Bidirectional Charging – Worth the Hype?

Exploring Use Cases from Vehicle-to-Home to Vehicle-to-Grid

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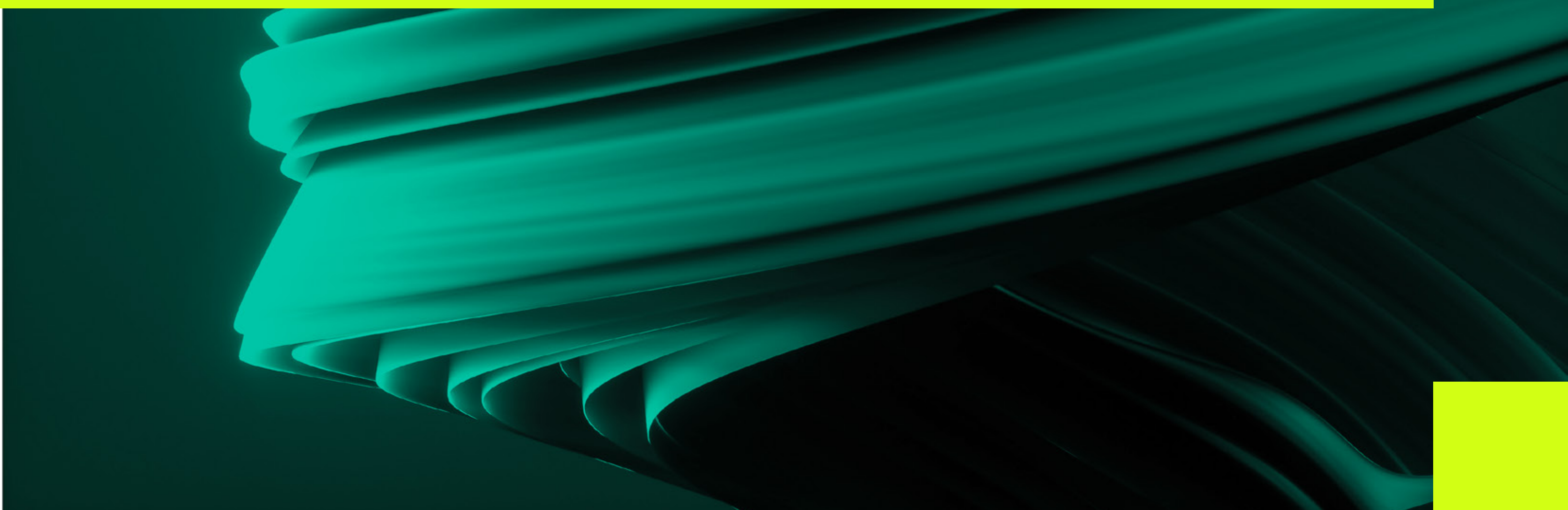

WHAT TO EXPECT

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WHAT TO EXPECT

LIST OF ABBREVIATIONS

DER	Distributed Energy Resources
DSO	Distribution System Operator
E2E	End-to-End
EV	Electric Vehicle
FCR	Frequency Containment Reserve
HEMS	Home Energy Management System
OEM	Original Equipment Manufacturer
PV	Photovoltaic
RES	Renewable Energy Sources
TSO	Transmission System Operator
V2B	Vehicle-to-Building
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
VPP	Virtual Power Plant

WHAT TO EXPECT

BIDIRECTIONAL CHARGING: DRIVING GRID RESILIENCE & REVENUE GROWTH

The transformation of our energy and mobility systems is accelerating, and bidirectional charging is emerging as a pivotal technology in this evolution. As the energy landscape shifts toward greater sustainability and efficiency, bidirectional charging — where electric vehicles (EVs) can both draw power from and return power to the grid or other loads — offers transformative potential. This capability not only enhances grid resilience and stability but also opens up new revenue streams for end consumers and market participants such as energy providers and Original Equipment Manufacturers (OEMs).

