additional product for users of electric vehicles at the interface between the mobility and energy sectors. With the right price signals, flexibility services can be provided for the energy system, thereby tapping into further revenue potential for customers.

Bidirectional charging can contribute to sector coupling through the provision of flexibility services. Overall, this can contribute to a further flexibilisation of the energy supply, to the reduction of greenhouse gases and to the conservation of resources. Different opinions exist on the contribution towards the energy transition, the economic benefits and the effects on the distribution grids.

For the successful nationwide introduction of bidirectional charging, the availability of suitable vehicles and charging facilities as well as their interoperability – from the vehicle to the charging facility through to the grid connection point – play a key role so that services can be offered to users on this basis without discrimination. Realistic development paths and comprehensible ramp-up scenarios for vehicles, charging equipment and grids are presented in the document (WG 2).

The analysis focuses on use cases from the user's perspective:

- What options exist for private and commercial customers or third parties commissioned by them to use e-vehicles as buffer storage for local generation and self-consumption optimisation in order to increase their degree of self-sufficiency?

- What opportunities arise for other user groups without their own generation/storage to generate additional income from V2G applications by marketing their electricity or flexibility from the vehicle battery and strengthening the energy system?

For all applications, both the economic benefit of individual use cases for the user and the necessary incentive systems are evaluated. This analysis is based on the premise of enabling sustainable and viable business models that can be implemented by consumers (private and commercial customers) and aggregators, and that do not require funding support in the medium term (WG 3).

The document also outlines the technical and legal regulations required for the introduction of bidirectional charging. In particular, existing hurdles for bidirectional charging and weaknesses of the current legal framework (e.g. EnWG, EEG and EnFG) for electricity storage are addressed. It also categorises the technical connection rules (TCR) and the technical connection conditions (TCC) as well as the technical and communication standards between vehicles, charging facilities (in particular wallboxes) and energy management systems and grid connection points.

In addition, the European requirements for the energy and performance data necessary for bidirectional charging, for example from RED III, whose rapid implementation into national law must create the necessary legal framework, are discussed. Based on the analysis, proposals will be made to successively further develop the technical and regulatory framework and create the conditions for the successful introduction of bidirectional charging. (WG 4 and WG 5).

Finally, development paths, opportunities and risks are presented in a roadmap and recommendations for action are made. A path is shown as to how and to what extent electric vehicles can be used in an intelligent and user-friendly manner for bidirectional charging in order to create both additional applications and revenue opportunities. The aim is to enable non-discriminatory bidirectional charging for all participants (WG 6).

2 Availability of vehicles, charging options and grid capacities

The introduction and wider use of bidirectional charging requires the availability of bidirectionally chargeable vehicles and charging facilities as well as the corresponding systems and concepts for energy management and metering. The following sections therefore outline realistic development paths and plausible ramp-up scenarios for the vehicles and charging facilities concerned. Furthermore, bidirectional charging also involves certain requirements for measurement technology and the grid connection.

2.1 Availability of vehicles

To date, feeding electricity back into the building (V2H) or into the energy system (V2G) has generally been performed as part of field tests and pilot projects using specially converted vehicles and prototype charging facilities. However, it is now foreseeable that an increasing number of electric vehicles available on the market will support bidirectional charging technologies. But as the necessary system standards are also not yet available on the vehicle side (see Chapter 4), these are proprietary implementations, meaning that interoperability is not yet guaranteed.

When implementing bidirectional charging, manufacturers utilise both AC and DC solutions for the feed-in of energy. The majority of manufacturers have initially implemented direct current (DC) feed-in technology, as this can be realised in the vehicle without the need for an additional component on the software side. However, DC energy feed-in requires a special DC wallbox, which is currently comparatively expensive. The feed-in of alternating current (AC), on the other hand, requires a so-called bidirectional onboard charger (OBC) in the vehicle, whereby the bidirectional AC wallbox currently offers cost advantages over the DC wallbox. Due to the different advantages and use cases, the Advisory Board generally anticipates that both technologies – DC and AC – will establish themselves on the market.

The Advisory Board expects that the number of bidirectional vehicles available on the market will continue to increase in the coming years. The results of the so-called Cleanroom Talks, which were conducted by the National Centre for Charging Infrastructure (NLL – Nationale Leitstelle Ladeinfrastruktur) with car manufacturers, indicate that the availability of bidirectional vehicles of new model generations will increase noticeably from 2025 (see Figure 3 and Annex 1).

Accordingly, at least two manufacturers intend to deliver at least 25 per cent of their vehicles with bidirectional technology by 2025, at least one manufacturer plans to deliver 50 per cent and at least one manufacturer plans to deliver 75 per cent. The ISO 15118-20 standard, which is relevant for bidirectional communication between vehicles and charging equipment, is to be implemented by all manufacturers surveyed from 2025.

The German government's coalition agreement states that up to 15 million fully electric vehicles will be registered on German roads by 2030, which will have a storage capacity of several hundred GWh. The current figure is just under 1.2 million.

	2025	2030	2035
AC feed-in capability	At least one manufacturer plans at least 25 %.	At least two manufacturer plan at least 75 %.	
DC feed-in capability	At least one manufacturer plans at least 25 %. At least one manufacturer plans at least 50 %. At least one manufacturer plans at least 75 %.	At least one manufacturer plans at least 50 %. At least one manufacturer plans at least 75 %.	At least half the manufacturers plan at least 75 %.
Vehicle-to-Device	At least one manufacturer plans at least 25 %. At least one manufacturer plans at least 75 %.	At least one manufacturer plans at least 25 %. At least one manufacturer plans at least 75 %.	At least three manufacturers plan at least 50-75 %.
ISO 15118-20	All manufacturers will have ISO 15118-20 implemented by 2025.		

Figure 3: NLL Cleanroom Talks; Source: NLL

As new registrations are expected to increase from 2025 in particular, it can therefore be assumed, taking into account the results of the Cleanroom Talks, that a significant number of fully electric vehicles in the German market will already be capable of energy feed-in by 2030. Modelling by the German Research Centre for Energy Economics (Forschungsstelle für Energiewirtschaft München e.V.) concludes that more than a third of fully electric vehicles on the market will be used bidirectionally by 2030 in order to make efficient use of renewable energies and minimise the economic costs of the energy system.[2] Based on the assumptions made regarding the further development of system costs and revenue potential, a good 3 to 5 million vehicles could be used bidirectionally by 2030. In practice, the actual number of vehicles used bidirectionally will depend on numerous parameters, with the adoption of bidirectional charging by users being the decisive factor. According to the Advisory Board, this requires fully standardised, interoperable solutions as well as a proof of concept and an appealing business case, the latter of which must be provided or guaranteed by the providers.

2.2 Availability of charging facilities

In addition to the availability of bidirectional vehicles, bidirectional charging requires the corresponding charging facilities. Due to a lack of existing technical standards, the availability of bidirectional charging equipment in practice is currently purely on a prototype basis.

The Advisory Board is aware of 21 bidirectional charging systems from different manufacturers whose market launch has been announced or which have been used in pilot projects. The market maturity of the different systems varies. Several proprietary bidirectional DC charging systems have been announced to date, but these are predominantly limited to a few vehicle models on the market and mostly interact in a one-to-one relationship. At present, DC charging facilities are considerably more expensive than AC charging facilities. In the medium to long term, the costs of bidirectional DC charging facilities are likely to fall due to scaling. Some announced solutions for bidirectional charging on the market combine the PV universal inverter with the DC charging device in a single unit in order to feed the DC current from the PV system and the comparable DC current from the vehicle battery into the domestic grid in a grid-compliant manner.

The availability of bidirectional AC charging devices is expected from 2024 on a proprietary basis and, according to the Advisory Board, should increase significantly with the availability of existing international standards.

	AC	DC		AC	DC		AC	DC		AC	DC
ABB	○	✓	Delta	✓	✓	Evtec	○	✓	Kostal	○	✓
Ambibox	○	✓	Eaton	○	✓	Fermata	○	✓	Nichicon	○	✓
AME	○	✓	Enovates	○	✓	Ford	○	✓	Nuvve	○	✓
BorgWarner	○	✓	Enphase	○	✓	InCharge	○	✓	Silla	○	✓
dcbel	✓	✓	Enteligent	○	✓	Indra	○	✓	Wallbox	○	✓

Figure 4: Charging facility availabilities. Source: TMH

[2] T. Kern and S. Kigle, "Modeling and evaluating bidirectionally chargeable electric vehicles in the future European energy system", Energy Reports, vol. 8, no. 16, p. 694–708, 2022. DOI: 10.1016/j.egyr.2022.10.277

2.3 Effects on the energy system and electricity grids

In principle, the electricity system in Germany is becoming increasingly decentralised and flexible. Like load management, for example, bidirectional charging is a specific type of flexibility. As a flexibility option, bidirectional charging can contribute to sector coupling. However, opinions differ on its future contribution to the energy transition and the extent of the economic benefits:

From the perspective of the automotive industry Advisory Board members, bidirectional charging can significantly help to utilise renewable energies more efficiently in the future and thus reduce the economic costs of the energy system and CO_2 emissions. As part of grid and system services, bidirectional charging can also help to stabilise the electricity grids in the future.

For the energy and charging industry, bidirectional charging is also a building block for the energy transition. However, economic benefits will only be realised if the flexibility offered by electric vehicles is sufficiently large and competitive with other flexibility solutions and does not cause additional grid expansion at the distribution grid level due to higher concurrencies. In addition, the potential contribution towards reducing CO_2 emissions is steadily decreasing due to the increasing share of renewable electricity (80% in 2030).

With regard to a possible repercussion on the electricity grids, a distinction must be made with respect to the effect or utilisation of bidirectional charging between the grid levels.

For the transmission grid level, bidirectional charging could be integrated into the balancing energy market in the future to provide positive and negative balancing energy. Some of the first pilot and R&D projects are currently taking place at Bayernwerk & Tennet and Transnet BW, for example.

In the distribution grids, bidirectional charging may lead to changed load and feed-in curves in the local distribution grids in the future if there is greater market penetration. How this affects the capacities of the respective electricity grid depends, among other things, on which bidirectional use cases are offered and actually utilised by customers.

The Advisory Board's energy industry members assume that, based on current knowledge, bidirectional charging will not reduce the need for expansion with regard to the distribution grid, as bidirectional charging is primarily used to optimise self-consumption as well as for the purpose of power trading or balancing energy. It is more likely that the need to expand the distribution grids will increase.

The automotive industry shares the view that V2H (optimisation of self-consumption) and the market-oriented use cases of V2G (participation in electricity markets) offer the greatest benefits for users and the energy system. In addition to the position of the energy industry, the automotive industry highlights the fact that the grids must be comprehensively expanded and digitalised due to the electrification of heating and mobility. With a realistic mix of use cases and the right framework conditions (time-variable grid charges, Section 14c EnWG), bidirectional charging can potentially have a positive impact on the need to expand the grid, such as in comparison to scenarios with a high proportion of price-controlled unidirectional charging applications.

The energy industry argues that the change in charging facilities from a pure consumption facility to a system capable of feeding energy back into the grid also increases the complexity of grid connection, energy balancing/billing and power provision in the local grid section. In addition, there are increased procedural and administrative costs for these tasks for all market roles involved. Bidirectional charging also leads to higher grid costs, while at the same time customers with bidirectional charging pay lower grid charges in the event of PV self-consumption optimisation due to their reduced electricity consumption.

The automotive industry, on the other hand, is of the opinion that the decentralised energy transition brings with it changed requirements that are only insignificantly related to bidirectional charging. The complexity of grid connection, balancing and billing arises in a similar way for PV systems and bivalent storage systems. Grid operators and suppliers are therefore faced with the challenge of digitalising their grids and market processes. Higher grid costs are not to be expected due to bidirectional charging. According to studies (FfE, AGORA, ETH, P3), the economic costs of the energy system can actually be reduced by bidirectional charging.

Excursus: results of the ffE's BDL project

In the "Bidirectional Charging Management" (BDL – Bidirektionales Ladeanagement) research project funded by the BMWK, a holistic, user-orientated service for integrating bidirectional electric vehicles into the energy system was developed and tested.