CHALLENGES

Harnessing this potential is a complex task. Market participants face significant challenges. The implementation of bidirectional charging involves navigating intricate technical frameworks, evolving regulatory landscapes, and determining viable commercial strategies. The timeline for product launches and widespread adoption remains uncertain, further complicating decision-making for stakeholders across the value chain. Unsurprisingly, we only see very few, proprietary offers on the market today – despite the topic being already discussed for over 20 years.

WHAT TO EXPECT

YOUR GUIDE TO BIDIRECTIONAL CHARGING: KEY USE CASES SIMPLIFIED

This publication is designed to **help you navigate the complexity of developing profitable bidirectional charging products** with confidence. We provide a **comprehensive exploration of the key use cases for bidirectional charging from a German market perspective** focusing on passenger vehicles, each presented in a concise one-pager format. For every use case, we offer:

Detailed description:
Clear explanations of how each use case works and the benefits it provides.

Maturity assessment:
Insight into the current technological readiness, regulatory environment, and business viability.

Barrier analysis:
Identification of the main obstacles that must be overcome across technological, regulatory, and business dimension.

Market insights:
A snapshot of the market landscape to help you understand the current state and future potential.

Our goal is to **leverage our knowledge and capabilities** to help you **unlock the full potential of bidirectional charging**, bringing innovative solutions to life.

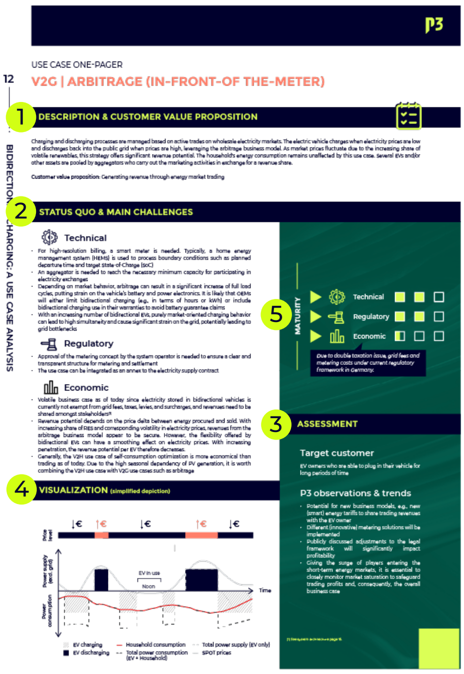
We are happy to discuss the results with you.

Together, we can **turn the vision** of bidirectional charging **into reality**, driving your business forward and contributing to societal progress.

Enjoy!

WHAT TO EXPECT

INTRODUCTION TO ONE-PAGER FORMAT



1. **Use case, description & customer value proposition**
   Brief explanation of the logic behind the use case and benefit from customer perspective.

2. **Status quo & main challenges**
   Analysis of the use case in terms of its feasibility from a technological, regulatory and economic perspective.

3. **Assessment**
   Potential target customers and relevant market observations related to the specific use case.

4. **Visualization**
   Simplified illustration of the use case containing energy flows and other relevant parameters over the course of 24 hours.

5. **Maturity**
   For each use case, an assessment is provided in terms of technical, regulatory, and economic maturity. This evaluation reflects **P3's qualitative analysis** of the market conditions as of **January 2025**.

MATURITY ASSESSMENT CRITERIA

TECHNICAL

- **Technology readiness:** At what stage is the technology—lab testing, pilot projects, or large-scale deployment?
- **Interoperability & standardization:** Are there established communication protocols (e.g., ISO 15118, OCPP) and compatibility across vehicle and charger manufacturers?
- **Hardware & infrastructure availability:** Are bidirectional chargers, inverters, and vehicle systems commercially available and scalable?
- **Performance & reliability:** How well does the system function under real-world conditions (e.g., efficiency losses, battery degradation, latency in response time)?

REGULATORY

- **Legal & regulatory framework:** Are there established regulations permitting bidirectional energy flows (e.g., energy market rules/laws)?
- **Grid access:** Can EVs and aggregators participate in energy markets (e.g., frequency regulation, capacity markets, demand response)?
- **Taxation & tariffs:** Are bidirectional energy flows taxed or incentivized (e.g., taxes, levies and surcharges)?