On the one hand, the project analysed the impact on the European energy system and, on the other, on local power grids in Germany. An excerpt of the extensive research results is presented below as an example.

1. Bidirectional charging in the European energy system

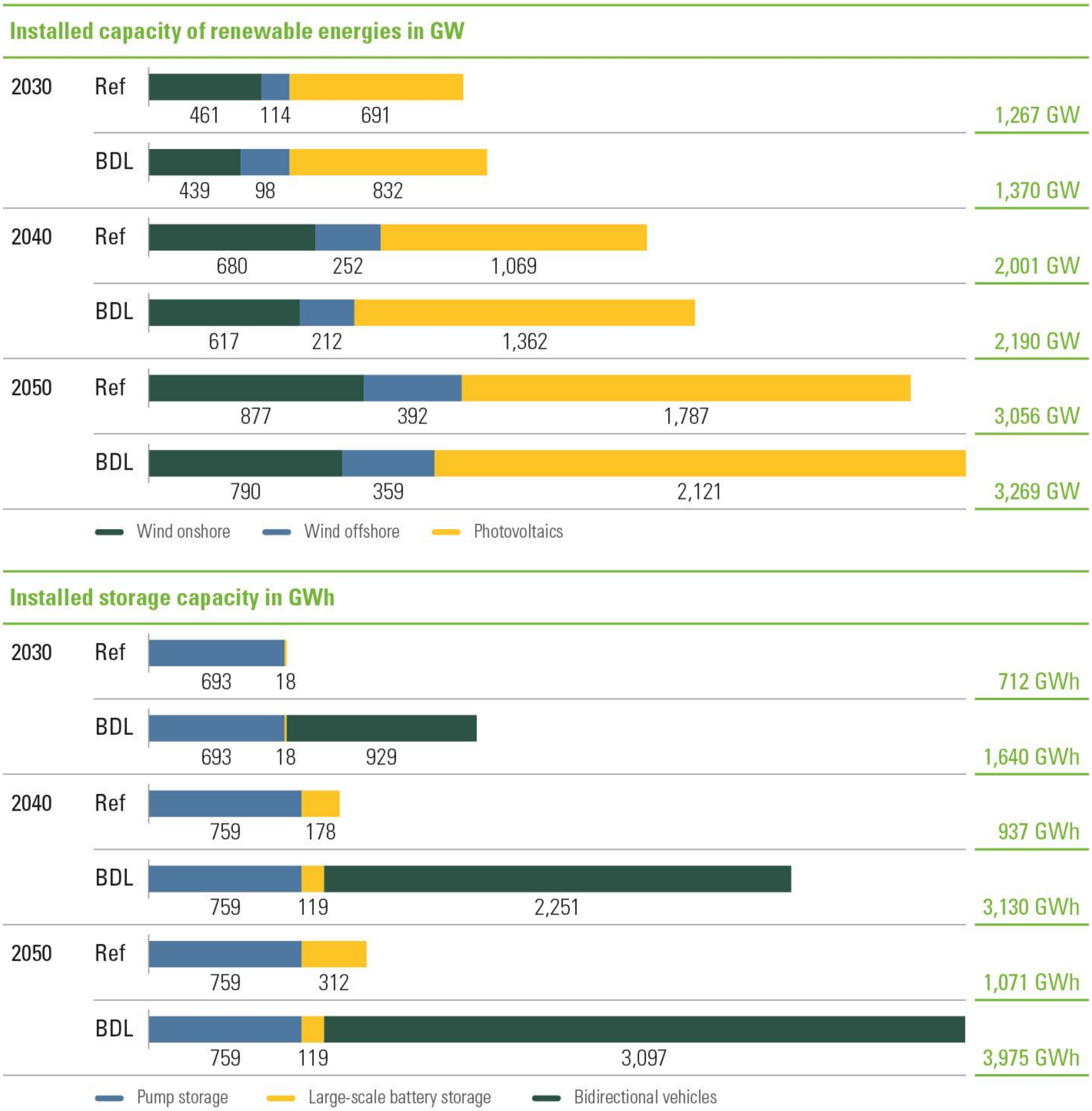

Figure 5: Installed capacity of renewable energies, thermal power plants and installed storage capacity of mobile and stationary storage systems in Europe for the years 2030 to 2050 for the two scenarios Ref and BDL. Source: FFE

As part of the BDL project, the effects of bidirectional charging (in particular V2G) on the European energy system were analysed. Selected results are presented above. When considering the overall results of the BDL project, it must be remembered that this is a pan-European analysis. This influences, among other things, the assumed energy distribution as well as the potential for savings, particularly in southern Europe with its high PV potential.

Assuming that around 30% of the electric vehicle fleet could be charged bidirectionally and used as storage for commercialisation, this results in reduced requirements for the construction of peak-load power plants (gas and hydrogen) and large-scale battery storage compared to a reference scenario without the use of electric vehicles ("Ref"). In addition, as part of the BDL project, the Karlsruhe Institute of Technology (KIT) analysed the effects of bidirectional charging on the integration of renewable energies and the avoidance of curtailment of surplus renewable energy volumes.

In affected regions with high renewable energy generation and feed-in (particularly in southern Europe with high PV potential), a reduction in curtailment volumes of up to 20 per cent was shown.

2. Bidirectional charging in the local distribution network

		Grids with expansion requirements 2040
Use case analysis	V2G: Marketing at electricity exchange and TaLS* reduction	71 %
	V1G: Controlled charging with variable electricity tariffs	69 %
	Reference: All Flex options demand-led (e. g. direct charging)	43 %
	V2H: PV self-consumption increase and commercial peak load capping	42 %
Use case mix	Real: Realistic scenario with use case mix (17 % V2H, 13 % V2G, 70 % direct charging)	41 %
	Real, §14a: Realistic scenario and §14a EnWG (draft: fully flexible, intervention duration 2 h)	32 %

Figure 6: Overview of the grids with expansion requirements for the different use cases for bidirectional electric vehicles and battery storage in 2040.

*TaLS: Taxes, levies, surcharges

Overall, the BDL project shows different effects on the grid load depending on the use case and the assumed participation of all vehicles in these use cases. On the one hand, bidirectional charging can slightly reduce the network load if self-consumption is increased, but can also significantly increase it if purely tariff-based optimisation is carried out using variable prices without taking the local network situation into account.

The effects on the need for expansion in the distribution grids determined as part of the BDL project, illustrated using a distribution network as an example, are characterised by the increasing simultaneity in the charging and discharging of electric vehicles with the use of central control signals (variable electricity tariffs, day-ahead/intraday prices, control signals for the provision of ancillary services). The following results can be derived from this example:

1. The electrification of the transport and heating sector by 2040 will lead to a need for expansion in 43% of the low-voltage networks without utilising the flexibility of demand-led operation.

2. This expansion requirement will be significantly increased (to 69% of the grids) by controlled (unidirectional) charging (V1G) with dynamic electricity tariffs, which, assuming that all electric vehicles participate, will result in high simultaneity. Dynamic electricity tariffs must be offered by every electricity supplier from 2025.

3. Bidirectional charging (V2G) increases the expansion requirements in this scenario to 71% due to the higher flexibility.

4. Mixing the V2H and V2G use cases (real; participation rate of 30% of vehicles) leads to slightly lower expansion requirements than demand-led charging (41%).

5. The need for expansion can be reduced in particular through targeted intervention by distribution network operators (Real, §14a; see discussion on EnWG §14a) or dynamic network charges. However, these two aspects should be viewed independently of the issue of bidirectional charging.

6. The results presented show that there will be a considerable need to expand the grid in the coming years due to increasing electrification at the low-voltage level. In addition to the electric vehicles considered in detail here, heat pumps, which have high simultaneities in winter, are often responsible for this.

3 Use cases from the perspective of customers

This chapter looks at the applications and use cases from the customer's perspective, the key drivers and obstacles for bidirectional charging and possible economic potential. It also proposes measures for concrete implementation in these areas.

3.1 Overview of use cases

In general, bidirectional charging enables the user to utilise the vehicle as an electricity storage device in various ways for their own benefit. The possible applications for customers and users can be differentiated according to the part of the energy system from which electricity is drawn or fed back:

1. From/into the **customer's household/local network** (behind the grid connection point with electricity meter of the electricity supplier or metering point operator, also "behind the meter").

2. Drawing/feeding from/into the **public electricity grid** (with distribution and transmission grids, also "front of the meter").

In In this context, the following use cases are **grid-connected**, i.e. not separate from the electricity grid:

- V2H (vehicle-to-home) with **increased self-consumption, tariff-optimised** charging and emergency power supply

- V2G (vehicle-to-grid) for the **energy market and system services**

- V2B (vehicle-to-building) such as for **load/fleet management in companies**

In addition, there are applications that take place as V2L (Vehicle-to-Load) or as stand-alone network operation **decoupled from the grid**, i.e. separate from the electricity grid. However, this document focuses on grid-connected use cases, as this is where the greatest implementation hurdles exist.

The Advisory Board considers V2H and V2G to be the most relevant use cases for the customer. These are therefore analysed below. The V2B use case is also analysed.

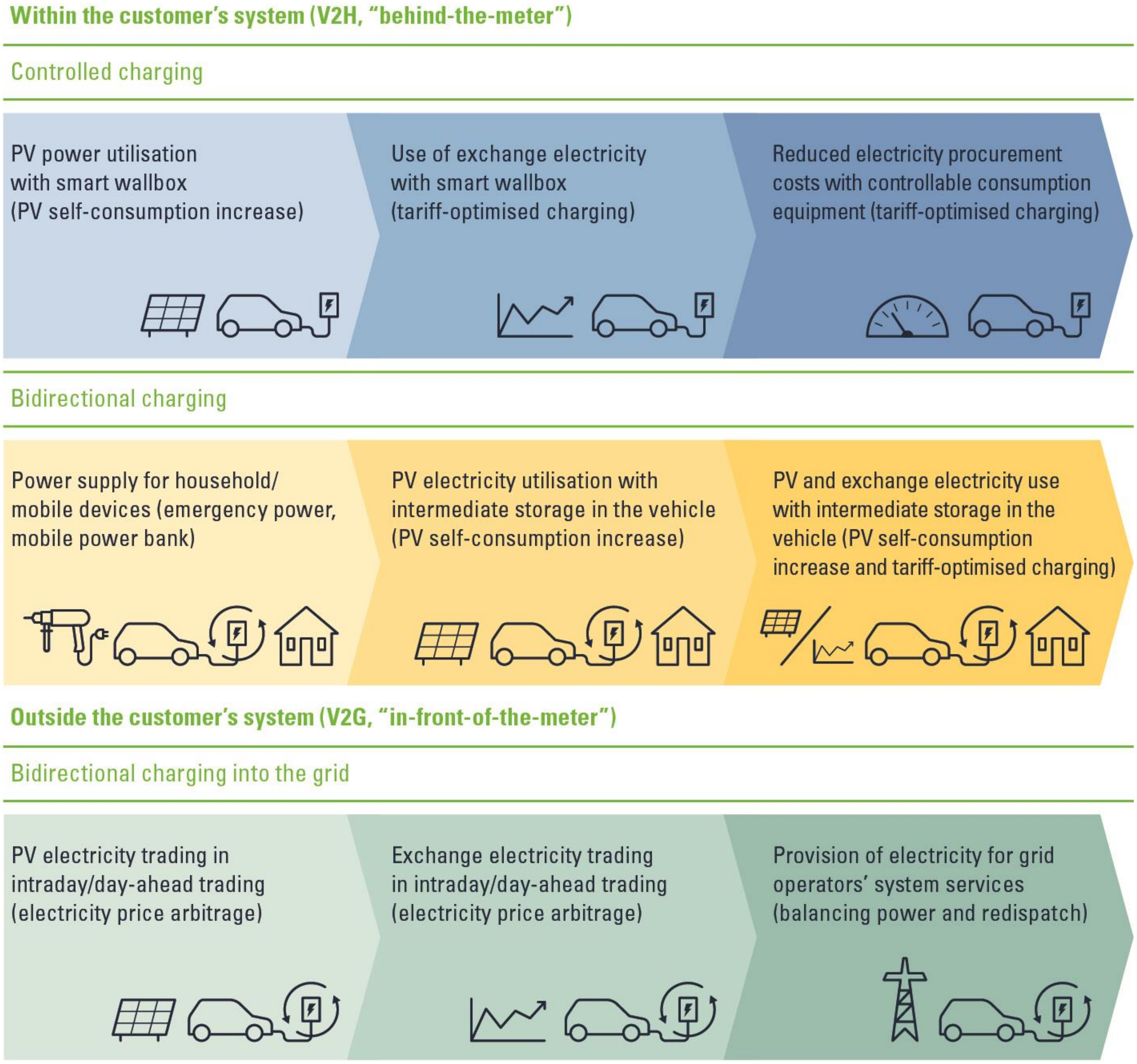

Figure 7: Bidirectional charging use cases. Source: ADAC

3.1.1 Vehicle-to-Home (V2H)

The term V2H covers the use cases of increasing self-consumption and tariff-optimised charging/discharging into the local grid (*behind the meter*).