ECONOMIC

- **Business case viability:** Are there proven revenue streams (e.g., grid services, energy savings, incentives) that make the use case financially attractive?
- **Cost of implementation:** How expensive are the required hardware, software, and infrastructure investments?
- **Return on Investment (ROI) & payback period:** How long does it take for users to recover costs and start profiting?
- **Market demand & scalability:** Is there sufficient demand from consumers, businesses, or grid operators to scale the use case?
- **Energy pricing & market incentives:** Are dynamic tariffs, subsidies, or capacity payments available to support the business case?

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Important: The analysis focuses on bidirectional charging only, excluding the perspective to perform the use cases with unidirectional charging steering. Economic potential is highly dependent on individual customer's profiles, such as driving distance and charging behavior.

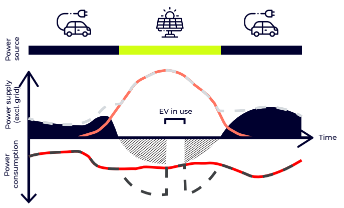
WHAT TO EXPECT

USE CASE OVERVIEW

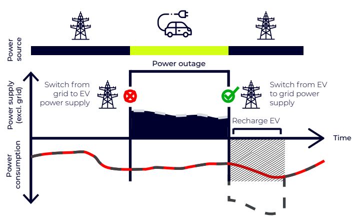
There is no shortage of use cases for bidirectional charging, and new ones continue to emerge with changing energy market regulation. This paper focuses on the eight use cases that are most prominent in the context of bidirectional charging for passenger cars, clustered across three domains: Vehicle-to-Home (V2H), Vehicle-to-Building (V2B), and Vehicle-to-Grid (V2G), where some use cases can be categorized to both V2H and V2B.

Vehicle-to-Home
V2H is designed to serve the energy needs of a household by enabling electricity from an EV battery to flow back into to household. This process occurs independently of the public grid, operating "behind the meter".

SELF-CONSUMPTION OPTIMIZATION

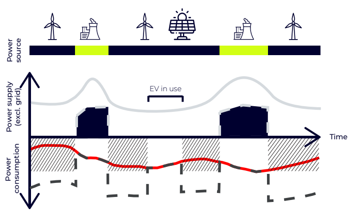


EMERGENCY POWER & REMOTE MICROGRID

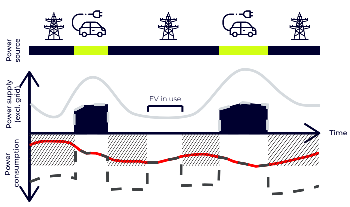


Vehicle-to-Building
V2B is similar to V2H but applied at a larger scale, where an EV provides energy to an entire building, such as an office or apartment complex.

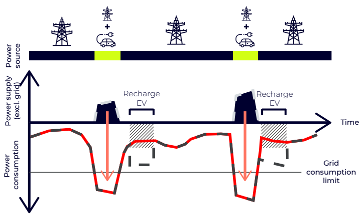
CO_2 - OPTIMIZATION



ENERGY TARIFF OPTIMIZATION (BEHIND-THE-METER)

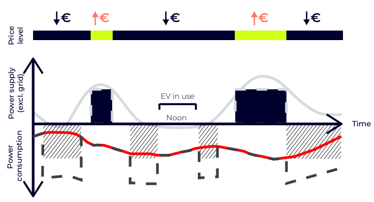


FUSE PROTECTION & PEAK SHAVING

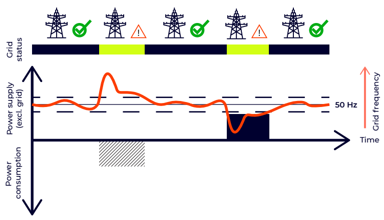


Vehicle-to-Grid
Unlike V2H, V2G enables EVs to feed stored energy back into the public grid ("in front of the meter").1

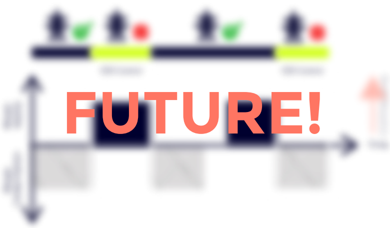
ARBITRAGE (IN-FRONT-OF THE-METER)



FREQUENCY SERVICES



OTHER ANCILLARY SERVICES



DEFINING KEY TERMS

GLOSSARY

Term	Definition
Balancing Market	The balancing market is a segment of the electricity market where grid operators procure balancing services to ensure that supply and demand remain in equilibrium in real-time. This market addresses short-term fluctuations in the power system.
Capacity (Market-Side) Aggregator	Companies that pool and manage distributed energy resources (DERs) on the energy market, such as EVs capable of bidirectional charging, to provide collective capacity and flexibility to electricity markets, optimizing participation in demand response and ancillary services.
Data Aggregator	An IT platform that collects (and analyzes) external data from various sources, like weather forecasts and grid data.
Device (Technology) Aggregator	An IT platform that communicates to (edge) devices. It provides a hardware- and software-agnostic standardized interface to third parties to monitor, control, and aggregate single or a pool of devices.
DER (Distributed Energy Resources)	Distributed Energy Resources (DER) are small-scale power generation or storage units that are connected to the grid but typically located close to the point of energy consumption, such as in homes or businesses. DER include renewable energy sources like solar panels, wind turbines, energy storage systems like batteries, and even electric vehicles with bidirectional charging capabilities.
DSO (Distribution System Operator)	Organizations responsible for operating, maintaining, and developing the electrical distribution network.
EV OEM (Original Equipment Manufacturer)	Companies that manufacture electric vehicles and their components.

DEFINING KEY TERMS

GLOSSARY

Term	Definition
Flexibility Aggregator	An actor offering and operating an IT platform that aggregates and disaggregates individual distributed energy resources (DER). It manages, communicates, and forecasts the available flexibility of the asset pool. Typically, it utilizes the concept of a virtual power plant (VPP).
Metering Point Operator	Service providers responsible for installing, maintaining, and operating metering equipment that records electricity consumption and production.
Local HEMS (Home Energy Management System)	Hardware (such as smart meters, sensors, and controllers) and software (apps or platforms) used in local power networks (e.g., buildings) to optimize energy consumption, storage, and production, potentially including bidirectional charging by managing EV battery use within the home energy ecosystem. Can also be used as a local gateway by Smart Energy Providers or Device (Technology) Aggregators.
Smart Energy Provider	Companies that offer advanced energy solutions to end customers, leveraging technologies like smart grids and bidirectional charging to provide dynamic pricing, grid support, and enhanced energy efficiency.
TSO (Transmission System Operator)	Companies that manage the high-voltage transmission networks, ensuring the reliable transport of electricity over long distances and the balancing of supply and demand.
VPP (Virtual Power Plant)	A VPP is a digitally aggregated system of distributed energy resources (DER), optimized and coordinated often autonomously while considering the individual operating constraints of each asset. It interacts with the grid, provides ancillary services, and participates in energy markets.

USE CASE ONE-PAGER

V2H | SELF-CONSUMPTION OPTIMIZATION

DESCRIPTION & CUSTOMER VALUE PROPOSITION

Charging and discharging processes of the EV maximize the self-consumption of self-generated photovoltaic (PV) electricity. Surplus electricity that cannot be consumed directly is temporarily stored in the vehicle's battery and used later to supply electricity to the household, provided that the EV is at home and plugged in. This minimizes the need to draw electricity from the grid, increasing self-consumption and the degree of self-sufficiency, thereby reducing energy costs. The vehicle's battery functions similarly to a conventional stationary home battery storage system and can substitute or complement it. This setup can also be utilized in combination with time-based electricity tariffs to further optimize energy usage and savings.