In the case of **self-consumption optimisation**, the storage system of the electric vehicle and the PV system are used to optimise the household's grid consumption. If there is a surplus of electrical energy from the PV system, the vehicle is charged – if one is available. If the household subsequently draws power from the grid, the vehicle is discharged – if possible – to such an extent that the household load can be met. In this way, grid consumption (and consequently also the level of grid charges and grid levies) can be minimised.

From a regulatory perspective, this use case is already possible, but requires the individual authorisation of the respective network operator from an output of 12kVA (see above).

Relevant factors influencing V2H include the output of the PV system, household electricity consumption, the feed-in tariff, the plug-in behaviour of the electric vehicle, the discharge capacity of the vehicle battery, the availability of green electricity and its seasonal and local dependency. Further potential for V2H arises from the interplay of heat pumps, falling feed-in tariffs and rising electricity prices.

The **tariff-optimised charging/discharging** use case considers the use of time-variable electricity tariffs by charging at times when electricity prices are low and discharging the vehicle battery to supply the household at times when electricity prices are high. The aim is to procure energy as cheaply as possible by shifting charging to low tariff times and supplying the household load from the vehicle battery at high tariff times.

In the **island (grid) operation** use case, a local grid is operated without a connection to the electricity grid, e.g. during an outage of the distribution network or if such a network is not available. In this case, the electricity from the vehicle is fed into the local grid to supply a household with electricity and thus enable temporary self-sufficient operation. Switching to off-grid operation by disconnecting from the grid is done either manually or fully automatically. This use case can therefore increase the security of supply.

For the sake of completeness, **Vehicle-to-Load (V2L)** and **Vehicle-to-Vehicle (V2V)** are also briefly outlined in this context. These use cases describe the supply of a single consumer from a 230V AC socket in or on the electric vehicle or the direct charging of an electric vehicle from another electric vehicle.

3.1.2 Vehicle-to-Grid (V2G)

The term V2G is used to describe use cases in which electricity is drawn from the public electricity grid (*front of the meter*) and fed into it.

It is possible for several V2G use cases to be realised together and offered via contractual partners/aggregators. These use cases must be considered in a comprehensive manner from the user's perspective. Further development of the legal framework is required in order to be able to utilise these use cases.

From the users' perspective, it is essential to enable the generation of financial added value. In this respect, the aim is to charge and temporarily store as much low-cost energy as possible so that it can be utilised profitably at a later date in a competitive environment. Times of low electricity prices are also often characterised by a high proportion of renewable energies. This means that V2G use cases can offer potential for additional flexibility and for the integration of renewable energies. However, the extent of the potential is a matter of debate.

The following figure from the BDL project shows the possible effects of bidirectional charging ("bidi") on the CO_2 emissions of electric vehicles compared to unidirectional uncontrolled and unidirectional price-controlled charging ("uni").

* German energy system in the respective modelled year; number of EVs 12.9 million in 2030 (of which 50 % uni, 50 % BiDi), 30.3 million in 2040 (of which 29 % uncontrolled, 21 % uni, 50 % BiDi) and 37.4 million in 2050 (of which 50 % uncontrolled, 50 % BiDi)

** Emissions per vehicle result from the modelled charging and discharging profiles with an annual mileage per unit and year: 14,052 km in 2030, 13,763 km in 2040 and 13,484 km in 2050

Figure 8: Influence of the charging strategies on the vehicle's operational LCA emissions

1. Controlled charging reduces emissions by charging at times with low emissions (and low electricity prices).

2. Bidirectional charging partially leads to negative emissions by charging at times with low emissions (and low electricity prices) and discharging at times with high emissions (and high electricity prices) displacing the use of conventional power plants. (Simple calculation based on: Emissions charging processes - emissions discharging processes.)

3. the effect is more pronounced in absolute terms in the 2030 system than in 2040/2050, as increasingly fewer emissions will be emitted in the electricity system (and therefore fewer can be reduced). On the other hand, the value of a reduced kg of CO_2 is higher in the 2040/2050 system, as the reduction of CO_2 emissions becomes increasingly complex.

4. Furthermore, the impact will be greater in Germany in 2030 than in France, for example, as the electricity mix in France has fundamentally lower average specific emissions due to nuclear energy.

5. Taking the expected CO_2 emissions in Germany in 2030 into account, the savings from bidirectional charging represent a further but altogether rather small component in achieving the target.

V2G use cases typically involve aggregating (bundling) a large number of electric vehicles capable of feeding energy back into the grid and marketing the resulting amount of energy in a centralised manner. This is done via contractual partners and aggregators who can offer or utilise the flexibility in various markets.

The following energy market products exist for marketing the feed-in from vehicles:

- **Intraday**
- **Day-Ahead**

In addition, the following grid-serving products exist for transmission system operators (TSOs):

- Control reserve (FCR, SCR, MCR)
- Redispatch (3.0)

Finally, the following grid-serving product exists for distribution system operators (DSOs):

- Grid service in the distribution network

3.1.3 Vehicle-to-Building (V2B)

The **V2B use case** is a local use case with several vehicles and with registered load measurement (RLM) at a (company) location.

Here, the feed-in-capable electric vehicles are charged and discharged in a tariff-optimised manner or optimised to the yield of a local power generation system (e.g. PV system) in order to increase the power generation system's own consumption and minimise electricity consumption in certain time windows. In addition, the peak load can be reduced, with the electric vehicle being charged at times of low load and discharged at times of peak load, with the aim of reducing the maximum load (on average over a quarter of an hour) in the billing period (month/year). The source of revenue is a reduced power price that is charged for the maximum load.

3.1.4 Preliminary conclusion on the subject of use cases

The Advisory Board assumes that a combination of V2H/V2B (self-consumption optimisation and tariff optimisation) and V2G is likely to become established. Among the various use cases, V2H/V2B will initially establish itself on the market; in the medium term, V2G will develop on the market via aggregators or service providers. The joint use of a PV system, domestic storage and a bidirectional e-vehicle can lead to greater economic efficiency for users.

However, the integration of the home and electricity market and the consideration of mixed forms also result in requirements for tax and regulatory framework conditions (see also Chapter 5).

3.2 Drivers and barriers for user motivation

The motivation of users and the associated revenue potential are heavily dependent on vehicle and wallbox parameters, encumbrances on a property (e.g. easements), market prices and user behaviour. Here, too, a distinction can be made between user groups (vehicle users, homeowners, vehicle fleet/fleet, etc.). The following are the most important drivers and barriers to user motivation:

Drivers	Barriers
- Security/self-sufficiency (e.g. in connection with heat generation)	- Availability of vehicles & BiDi wallboxes, acquisition costs for BiDi wallboxes - Lack of non-proprietary, interoperable solutions including implementation of the necessary interfaces
- Increase in self-consumption: Intermediate storage and utilisation of self-generated energy vs. grid supply, reduction of carbon footprint, direct participation in the energy transition, heat generation synergy	- Warranty and terms of use - Vehicle battery (number of charging processes, service life restrictions, ...), additional costs for using the functionality
- Increasing the cost-effectiveness of electric vehicles through revenue potential, marketing of storage capacity	- Data protection/security/trust
- Increasing cost-effectiveness at system level (e.g. replacement for home storage)	- System complexity, need for education, legal ownership clarity of vehicle and use of energy, tax treatment (charging/transport/use) - Data availability/utilisation of internal vehicle data in relation to the battery for HEMS control

3.3 Revenue opportunities and possible incentives

With the right user motivation, users have the following specific revenue opportunities:

Savings opportunities from V2H, PV self-consumption optimisation

- Optimising self-consumption leads to lower grid consumption with a corresponding reduction in the feed-in of renewable energies. The savings result from the delta between the electricity tariff and the EEG remuneration or direct marketing.
- From tariff-optimised charging/discharging: Grid consumption and charging of the EV is placed in the low tariff timeslots, in high tariff timeslots electricity is drawn from the EV for household consumption, thus avoiding grid consumption in the high tariff timeslot. Savings are made by avoiding consumption during high tariff periods.

Savings opportunities from V2B peak load capping:

- Avoidance or reduction of the peak load, which is used to calculate the power price component in the electricity bill.

Revenue opportunities from V2G:

- Customer contributes the flexibility and storage capacity when charging their own EV for marketing in an "aggregator" business model. The revenue generated here is paid out to the customer on a pro rata basis. In principle, this marketing is possible both independently of the existing electricity supply contract (in which case balancing group equalisation between the supplier and aggregator is required) and in combination with an electricity supply contract. In the first case, the customer would (as of today) become a small business under tax law, in the second case this would not be the case, as the revenue generated would be offset against the electricity procurement costs in the electricity bill.

Incentivisation options:

- **A greater level of creditability of green electricity** for charging and the consideration of bidirectional charging in the context of **GHG quotas**
- **Reduction of TCO (differentiation according to use case):**
  - Funding support for V2G vehicles
  - Funding support for bidirectional wallboxes
- Review of income and business tax conditions for V2G revenues

In order to be able to utilise incentivisation opportunities, appropriate framework conditions must be created, which are discussed in more detail in Chapter 5.

3.4 User perspective

The following section outlines the possible concerns that (potential) users of bidirectional charging may have. These reservations must be taken into account when considering how bidirectional charging can be made possible without discrimination.

1. General knowledge relating to bidirectional charging

The technical and legal issues surrounding the use of bidirectional charging are complex and can act as a deterrent to potential users. One solution could involve the relevant stakeholders providing information on bidirectional charging in an understandable and harmonised process with the help of low-threshold comparative examples. This requires targeted and timely preliminary communication that, among other things, realistically demonstrates potential and ensures early differentiation between V2H and V2G in order to reduce complexity. Any promises made in advertising or product information must be kept.

2. Flexibility and mobility restrictions (technical and contractual):

With regard to flexibility restrictions, concerns could arise that the available range is restricted by bidirectional charging to such an extent that the usual or expected mobility can no longer be guaranteed. One solution could be that individual and time-dependent minimum ranges and target charge levels can be adjusted by the user at any time. They need the certainty that the values set by the charging app, such as departure time and minimum range and minimum charge level, will be adhered to at all times. To this end, it must be ensured that the vehicle data required for this can be accessed. The data collection required for this is GDPR-relevant and must be anchored in the terms of use (data protection concept).

Additional contracts to be concluded with suppliers/aggregators in order to use bidirectional charging could unsettle users. One solution could be to offer customised, flexible contract modalities for the customer, where it is possible to temporarily not use bidirectional charging.

3. Financial concerns

Potential users may be concerned that the use of bidirectional charging will result in higher investment and operating costs (e.g. due to the purchase of suitable charging equipment or home energy management systems). It may be unclear to them in advance what the cost-benefit ratio will be. One solution could be to show users example investment and operating cost calculations as well as an individual (potential) revenue situation in advance. Overall, the total costs that the user may incur must be presented transparently. In this context, the prices and revenues for charging and discharging must also be made transparent and comparable (e.g. displayed via an app).

4. Transparency of use

Users must be able to see how much was charged or discharged and when, and what benefits or added value were generated. Internal vehicle data relating to the battery, such as the charging and discharging data including charging cycles of the vehicle battery, must be fully and transparently traceable for users and the service providers they commission. Contact persons must be available in case of queries. Failure to do so may present an obstacle to the practical use of bidirectional charging.

5. Risk of loss of warranty/excessive reduction in revenue potential

Users may fear that the increased load on the vehicle battery due to the use of bidirectional charging could result in a restriction of the warranty and reduced arbitrage profits due to a reduced number of cycles on the part of the OEM. One possible solution would be clear warranty conditions that include bidirectional charging and indicate clear utilisation paths.

6. Data protection

Concerns could arise that users' data privacy could be undermined and that the technology used for bidirectional charging enables data misuse. One solution is to ensure that market participants only receive the data required to fulfil their tasks in all of the above points. Users must be able to find out at any time who is using which data and why, and must be able to determine to whom they wish to transfer data usage. The technology used must fulfil common security requirements (see BSI certificate for SMGW, MsBG).

7. Technical functionality/security

There may be concerns that system components (wallbox, PV system, vehicle, HEMS, etc.) are not or only partially compatible with each other, that certain services are not possible and that updatability is not guaranteed for a long period of use.

8. Ownership of vehicle/feeding in electricity from third parties

Users who are not the owner of the vehicle, e.g. because they lease the vehicle or use a company vehicle, could fear an unclear legal situation or, for example, feed electricity charged at the employer's premises (free of charge) back into the grid at home. For possible solutions on the vehicle side, please refer to point 6. Legal and taxation issues must be clarified with regard to feeding electricity into the grid.

9. Lock-in effects / reusability and exchangeability of charging equipment

Users may be concerned that they will be permanently tied to one service provider. The solution is the swift replacement of proprietary systems with interoperable solutions from the vehicle to the SMGW and the avoidance of barriers to market entry. Subject to the respective contractual agreement, users must be able to commission different aggregators to market their flexibility.

4 Current status of necessary national and international standardisation for the market-ready implementation of bidirectional charging technology

With the current ramp-up of electric mobility, market functions that can be applied to customers are becoming increasingly important. High expectations therefore lie in the use of bidirectional charging technology, which should offer customers the opportunity to participate in the energy market as so-called prosumers. Bidirectional charging offers a wide range of technical solutions for various applications. However, there is a long way to go from proof of concept of technical feasibility in pilot projects to interoperable, cross-manufacturer applications with standardised, market-ready products, and electrical safety must not fall by the wayside. While most standards for AC and DC charging already have a high degree of maturity, there are still no standardised requirements (either technical or market-related) for the case of feed-in charging that specify feed-in in AC or DC at the present time. Yet it is important to realise that technological implementation on the vehicle or infrastructure side alone is not sufficient for a market-ready application. Rather, different areas must interact with each other.

These include:

- Car manufacturers
- Manufacturers of charging equipment
- Manufacturers of energy management systems
- Grid operators
- Operators of charging facilities

Market-ready systems require the existence of an **electrically safe, interoperable** overall system consisting of vehicle - charging facility - grid connection point.

For commercial operation, there must also be a **secure and reliable market connection** in accordance with network and market requirements, with integration into legally compliant billing systems.

A manufacturer-independent, interoperable, non-discriminatory and widespread feasibility of bidirectional charging is part of an overall picture consisting of the interaction of indispensable international technical norms and standards and the dependence on national technical regulations. These national and international regulations are subject to very different time horizons, which must also be considered in relation to the regulatory framework during implementation.

4.1 Fundamentals of a standardised overall system

A standardised overall system for bidirectional charging comprises the technical and legal framework.

The overarching energy industry legislation and ordinance procedures (EnWG, GNDEW, MsbG) are sufficiently mature. Minor adjustments may be necessary as part of cyclical revisions or amendments. However, these will not significantly change the fundamental course of bidirectional charging.

The requirements of the legal and regulatory framework described in chapter 5 must be translated into technical solutions. This is generally undertaken via technical regulations in the form of standards, application rules, guidelines or specifications.

The aim of standardisation is to define a holistically safe and functionally applicable system. The following areas are the focus of technical standardisation:

- Electrical safety and cross-manufacturer interoperability between **grid connection point, charging device and the vehicle**
- Requirements for the use of legally compliant **billing systems**
- **Communication protocols** for control and digital market connection

Various organisations are involved in the implementation and must make contributions to the overall system in the form of technical requirements.

In addition to the FNN, which draws up technical application rules for network technology/network operation, the DKE is responsible for developing standards for electrical safety, measurement and metering as well as information security in the form of several committees. The VDA NA Automotive draws up standards relevant to the vehicle system. A list of nationally responsible organisations is included in the appendix.

The DKE and VDA NA Automobil constitute national mirror committees to the international organisations IEC and ISO.

4.2 Technical implementation and regulations

From an electrical engineering perspective, a distinction needs to be made between energy feed-in with and without coupling to the public grid. Coupling to the public grid is also present in most applications in the vehicle-to-home (V2H) sector, such as self-consumption optimisation, which means that the grid connection guidelines defined in the FNN must also be complied with technically.

For all applications, regardless of whether the inverter is located in the vehicle or in the infrastructure, the overall feed-in system, consisting of the vehicle and charging equipment, must fulfil the corresponding requirements of the upstream installation and the grid connection.

The technical solutions defined for the supply of individual operating resources are limited to the V2L application, in which individual operating resources are supplied from the traction battery via household or industrial plugs.

The supply of a building from one of these plug-in devices is not envisaged. The use case of feed-in via the DC interface with a stationary inverter is very similar to feed-in from the photovoltaic sector, so that analogue considerations can be used for this case.

As with charging, the alternating direction can alternatively take place in the vehicle. With regard to compliance with the requirements of the grid connection guidelines, a clear assignment of the functionalities between the vehicle and the charging device still has to be made by means of the pending standardisation.

The technical regulations that are essential for energy feed-in are described below. The smart metering system is presented as the components smart meter gateway, smart metering device and CLS control box.

Regulations for the technical implementation via the DC interface

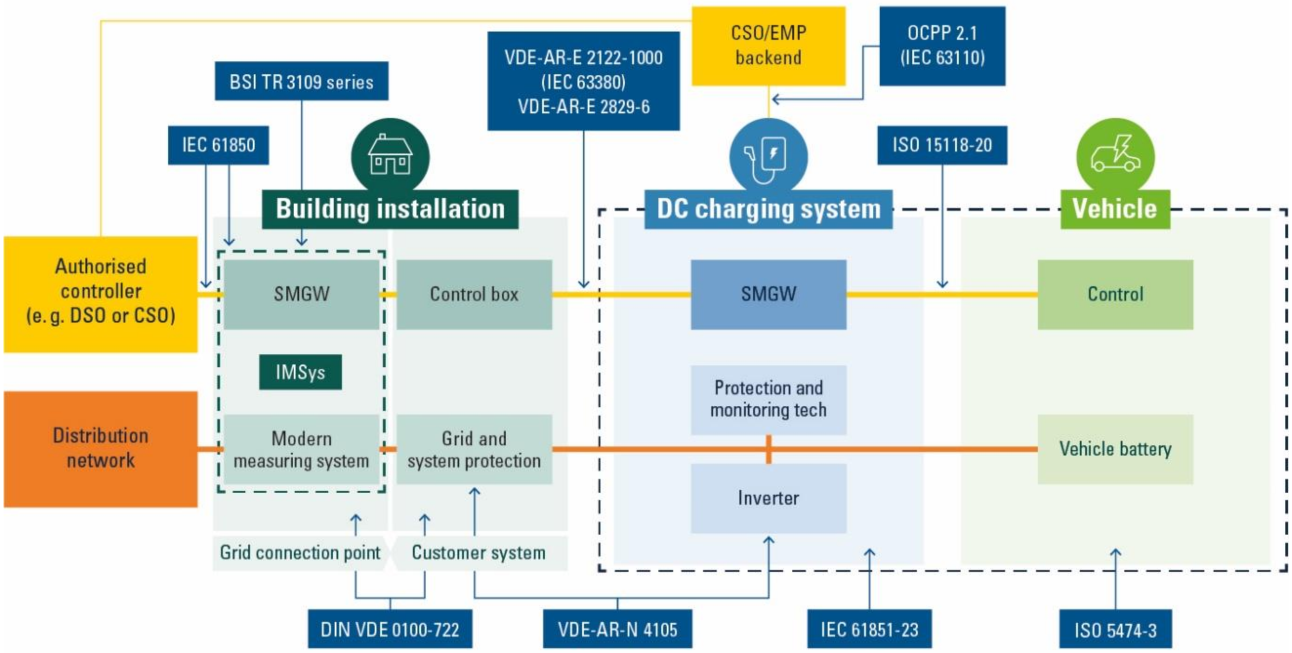

Figure 9: Depiction of regulations on DC feed-in via CCS Combo; Source: Own depiction

Regulations for the technical implementation via the AC interface

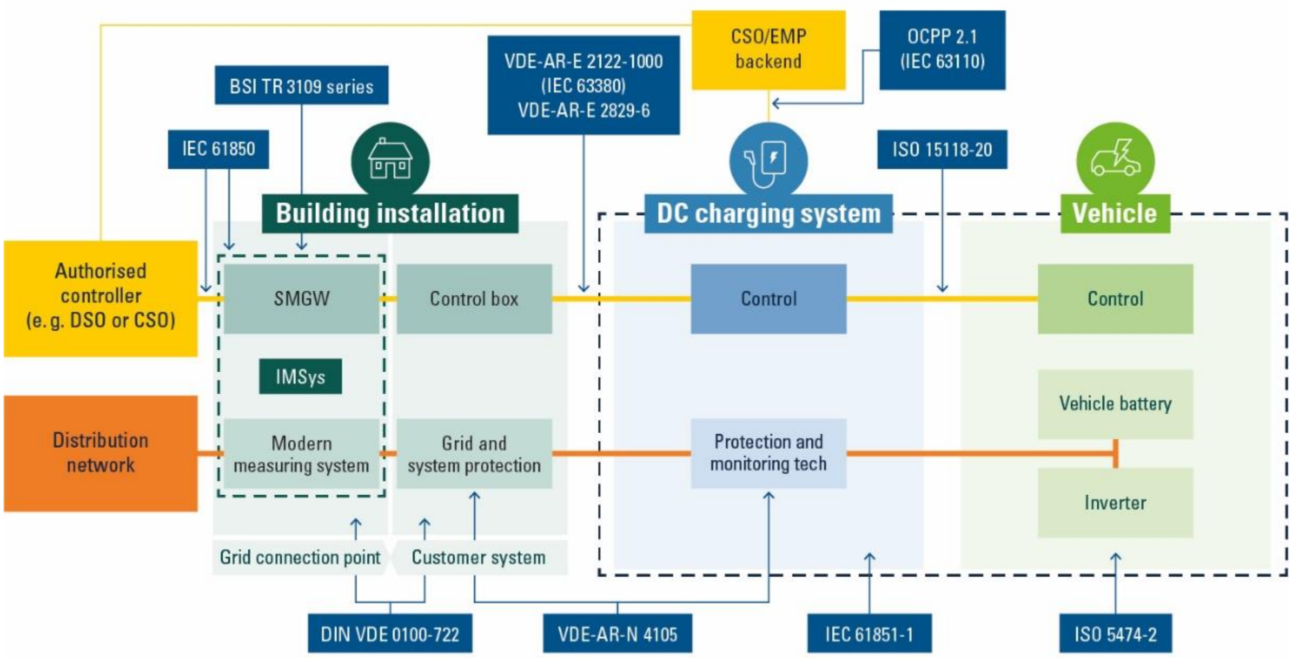

Figure 10: Depiction of regulations on AC feed-in; Source: Own depiction

4.3 Pending work on regulations

From the interrelationships described above, it is clear that bidirectional charging (BDC) is affected by several technical regulations and stakeholders.

On the basis of the systemic interaction, BDC cannot be realised either as a simplified electrical extension in the vehicle (in the case of AC BDC) or through a software update of the charging system. In addition to hardware and software requirements for the feed-in system consisting of the vehicle and charging equipment, far-reaching adaptations in the building installation through to the back-end systems of the charging point operators and aggregators are to be expected.

In order to make bidirectional charging market-ready, the prerequisites must be created by all stakeholders.