Customer value proposition: Saving electricity costs by maximizing self-consumption

STATUS QUO & MAIN CHALLENGES

Technical

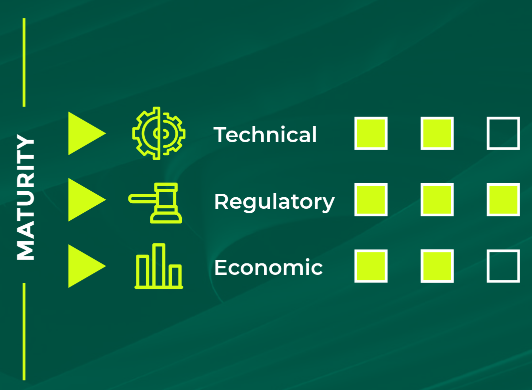
- Technically feasible with minor further development needs (e.g., HEMS), yet only proprietary systems so far exist with a lack of standardized interfaces for communication across the ecosystem, such as the delayed industry implementation of ISO 15118-20
- Low household demand resulting in low End-to-End (E2E) efficiency due to high energy losses from low discharging power (<1 kW)
- There are still challenges related to measurement and billing
- Requires the EV to be plugged in during surplus PV generation as well as increased household consumption

Regulatory

- Low regulatory barriers as no power flows into public grid

Economic

- Cost savings are possible due to the fact that electricity prices have been higher than PV feed-in tariffs
- Economic feasibility highly depends on the spread between electricity tariff, PV feed-in tariff, and hardware costs
- Saving potential is highly dependent on household consumption, solar energy generation, driving behavior/ availability of the bidirectional EV
- Controlled uni-directional charging can already lead to significant savings with only minor additional benefits from bidirectional charging if stationary battery storage is already being used
- Due to the high seasonal dependency, it is worth combining this use case with V2G use cases such as arbitrage. Generally, increasing self-consumption is more economical than trading as of today



ASSESSMENT

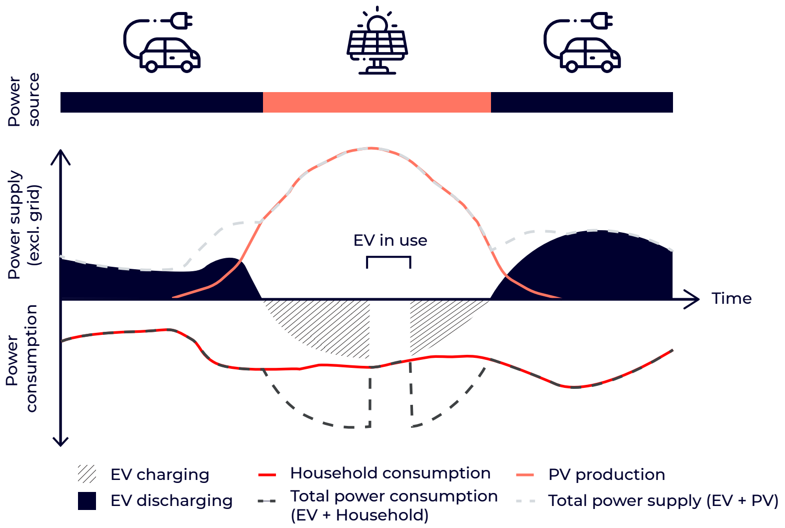
Target customer

EV owners with PV with small or no battery storage system and significant PV electricity surplus

P3 observations & trends

- High potential for bundling electricity tariffs with V2H software for better customer retention and additional revenues
- Dominance of subscription-based models for services
- Local HEMS provider have to overcome hurdle of initial hardware installation

VISUALIZATION (simplified depiction)



USE CASE ONE-PAGER

V2H | EMERGENCY POWER & REMOTE MICROGRID

DESCRIPTION & CUSTOMER VALUE PROPOSITION

In the event of an unexpected power failure at the grid connection, the emergency power function switches to consuming from the vehicle's battery to continue supplying the house with electricity. This ensures the household remains unaffected by power grid failures. For homes that are not connected to the public electricity grid, such as a remote mountain hut, the vehicle's battery provides the necessary electricity supply. The vehicle's battery effectively replaces the need for a traditional generator, ensuring a reliable power source in off-grid locations. Today, this is still an edge case in Germany.