In the following, the respective technical status is assessed in relation to pending work in the most important technical regulations in order to enable systemic interaction.

The description is preceded by a list of the most important relevant standards with their planned publication dates. It should be noted that publication as a "final standard" does not generally mean immediate application in the market. IT-heavy standards, in particular, require an adequate period of implementation and validation.

4.3.1 Electrical safety

Charging system (IEC 61851) ↔ Vehicle (ISO 5474-1/-2/-3)

Necessary regulations:

IEC 61851-1 → Publication of Edition 4 i s scheduled for **03/2025**. According to the Plenary Report (WG12), publication is planned for **04/2026**. A correction on the IEC side is therefore expected.

IEC 61851-23 → Schedule for a revision is not yet available. → At least 1-2 years until maintenance was discussed at the plenary session. With an optimal project duration, 12/2027 or 01/2028 would then be possible.

ISO 5474- Parts 1 to 3 → Schedule for the revision is **not yet available.**

- Far-reaching extensions for BDC are necessary in both relevant standardisation bodies for the electrical safety and interoperability of charging facilities and vehicles. These will be implemented as part of the international standardisation work (IEC and ISO) within the designated time frames, but a reliable roadmap for AC and DC feed-in cases must be developed in both sets of standards.
- AC feed-in-capable charging equipment: Development of the requirements as part of the ongoing revision of IEC 61851-1 ED4. Expected publication beginning of 2026.

- DC feed-in charging facility: Development of the requirements in the course of the next revision of Edition 3 of IEC 61851-23, which has not yet started. The finalisation of ED2 of IEC 61851-23 is currently being conducted, in which no requirements for bidirectional charging for the Combined Charging System (CCS) are defined. A timetable for ED3 of IEC 61851-23 is not yet available.
- AC and DC feed-in-capable vehicles: Development of the requirements in the course of the next revision of Edition 2 of the ISO 5474 series and of Parts 1 to 3, which are decisive for conductive charging, which has not yet been started. The finalisation of ED1 of ISO 5474-1/-2/-3 is currently being conducted, in which only the operation of individual equipment (V2L) via the AC charging interface is described. A timetable for ED2 of ISO 5474 is not yet available.

4.3.2 Technical requirements for the grid connection

Grid connection point (VDE-AR-N 4100, VDE-AR-N 4105)

Necessary regulations:

VDE- AR-N 4100 → Amendment 2023 is incomplete for BDC. Next revision is **still open**.
VDE- AR-N 4105 → Final requirements only planned with the update of the **2030** revision.
FNN Notice (with 4105 revision 2025) → Notice is planned with the revision for **2025**.

Currently, grid-connected use cases for V2H must be approved according to individual specifications of the grid operators, as the corresponding regulations for the grid connection will only be processed in the next few years (see following paragraphs), so that an overarching legal presumption of conformity can be assumed. Certification of charging equipment and vehicles is therefore based on analogous considerations to existing regulations, which will be expanded in the coming years to include requirements for bidirectional charging.

All grid-specific regulations are affected by adjustments. VDE-AR-N 4105 is a particular focus. BDC requirements can no longer be taken into account for the 2025 revision; the subsequent relevant revision is scheduled for 2030.

The FNN is currently planning to create a notice (creation from 2024) on the BDC (reference in 4105-2025 to FNN notice). This notice is intended to describe technically permissible solutions. However, it should be noted that an FNN notice cannot have a legal presumption of conformity, as is the case with a VDE application rule with a public objection procedure. With regard to grid connection activities, it should be taken into account that the regulatory requirements for grid supply and grid feed-in systems are currently being revised at European level via ACER. These will have a major impact on the regulations listed under this point in particular.

4.3.3 Digital communication

Vehicle - charging system - backend

Necessary regulations:

ISO 15118-20 → Publication of the amendments is expected for **Q4/2023**.
IEC 63110-1 → Published since 07/2022, but not yet applied in the market. The standard is an alternative to the widespread use of OCPP 2.1, or OCPP 2.2 in the future. The currently initiated IEC integration process of OCPP into IEC 63110 is being observed by the DKE but a target date cannot currently be specified.
IEC 63380-1 → Publication planned for **09/2024**.
IEC 63380-2 → Publication planned for **01/2025**.
IEC 63380-3 → Publication planned for **01/2025**.

ISO 15118 and **IEC 63110** (replacing OCPP in the future) are **essential** as **digital** communication standards for the implementation of BDC and must be considered **in conjunction** with other systems.

- Market-ready implementation and applicability of ISO 15118-20 is not expected **before 2025**. Adaptations to AC BDC are currently being added to Part 20 of the standard. Reliable adoption of the standard was expected in Q4/2023 so that conformity tests for interaction could begin in the course of 2024.
- IEC 63110 applications are currently not foreseeable, but will in any case require a longer time horizon. It is estimated that this will extend into **2026**. It remains to be seen whether OCPP will be integrated into IEC 63110 via an IEC PAS process or whether it will continue as an independent industry standard or IEC standard. Further versions from OCPP 2.0 onwards are geared towards bidirectional charging.

4.3.4 Measuring, controlling and digitalising

Necessary regulations:

BSI TR 3109- Series → Published except for part 5, but **no** information on revisions.
CEN EN 50732- Parts 1 to 3 → Publication of first draft planned for **09/2029**. Publication date still open.
VDE- AR-E 2829-6-1 → Published since **12/2022**.
VDE- AR-E 2829-6-2 → Published since **09/2023**.
VDE- AR-E 2829-6-3 → Published since **09/2023**.
VDE- AR-E 2829-6-4 → Published since **09/2023**.

A prerequisite for full market implementation is the applicability of a smart metering system based on the BSI TR 3109 series. Topologically, this also requires a control box that can send control signals to the charging device in accordance with CLS requirements and, subsequently, metering systems that will be certified in accordance with the European standard CEN EN 50732 in the future. However, control is also possible without a gateway, provided that the requirements for a CLS connection can be implemented.

- Applicable smart metering systems must be able to record bidirectional energy flows without errors with market-ready CLS control boxes and interaction with IT systems of EMPs and CPOs, which is not realistic **before 2026**.

- The finalisation of the VDE-AR-E 2829 series as an implementation of local control of the charging device was recently completed.

- Downstream measuring systems must have certifications (probably in accordance with CEN 50732) in relation to the amount of energy delivered. The European harmonisation and standardisation process that has been initiated will be completed by **around 2027**. However, work is currently underway on a second edition of VDE-AR-E 2418-3-100, which will be able to process bidirectional energy flows, among other things. In terms of content, however, the requirements will be incorporated into the international standardisation project as a priority. This means that Edition 2 of the national application rule would only be considered if a major delay to the international CEN 50732 project were foreseeable.

- Systematic, holistic connection to a market platform, taking grid-relevant situational aspects and the number of more than 850 distribution grid operators into account, will not be possible before **2030**.

4.4 Interim conclusion on technology, standards and interoperability

The availability of market-ready products cannot be mapped via a single set of rules, but must have a defined level of maturity as an overall system for all stakeholders.

Analysing the maturity levels of technical regulations shows that it takes considerable time to develop fully comprehensive solutions.

Nevertheless, it is important to support the standardisation process, which is based on international consensus, and not to take a special path at national level. Only on the basis of international standardisation can German industry survive in international competition and contribute to making Germany the leading market and leading provider in the field of electric mobility.

Under no circumstances should compromises be made in the area of electrical safety, which must be fully guaranteed from the grid connection point to the traction battery across all installation variants.

In this regard, it is equally important to bear in mind that the installation of a bidirectional charging system always represents an intervention in the electrical system, which must be reported to and authorised by the grid operator and must also be performed by an installation company registered in an installer directory in accordance with Section 13 NAV. Particularly in the case of systems with several charging points for which a dynamic load management system was originally installed for the unidirectional charging process, the cable installation must be checked with regard to the maximum expected feed-in currents and grid and system protection must be installed for systems with a feed-in power of > 30 kVA.

5 Required regulatory action

Chapter 5 deals with the regulatory action that must be taken to remove the legal hurdles that still exist for bidirectional charging. From a regulatory perspective, it addresses overarching topics across all use cases as well as topics for V2H and V2G.

5.1 Overarching topics across all use cases

The working group has identified fields of action that are relevant across all use cases and should be addressed promptly in order to remove existing barriers to the use of bidirectional charging, create legal certainty and incentivise investment in bidirectional charging technology. It should be noted that no individual aspects of the overarching issues can be resolved, as each hurdle in itself would at least make the rollout, scaling and non-discriminatory implementation in the market much more difficult or even completely prevent it.

Recommendations for action on technical connection rules (TCR) and technical connection conditions (TCC)

In the view of the working group, the TCRs are currently only adequately defined for energy procurement during bidirectional charging (BiDi) within the framework of VDE-AR-N 4100, but not for feeding energy back into the grid. Analogous to the changes to the "Requirements for Generators" (here: RfG) planned by ACER and currently under discussion, VDE-AR-N 4105 should also explicitly include bidirectional vehicles and corresponding charging facilities. The various future use cases (V2H, V2G etc.) have not yet been taken into account in the relevant standards (requirements for connecting storage systems, electrical installation standards and protection technology etc., reference to WG 4).

As the TCRs generally refer to these standards, this can certainly lead to problems in practice and to the rejection of BiDi applications by the distribution system operators (DSOs), especially if they do not incorporate the planned FNN note on BiDi charging into their own TAB. In addition, there is a risk of different procedures in the respective grid areas, which represents a hurdle for scalability in particular. In future, the legislator must ensure that all DSOs permit all V2X use cases in their TCCs, provided that the corresponding BiDi vehicles and charging facilities fulfil the relevant technical requirements. In order to accelerate BiDi market and technology maturity, it must also be ensured that the VDE adapts/develops the requirements at short notice before the end of the regular revision cycle. In principle, the aim should be to have as standardised and simple a procedure as possible for the grid connection in all grid areas of bidirectional charging points.

Recommendations for action for the regulation of taxes, levies and surcharges for temporarily stored electricity

The working group considers it crucial that mobile storage systems, due to their growing importance for sector coupling between the transport and energy sectors and their ability to offer market and grid-supporting services, benefit from the same concessions as stationary storage systems in terms of exemption from taxes, levies and surcharges, subject to the conditions listed below. In addition, measures should be taken to increase the cost-effectiveness of all types of storage facilities.

The working group sees two possible approaches for realising this for storage facilities:

Option 1: Adjustment of the rules for stationary and mobile storage facilities

It should be noted at the outset that Option 1 represents an opportunity to remove existing regulatory hurdles. At the same time, the working group believes that Option 2 described below represents a more straightforward and pragmatic approach.

Essentially, Option 1 is about ensuring that mobile storage systems receive the same benefits as stationary storage systems. This would require the removal of specific hurdles for all types of storage systems, which are explained below.

Currently, stationary electricity storage systems that are used exclusively for the intermediate storage of electricity from the public grid are exempt from the payment of any grid fees for 20 years after commissioning (according to the amendment to the EnWG for commissioning until 3 August 2029) in accordance with Section 118 (6) EnWG if the stored electricity is fed back into the same electricity grid.

Given that vehicles are involved, the requirement in Section 118 (6) EnWG to feed energy back into the same grid is impractical. Energy fed back into the grid should therefore be exempt from grid charges across the board and not just for 20 years, but permanently if it is fed back into "one grid" (previously: "into the same grid"). In addition, the time limit on the utilisation of an exemption from grid fees is no longer appropriate from today's perspective and should therefore be removed.

Furthermore, an application of Section 118 (6) EnWG to storage facilities that store both grey and green electricity is generally rejected by the DSOs. In order to create legal certainty, it would be necessary to clarify the wording that bivalently used stationary and mobile storage facilities are also covered by the scope of application of Section 118 (6) EnWG and that there is a right to implement balancing by means of a suitable metering and billing concept.

A further legal uncertainty in connection with the application of Section 118 (6) EnWG results from the planned stipulation of the BNetzA regarding Section 14a EnWG: According to the explanatory memorandum to the new direction of Section 118 (6) EnWG introduced in 2011, installations in accordance with Section 14a (1) EnWG should not fall under the scope of application. Due to the planned BNetzA stipulation, all storage systems from 4.2 kW onwards with a grid connection would be defined as a Section 14a system in future. As participation in Section 14a EnWG is no longer voluntary, this could mean that all grid-connected stationary and mobile storage facilities would generally not be able to claim exemption from grid fees in accordance with Section 118 (6) EnWG. Legal certainty should be urgently established here to the effect that stationary and mobile electricity storage systems can fall under the scope of application of Section 118(6) EnWG despite their (mandatory) participation in the BNetzA's Section 14a model.

Moreover, the exemption from electricity tax (Section 5 (4) StromStG) currently only applies to stationary storage facilities. The working group therefore believes that this exemption should be extended to mobile storage facilities within the scope of Section 9 StromStG.

Introducing a specific definition of "mobile storage" into the legal framework would only be one possible solution on the way to greater legal certainty. Alternatively, regulations for mobile storage units could be included in the relevant sections of the law.

Option 2: Extension of the offsetting option in accordance with Section 21 of the EnFG

In the view of the working group, the main starting point is Section 21 of the German Energy Financing Act (EnFG), which already exempts electricity temporarily stored in stationary (para. 1) or mobile storage facilities (para. 3) from the KWKG and offshore levy. The electricity quantities withdrawn ("consumed") and fed in ("generated") at the grid connection point are offset (similar to Section 118 (6) EnWG). In addition, the exemption from grid charges, StromNEV levy and electricity tax must be included here - equally for all storage technologies – with regard to the amount of electricity drawn from the grid for interim storage, so that the total amount of kWh stored in the overall system is only charged once with levies and surcharges. The BMWK should also examine the extent to which the concession levy under Section 48 of the German Energy Industry Act (EnWG) or other levies could also be subject to exemption under Section 21

EnFG. In order to avoid imbalances in the energy system, it must be ensured that the energy drawn from and fed into the grid can be balanced in all cases.

The working group also recommends that the BMWK carry out a comprehensive review of further necessary adjustments to the legal framework for electricity storage systems of all kinds. One example of this is the exclusivity principle enshrined in Section 19 (1) in conjunction with Section 19 (3) EEG.

Recommendations for action in terms of measuring the distinction between green and grey electricity

Electric vehicles are usually charged at different charging points and receive both green and grey electricity. Against the backdrop of the principle of exclusivity enshrined in Section 19 (1) in conjunction with Section 19 (3) EEG, obstacles arise that reduce the appeal of bidirectional charging in both V2H/B and V2G applications. For example, the simultaneous intermediate storage of grey and green electricity currently means that no remuneration under the EEG (feed-in tariff, market premium) may be claimed for the electricity temporarily stored in a stationary or mobile storage facility.

Problem 1

Electricity storage systems that qualify as EEG installations because they exclusively draw renewable electricity are entitled to priority grid connection and priority electricity purchase. The privilege of priority power purchase should not apply to EVs, as it cannot be ruled out that grey electricity is also purchased.

Problem 2:

Operators of PV systems receive an EEG feed-in tariff (see above). This privilege would be lost for the PV electricity temporarily stored in the EV and subsequently fed into the grid.

The problem descriptions above also show that V2H/B and V2G use cases can never be considered separately from a regulatory perspective. The reason for this is the fact that at the time of intermediate storage of electricity in the EV battery – and the payment of taxes, levies and surcharges – the intention to use the electricity for final consumption (e.g. use as traction power) vs. for feeding it back into a grid (e.g. for grid-serving applications) and the associated, appropriate reimbursement has not yet been determined.

To resolve these problems for all V2X applications, the working group therefore recommends abolishing the principle of exclusivity for all types of electricity storage systems and reviewing the extent to which the proof of electricity labelling (Section 42 EnWG) can be simplified. One conceivable simplification would be the previously mentioned authorisation to use MID meters instead of "measurement and calibration law-compliant" measuring devices to delimit electricity quantities, should this be possible under regulatory and consumer protection law.

In addition, the permission of measuring the distinction between green and grey electricity quantities on the basis of a 15-minute balancing at the respective charging point in accordance with Section 21 (3) EnFG, as already described above, would have to be enshrined in law.

In order to realise V2H/V2B applications as soon as possible, but also V2G applications in the long term, it must be examined how the revenue from the provision of flexibility can also be attributed to the vehicle owner. The current legal framework currently sees the charging point as the end consumer, which has proven to be correct and necessary in practice to avoid implementation complexities and must therefore be retained. Based on this, it should be examined to what extent the consumption of a mobile storage unit could be taken into account in Section 21 (3) EnFG in addition to the charging point and – but exclusively for the purposes of this pr-ovision could also be defined as an end consumer in order to incentivise bidirectional charging in a meaningful way for vehicle users.

To ensure the straightforward implementation of V2G use cases and provide an additional incentive, proceeds from V2G use cases could be exempt from income and business tax for private users. The effectiveness of comparable measures can be seen, for example, in the current handling of PV systems up to 30kWp.

Metering and billing should be made possible in both V2H/V2B and V2G applications, for example via MID-compliant meters (similar to the billing of company car drivers). In the case of mobile storage, metering would be easier to implement using the existing metering technology in the vehicle and more favourable for the user. The progress made in the rollout of smart metering systems by the GNDEW is also to be welcomed and absolutely necessary in this context. It would be helpful to develop a metering concept that fulfils the requirements described. This would provide a solid basis for the decision-making needs identified.

Recommendations for action on the transmission of data

Data and use cases relevant to the energy industry in the sense of Section 19 MsbG, which must be processed via the SMGW, have been specified and defined in more detail by the GNDEW. Care must always be taken to ensure that the mandatory use of smart metering systems for data transmission is limited to an appropriate, reasonable and practicable scope.

Despite the expected acceleration of the rollout of the iMS infrastructure, the use of existing measuring devices (e.g. MID meters) and communication channels (e.g. manufacturers' backend systems) for the transmission of data must be taken into account in terms of speed and costs. An obligation to use SMGW infrastructure can only relate to data relevant to the energy industry, i.e. data for standard and additional services relevant to billing, balancing or the grid.

To ensure secure operations, the gaps in the German mobile network in rural areas must be closed quickly.

Recommendations for action on the availability of vehicle data

When it comes to "data availability" from the vehicle, there is currently no standardised regulation across Europe on how the user can access the energy and performance data required for bidirectional charging from the vehicle. For example, the user or their aggregator must be able to access the kilowatt hours available in the vehicle, the energy required up to the target charge level or the charging and discharging power data for feeding energy back into the grid. This is also not specifically regulated by the Data Act, which only provides a general framework on the subject of data. The AFIR also does not regulate the handling of energy and performance data from the electric vehicle by users with sufficient specificity.

In principle, the revision or implementation of the relevant European regulations into national law, such as RED III, is essential. This stipulates that "vehicle manufacturers shall provide real-time in-vehicle data relating to battery ageing, battery state of charge, battery power setting, battery capacity and, where applicable, the location of electric vehicles to owners and users of electric vehicles and to third parties acting on behalf of owners and users, such as electricity market participants and providers of electric mobility services, on non-discriminatory terms, free of charge and in accordance with data protection legislation".

Based on existing preparatory work (BDEW paper PG Data, VDA paper PG Charging), the automotive and energy industries, together with the responsible authorities, ADAC and consumer associations, are setting up an expert dialogue on the energy and power data required for bidirectional charging and their exchange and are drawing up a list of the necessary data points for digital communication.

5.2 Topics for V2H/V2B

Once the approaches described above have been implemented, V2H/V2B solutions could be rolled out and maintained on the market in larger numbers and appropriate incentive and equalisation mechanisms for V2G applications could be implemented at a later date.

This also applies to non-discriminatory and standardised communication between various technical components within a customer's system (home energy management system, battery management system, backend systems) and the vehicle. Charging devices already receive the necessary data from the vehicle via ISO 15118 and can make this data available to other devices such as a HEMS via standardised protocols (e.g. EEBUS) and backend interfaces.

5.3 Topics for V2G

Recommendations for action in the provision of balancing power

Balancing power is likely to remain a small market with limited appeal and relevance for bidirectional charging in the future. Nevertheless, it could be examined whether the current requirements for the provision of balancing power are suitable for decentralised storage systems. In order to be able to utilise the - albeit low - potential in the future, some generally applicable points should be taken into account:

- Creation of automated prequalification processes, e.g. with the help of type prequalification, also for plant pools such as EVs
- Data-saving procedures for the provision of evidence
- Consideration of frequency contatainment reserve (FCR) as an energy use case in the BSI level model

Recommendations for Redispatch

With regard to the requirements for redispatch services, the working group also does not currently see any possibility of providing services via mobile applications. Although little relevance is also seen for this use case, the creation of an incentive-based system - in addition to the existing statutory Redispatch 2.0 – for the voluntary and unbureaucratic provision of redispatch services for decentralised generators / storage facilities / consumers that are not obliged to participate is recommended.

Recommendations for action for grid charges and the activation of market-based procurement of flexibility

In addition to the dynamisation of exchange electricity prices, the creation of time-variable grid charges based on the forecast temporal and spatial grid load can be a useful first step towards more system-friendly grid use. The BNetzA's current proposals for the shaping of Section 14a EnWG with concrete plans for the introduction of time-variable grid charges are largely to be welcomed in this respect. However, it should be noted that this could lead to large-scale and comprehensive synchronisation effects, which would place an additional burden on the electricity grids.

The BMWK and BNetzA should also examine the extent to which Section 14c EnWG can be effectively utilised to introduce market-based solutions for the use of electricity from mobile storage systems for local flexibility services

6 Roadmap

6.1 Preamble

Electric cars are temporary power storage units on wheels. Their full potential for the energy system is realised when they charge bidirectionally and feed electricity back into the grid. If this happens in a suitable market and incentive-based system, a win-win situation can arise. This chapter will outline how this can be achieved. The following section presents the target visions of the stakeholders involved and the steps and timelines that can be used to achieve these target visions.

6.2 Target visions

6.2.1 Target vision 2030 overall

In 2030, bidirectional charging is established on the market without discrimination in all use cases and can be operated interoperably by the user. In macroeconomic terms, the foundation has been laid for bidirectional charging to contribute to system stability, security of supply and climate protection by utilising additional potential for renewable electricity production. Legislators have adapted the legal framework to enable bidirectional charging.

All bidirectional use cases, especially the V2G use cases, are fundamentally possible from a regulatory perspective and the framework of norms and standards is suitable for interoperable use between the various vehicles and charging facilities as well as other components, such as energy management systems. Other identified needs for action have been clarified and scheduled. The manufacturer-specific warranty and terms of use for the vehicle storage system and charging components of the electric vehicle, which may extend beyond the statutory warranty, are considered to be part of the competition and are understood and accepted by all stakeholders as a possible limiting factor for bidirectional use cases.

Electric vehicles and bidirectional charging facilities are available at acceptable prices and are functionally compatible in the use cases desired by customers. The bidirectional charging equipment (wallbox) can be easily installed by service partners and, if necessary, integrated into an energy management system; possible registration processes with distribution network operators are known and can be performed easily and digitally. At the customer's request, the metering point operator must install a smart metering system that covers the metering concepts required for bidirectional charging. Bidirectional charging can be controlled by the user in a customer-friendly, flexible manner and with little effort. They increase the economic efficiency of their energy supply, increase their own security of supply (emergency power) and improve their own contribution to the power supply when using a PV system.

Smart metering systems can be used across the board, partly due to the improved expansion of the mobile phone network, so that complex systems with energy industry applications can be operated anywhere and without relevant restrictions or prohibitive costs.

6.2.2 Target vision 2030 customer/user

The customer/user would like to increase their individual security of supply and self-sufficiency by making use of bidirectional charging. The use of a PV system, a storage system and/or an electric vehicle contributes to a higher degree of self-sufficiency and the possibility of an emergency power supply. In addition, bidirectional charging can improve the economic efficiency of an individual's own energy supply, the vehicle and electric mobility as a whole.

Locally (V2H), this can result from increasing the self-consumption of electricity from the household's own PV system through intermediate storage and later utilisation of self-generated energy instead of grid consumption. If there are large electricity consumers in the household (e.g. heat generation), the potential increases.