Customer value proposition: Securing power supply and consuming electricity independent from the public grid

STATUS QUO & MAIN CHALLENGES

Technical

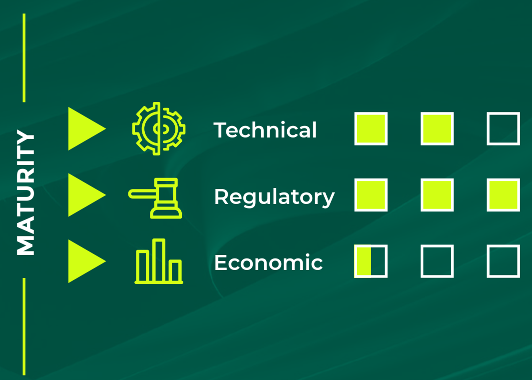
- Technically feasible with minor further technical development and standardization needs[1]
- First bidirectional charging emergency solutions are entering the market (Ford F150 Lightning©). However, these are proprietary solutions, as they come with a closed E2E hardware lock-in
- The widespread adoption of these solutions depends on a standardized communication between all components. Customers should have the flexibility to change their car or electricity provider without changing the home electrical setup

Regulatory

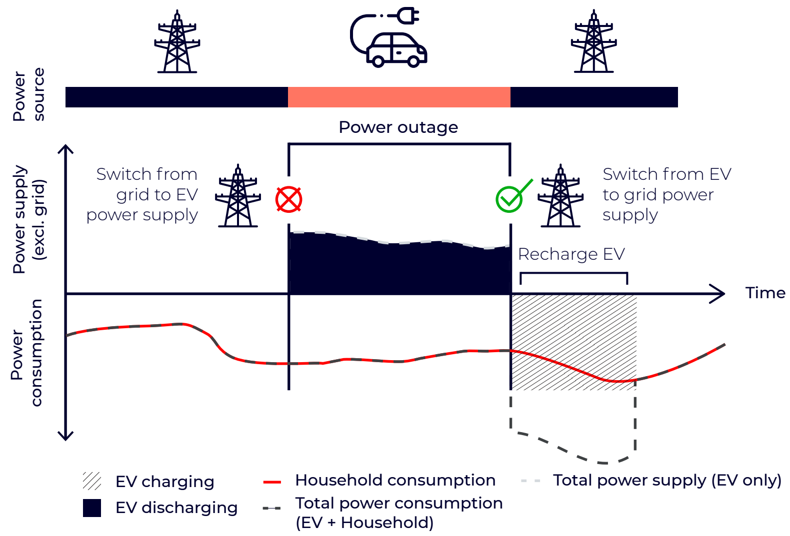
- Security regulations need to be met
- Low regulatory barriers as no power flows into public grid

Economic

- Currently, expensive proprietary solutions
- Total cost of ownership for bidirectional setup must be lower than large battery or fossil fuel solutions



VISUALIZATION (simplified depiction)



ASSESSMENT

Target customer

Individuals or organizations with low energy security and/ or in remote locations

P3 observations & trends

- Green alternative to fossil fuel powered generators and expensive large stationary batteries
- Limited relevance to European core markets due to relatively stable grids compared to e.g. North America with frequent grid failures

(1) For reference, see use case V2H | Self-Consumption Optimization on page 7.