However, greater economic efficiency is also possible when electricity is purchased from the grid through tariff-optimised charging/discharging of purchased electricity or through revenue potential from the storage marketing of the battery electric vehicle as well as through no or lower investment in a stationary home storage system (controlled charging and V2G).

This makes electric mobility more economically attractive for users in the long term thanks to advantages in the operating phase.

From the consumer's perspective, a reduction in their own CO_2 footprint and the individual contribution to the energy transition also speak in favour of using bidirectional charging. User investments in the initial phase should be future-proof with regard to the development of standards and norms and should not lead to stranded investments (hardware upward compatibility) or restrictions with regard to interoperability with future systems.

Target vision 2030 **Customer/User**	E-vehicles and BiDi wallboxes are available and functionally compatible in the use cases requested by the customer. The bidirectional wallbox is easy for service partners to install and, if necessary, integrate into an energy management system; possible registration processes with distribution network operators are known and easy to implement. At the customer's request, the metering point operator will install a smart metering system that covers the metering concept required for bidirectional charging. The user can utilise V2H via their own HEMS and easily commission different aggregators to market their flexibility on the energy markets (V2G). The data required for this is provided by the vehicle manufacturers within the specified regulatory framework. The user thus increases the economic efficiency of their energy supply, increases the proportion of self-supply when using a PV system, strengthens their own security of supply (emergency power) and is able to increase the level of flexibility.

6.2.3 Target vision 2030 OEM

Car manufacturers see the use of bidirectional charging as an opportunity to increase the customer benefits of electric vehicles. At the same time, there are macroeconomic advantages due to the possibility of integrating and optimising the vehicle and energy system. The contribution to climate protection through the improved intermediate storage of renewably generated electricity also leads to the greater acceptance of electric mobility.

Target vision 2030 **Automotive and charging systems OEM**	Car manufacturers offer mass-market-capable bidirectional and interoperable electric vehicles and provide their customers and the service providers they commission with the energy and performance data required for bidirectional charging. Bidirectional charging is in demand from customers and is established on the market. The provision of bidirectional charging by vehicle manufacturers has paid off and is being honoured by the market (no stranded investment for OEMs). All BiDi use cases, especially the V2G use cases, are possible from a regulatory perspective and can be operated successfully from an economic perspective. Obstacles that still existed in the middle of the decade will have been removed by 2030. All BiDi-relevant standards have been identified and reviewed by VDE, DKE, etc., and any need for action has been clarified and scheduled. The warranty and terms of use of the OEM for the vehicle storage and charging components of the electric vehicle are part of the competition and are understood and accepted by all stakeholders as a possible limiting factor for charging processes.

6.2.4 Target vision 2030 energy and charging sector

Energy and e-mobility service providers offer customers bidirectional charging in order to provide them with the best possible charging experience tailored to their use case and the effective utilisation/marketing of their flexibility. The use of all BiDi use cases is economically successful and the equal treatment of all storage technologies is ensured. This applies in particular to the exemption from taxes, charges, levies and surcharges. A suitable technical and legal framework, the interoperability of the various systems and non-discriminatory access to the necessary data from the vehicles, among other things, is ensured.

From a grid perspective, bidirectional charging is analogous to the decentralised feed-in of renewable energies, e.g. PV feed-in in the low voltage or wind power feed-in in the medium voltage, which has already existed for many years. Through digitalisation and the expansion of distribution grids, distribution network operators are supporting the integration of bidirectional charging as decentralised feed-in and storage systems for use as a further flexibility potential for the energy market. The necessary business and billing processes (incl. recording load profiles for end consumers) are suitable for the mass market. Distribution system operators utilise the flexibility offered by e-vehicles for system services (control energy).

Target vision 2030

Energy and charging sector

The energy and charging industry sees bidirectional charging as an attractive value-added service for its customers who use electric vehicles, from private customers to fleet operators. Providing added value for users and being able to offer this added value as part of electricity supply contracts, energy or flexibility services, for example, is a priority for the energy and charging industry.

In addition, in an increasingly decentralised and volatile energy world, the energy and charging industry sees the market-based implementation of flexibilities to increase the efficiency of the energy market as a highly beneficial addition. If necessary, this also includes system services and, in the long term, grid-supporting use such as redispatch.

The energy and charging industry therefore supports the realisation of bidirectional charging as a value-added service for users. The aim must be non-proprietary, technical "plug&play" solutions for vehicles, charging and energy management systems as well as non-discriminatory data access options to the vehicle to avoid lock-in effects for users.

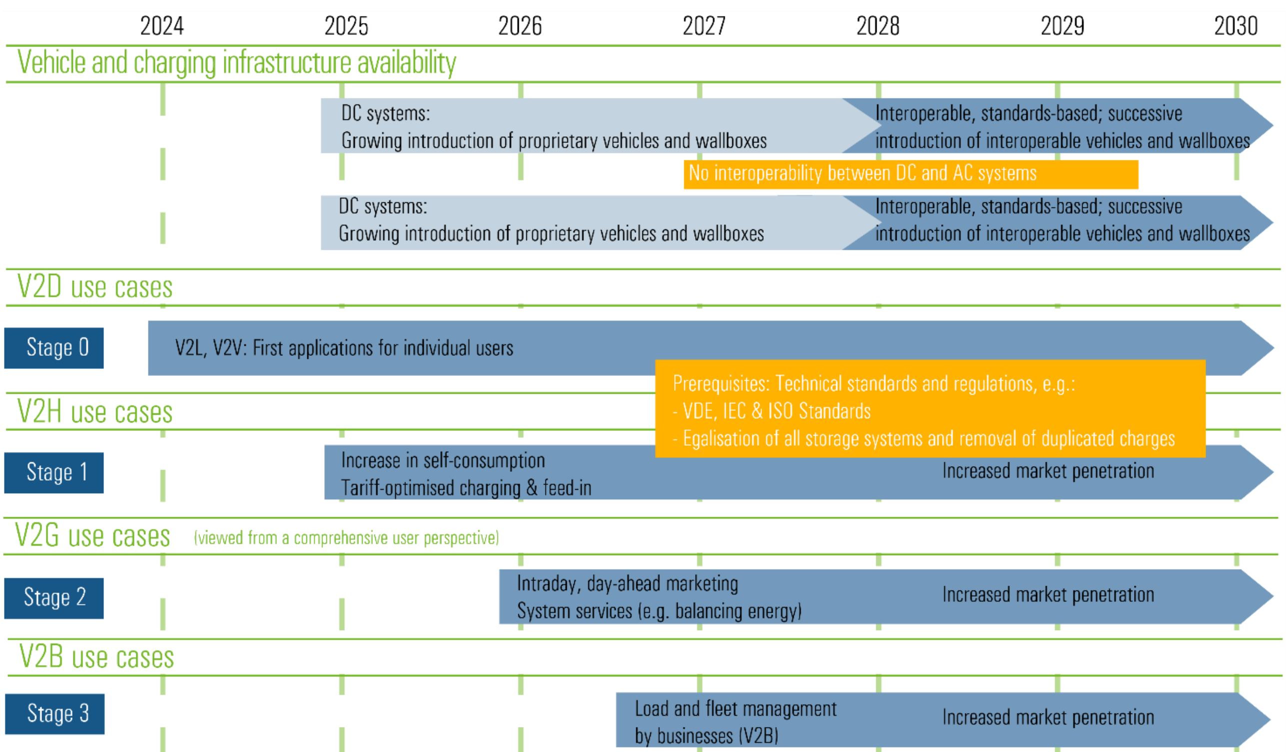

Figure 11: Roadmap overall; Source: Own depiction

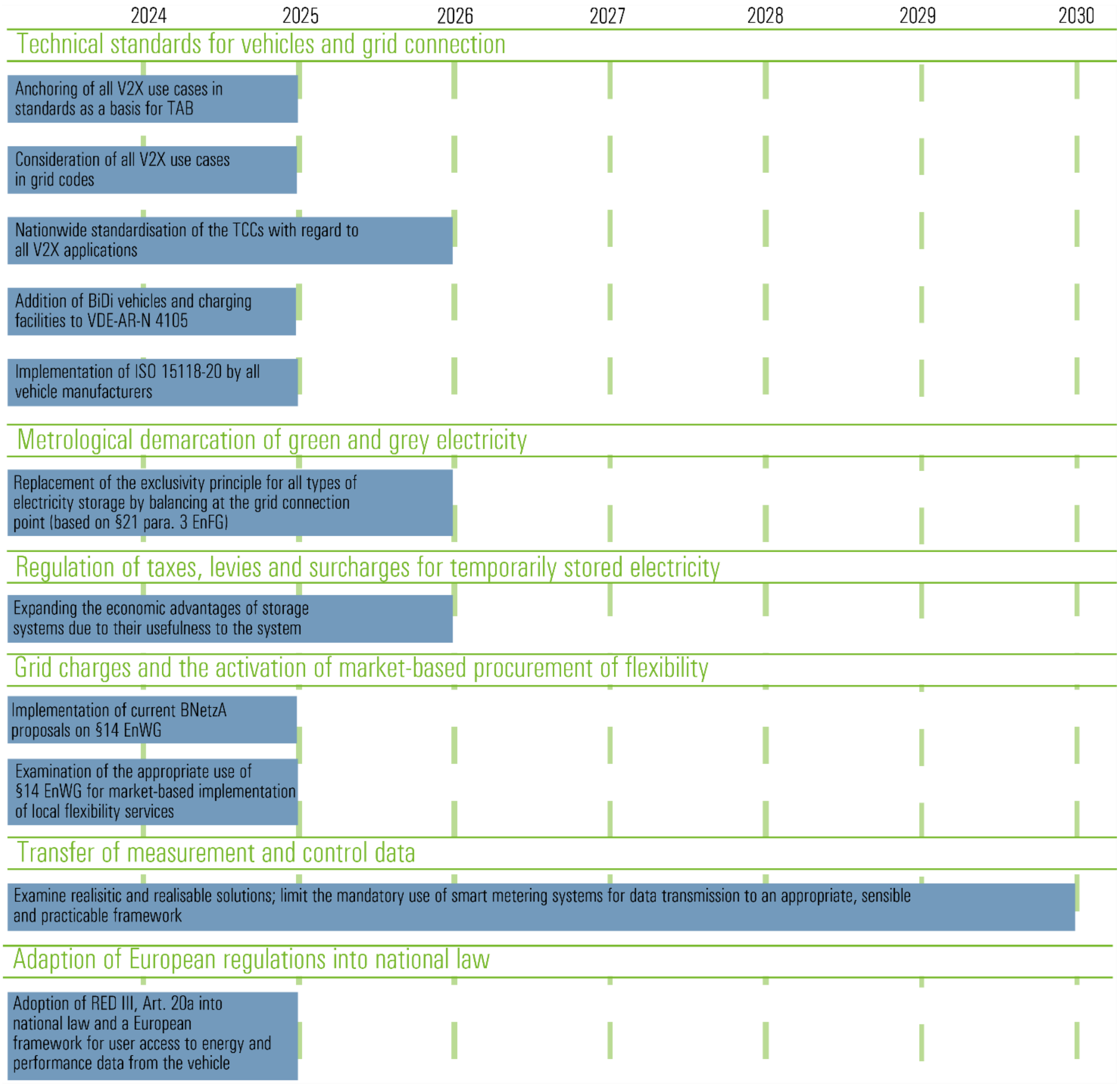

Figure 12: Roadmap extract, technology and regulations

Glossary – Extract

Term	Meaning
Proprietary	In-house development, not (yet) in compliance with accepted technical standards and norms
Interoperability	Compatibility and possible interaction of different systems, generally due to shared technical standards

Appendix

Appendix 1: Available vehicles according to the ADAC

Model	Plug	AC / DC	Art
Cupra Born (with 77 kWh and VW Group software 3.5)	CSS	DC	V2H: According to VW from early 2024 with Wallbox and S10 E Compact home power station from E3/DC / V2G (prepared²)
Genesis Electrified G80 /GV70	Schuko	AC (1-phasig)	V2L, Introduction of V2H and V2G expected in the next generation
Nissan Leaf	CHAdeMO	DC	V2H / V2G (prepared²)
Nissan eNV200¹	CHAdeMO	DC	V2H / V2G (prepared²)
Mitsubishi Outlander¹ / i-MIEV¹	CHAdeMO	DC	V2H / V2G (prepared²)
Hyundai Ioniq 5 / 6	Schuko	AC (1-phase)	V2L
Kia EV6 / Niro EV	Schuko	AC (1-phase)	V2L
MG 4 / 5 / Marvel	Schuko	AC (1-phase)	V2L
Skoda Enyaq (with 77 kWh and VW Group software 3.5)	CCS	DC	V2H: According to VW from early 2024 with Wallbox and S10 E Compact home power station from E3/DC / V2G (prepared²)
Volvo EX90	Schuko / Type 2 / CCS	AC (1/3-phase) / DC	V2L / V2H / V2G (prepared²)
VW ID.3, ID.4, ID.5, ID Buzz (with 77 kWh and VW Group software 3.5)	CSS	DC	V2H: According to VW from early 2024 with Wallbox and S10 E Compact home power station from E3/DC / V2G (prepared²)
Polestar 3	Schuko / Type 2 / CCS	AC (1/3-phase) / DC	V2L / V2H / V2G (prepared²)

¹ Model no longer available
² Refers to V2G

As at: 14.02.2024

Appendix 2: Availability of charging facilities

Manufac-turer	Model descrip-tion	CP	Perfor-mance (DC)	Price (approx.)	Ap-plica-tion	Notes
Wallbox	Quasar	1x CHAdeMO	7,4 kW	4.250,00 €		
Wallbox	Quasar 2	1x CCS	11,5 kW	5.350,00 €		Compatible with Cupra Born models
Kostal	BDL Wallbox	1x CCS	11 kW	3.500,00 €		Q4/2024
ionix	AVA	1x CCS	25 kW	n.a.	V2G	V2G-prepared

evtec	sospeso&charge	1x CCS/CHAdeMO	10 kW (16 A)	12.200,00 €		Distribution in CH
Alpitronic	HYC 50	2x CCS	50 kW	23.500,00 €		
Ambibox	Ambicharge	1x CCS	11kW	4.200,00 €		
Ambibox	Ambicharge 2	1x CCS	22kW	n.a.		
Enercharge	DCW20/DCW40	1x CCS	20/40kW	n.a.		
Volvo	BiDi-Charger	CCS/Typ2 ?		n.a.		announced
E3/DC	E3/DC S10 M					PV inverter + integrated DC wallbox
E3/DC	Edison DC Connect	1x CCS	10 kW		V2H	Announced 2024; in conjunction with or as a retro-fit option for E2 /DC home power stations
eaton	Green Motion DC 22	1x CCS / 2x CCS und CHAdeMO	22kW	n.a.	V2G	V2G capable in terms of hardware
BorgWarner	RES-DCVC125-480-V2G	1x CCS	125 kW	n.a.	V2G	
BorgWarner	RES-DCVC60-480-V2G	1x CCS	60 kW	n.a.	V2G	
dcbel	dcbel r16	2x CCS/CHAdeMO	15,2kW	6.900,00 €	V2H, V2G-ready	
Enteligent	Hybrid DC Bi-Directional Fast EV Charger	1x CCS	12,5/25kW	n.a.	V2G, V2H, V2BESS	
AME	V2G 3p10kW V2X Charger	1x CHAdeMO	10kW	n.a.	V2G	
Ford	Charge Station Pro	1x CCS	19kW	n.a.	V2H	Not yet available in DE; In conjunction with Siemens Smart Infrastructure
Nuvve	RES-HD60-V2G	1x CCS	60 kW	n.a.	V2G	
Nuvve	RES-HD125-V2G	1x CCS	125kW	n.a.	V2G	

Silla	Duke 44	2x CCS	2x 22kW	n.a.	V2H, V2G, V2V	
SolarEdge	SolarEdge Ladestation		24kW			PV inverter + integrated DC Wallbox
Endphase	Bidirectional Wallbox					
Enovates	Single Wallbox	1x Type2	7,4kW (1-phase)/22kW(dreiphasig)	n.a.	V2G	V2G optional for the Residential & Fleet and Professional models
Mobilize	Powerbox		22kW			Wallbox (in conjunction with Renault vehicles of the next generation)

Appendix 3: Bidirectional charging use cases

Name	Revenue location	Customer group	Control	Development in project
Peak load capping			Central	Customer implementation
Increase in own consumption			Local	Customer implementation
Time-based arbitrage (intraday)			Central	Customer implementation
Time-based arbitrage (day-ahead)			Central	Lab
Genuine green electricity (with PPA)			Central	Lab
Frequency containment reserve			Local	Lab
Local grid service			Central	Lab
Redispatch			Central	Lab
Provision of reactive power			Central	Lab
Tariff-optimised charging/discharging			Local	Lab
Fleet management			Local	Lab
Genuine green electricity (CO_2 charging)			Central	Simulation / Konzept
Emergency power supply	-	-	Local	Simulation / Konzept
Powerbox	-	-	-	Simulation / Konzept

At home / SLP customer — Industry / RLM customer — Network / Market / Syste.

Source: FfE: Bidirektionales Lademanagement (BDL). Intelligentes Zusammenspiel von Elektrofahrzeugen, Ladeinfrastruktur und Energiesystem, 2022

Appendix 4: Relevant organisations for the standardisation of bidirectional energy flows

VDE FNN (Forum Netztechnik/ Netzbetrieb)

As part of technical self-administration, the association develops technical application rules for grid integration and grid operation on the basis of a defined process (VDE AR N100).

The topics include system security, digitalisation, communication and connection guidelines. These are the focus of the energy transition and the necessary digitalisation.

In addition to the creation of application rules, the FNN provides information, position papers, studies, specifications and information sheets as documents for the public.

The VDE AR 4100 technical rules (as TCR) and VDE AR 4105 are particularly relevant to the focus on bidirectional charging. Furthermore, the work on the FNN control box as a specification is an important building block for the success of bidirectional charging as well as for the holistic process of the energy transition.

VDA NA Automobil

The VDA NA Automobil represents the standardisation interests of automotive and networked mobility at national, regional and international level. The remit of the VDA NA Automobil encompasses the creation of standards on requirements, interoperability, interfaces, quality and safety in the automotive sector.

This includes management standards and standards for networking motor vehicles with each other and with the infrastructure for their sustainable and optimised use on public roads.

The VDA NA Automobil is also responsible for the networking with other modes of transport and the environment required for road-based mobility as well as aspects of road safety, sustainability, data management, data exchange and the circular economy.

Moreover, the VDA NA Automobil is the body responsible for the standardisation of all equipment for road vehicles and their bodies as well as the standardisation of freight containers (ISO containers).

DKE VDE DIN

DKE Komitee 353 (Electric road vehicles)

DKE/K 353 is responsible for the development of standards for the charging process of electric vehicles. This includes the interface descriptions and requirements for stations for charging with direct and alternating current, wireless charging and battery replacement. The committee also deals with information security when connecting electric vehicles to the charging station.

The committee mirrors the activities of IEC/TC 69 and CLC/TC 69X. The international cooperation of IEC/TC 69 with ISO/TC 22 is reflected nationally in close collaboration with the Automotive Standards Committee (NAA – Normenausschuss Automobil).

The work of the committee is legitimised by EU mandates M/468 and M/533.

DKE Komitee 461.2 (Measuring systems for non-stationary electrical equipment)

DKE/UK 461.2 was constituted in February 2020 and, as the successor committee to DKE/GAK 461.0.21 (Preparation of electrical measuring device-related standardisation proposals for the Regulatory Committee in accordance with §46 MessEG), is responsible for drawing up technical requirements for legally compliant measuring systems within the field of electric mobility.

In addition to returning the specific measuring devices (AC and DC) to authorised working groups within K 461, a key focus of the committee's work is to achieve internationalisation of the national documents at European level in CENELEC (TC13) and to strive for listing in the MID (Measurement Instrument Directive).

DKE TBINK AK SMGW (working group on the activities of the BMWK/BSI on the SMGW)

The TBINK ("Technischer Beirat und Nationale Koordinierung" – "Technical Advisory Board and National Coordination") is a higher-level advisory body of the German Commission for Electrical Engineering (DKE – Deutsche Kommission für Elektrotechnik).

The Advisory Board observes current and existing national and international standardisation projects. It can convene a superordinate working group for large projects or plans that generally affect several committees.

The purpose of convening working groups is to synchronise the technical content of affected committees (K353, K461, K716, K901, K952) into a coordinated DKE position.

In the current federal project on the SMGW, the working group serves to mirror and comment on the ministerial drafts of existing or yet-to-be-developed standards.

DKE UK 221.5 (Future-proof electrical installations)

As a subcommittee of K 221 (Electrical installations and protection against electric shock), this working group defines the requirements for electrical generation systems in the low-voltage grid. The requirements of DIN VDE 0100-722 are developed in the working group DKE AK 221.5.5 (System consideration for the connection of electric vehicles).

Appendix 5: Brief descriptions of the necessary technical system standards and regulations

Below are brief descriptions of the regulations listed in the depictions contained in chapter 4:

VDE-AR-N 4100 (Technical rules for the connection of customer installations to the low voltage grid and their operation (TCR Low Voltage): This VDE application rule "TCR Low Voltage" summarises the technical requirements that must be observed during the planning, installation, connection and operation of electrical systems to the grid operator's low-voltage grid. The "TCR Low Voltage" applies to reference systems and – in conjunction with VDE-AR-N 4105 "Generation systems on the low-voltage grid" – also to generation systems.

VDE-AR-N-4105 (Generation systems on the low-voltage grid)

This VDE application rule VDE-AR-N 4105 specifies the technical requirements for generation and storage systems that go beyond VDE-AR-N 4100 "Technical rules for the connection of customer installations to the low-voltage grid and their operation (TCR Low Voltage)". Requirements for mobile storage systems are not yet included. Feed-in capable mobile systems will be described in a separate note to be prepared in the FNN at the beginning of 2024.

DIN VDE 0100-722 Installation of low-voltage systems, Part 722: Requirements for special types of premises, rooms and systems – Power supply for electric vehicles: The special requirements contained in this part of the DIN VDE 0100 (VDE 0100) series of standards describe:

- Circuits for the supply of power to electric vehicles
- Circuits for the feeding in of electrical energy from electric vehicles

As at now (08/ 2023), the requirements have not yet been specified in detail and will be further developed in the international format provided for this purpose.

IEC 61851 (Conductive charging systems for electric vehicles) serves as a series of system and product standards for conductive charging systems and focuses on electrical safety requirements for the charging network consisting of the vehicle and charging equipment.

For AC charging and feed-in systems, the basic requirements must be defined in Part 1 of the series of standards. For feed-in DC systems, the existing requirements of Part 23 of the series of standards must be extended or redefined.

IEC 63110 parts 1 to 4 define the communication between the charging device and the backend. It is intended to replace the industry standard OCPP in the future, or the requirements of the OCPP will be transferred to the standard.

IEC 63119 defines roaming and authorisation use cases based on IEC 63310.

VDE-AR-E2122-1000 ((Standard interface for charging points/charging stations for connection to local power and energy management) (currently in transition to IEC 63380). Describes the connection to a local energy management system and is a basic prerequisite for the controllability via the smart metering system required by EnWG §14.

VDE-AR-E2418-3-100 ((Metering systems for charging facilities) (currently in transition to **CEN EN 70532**). Describes minimum requirements for metering systems in electric mobility that comply with calibration law. The preceding German work since 2017 is currently being transferred into a European standard against the background of the harmonisation process of EU regulations.

BSI TR 3109 Series defines the requirements for a smart metering system for implementation as a German solution for market and grid-supporting control processes.

ISO 15118 Series, defines a digital high-level communication interface between the vehicle and the charging system as a standardisation package. The current focus is the upcoming implementation of ISO 15118-20 (Communication interface between vehicle and charging station – Part 20: Requirements for the second generation of the network and application protocol). This part of the standard extends the ISO 15118 series of standards to enable future functions, including bidirectional charging.

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Further information on the Advisory Board can be found here:
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