USE CASE ONE-PAGER

V2H/B | FUSE PROTECTION & PEAK SHAVING

DESCRIPTION & CUSTOMER VALUE PROPOSITION

The bidirectional powerflow is used to counter heavy loads at the grid connection point, thereby protecting fuses from overloading and/or reduce network connection fees[1].
This can be done on different levels:
- House, building, or factory level
- Charge point level with parallel charging vehicles (hub-satellite architecture)[2]

Customer value proposition: Saving energy costs and preventing overload by balancing power loads

STATUS QUO & MAIN CHALLENGES

Technical

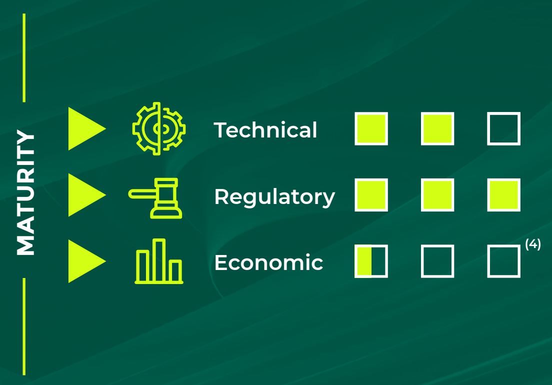
- Technically feasible with minor further technical development and standardization needs[3]
- Already established use case for unidirectional charging

Regulatory

- Low regulatory barriers as as no power flows into public grid

Economic

- Savings due to reduced peak load price (part of grid fees)
- Potential is mainly dependent on driving/ charging profiles and building load profile
- Highest benefit from shifting charging processes to night-time, hence more suitable for commercially used vehicles, especially in shift operation with high predictability, rather than employee cars



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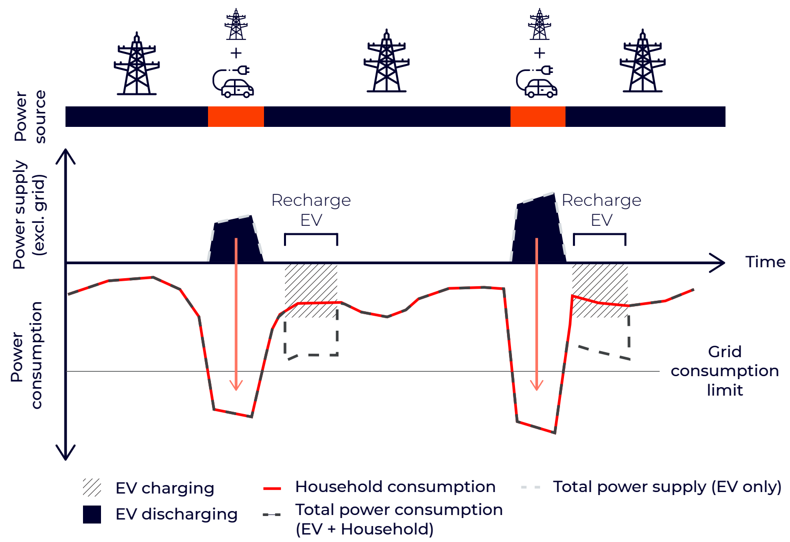


ASSESSMENT

Target customer

Individuals with comparatively low fuse limits at point of grid connection and organizations with high peak power charges

P3 observations & trends

- Intelligent charging management system needed to ensure smooth operation/ fulfil mobility needs
- Forecasting (demand and local production) and life metering needed
- Already established unidirectionally; can be expanded by bidirectional functionality (high customer acceptance)
- Limited relevance for private customers in Germany; primarily interesting for businesses. Full potential can be leveraged with heavy-duty vehicles

(1) Annual fees may be charged by System Operator based on peak power withdrawal.
(2) Bidirectionality enables energy transfer between the vehicle's batteries behind the point of connection.
(3) For reference, see use case V2H | Self-Consumption Optimization on page 7.
(4) Highly profitable for industrial buildings with peak power charges.

USE CASE ONE-PAGER

V2H/B | CO_2 - OPTIMIZATION

DESCRIPTION & CUSTOMER VALUE PROPOSITION

The charging process of the electric vehicle is optimized based on hourly emission factors, aiming to reduce operational emissions. The vehicle is charged during periods with an energy mix of low CO_2 emissions due to a high share of renewables and discharged locally when emissions are high. This strategy not only reduces overall emissions but can also contribute to cost savings. This can include local generation, e.g., via PV systems.

Customer value proposition: Improving carbon footprint

STATUS QUO & MAIN CHALLENGES

Technical

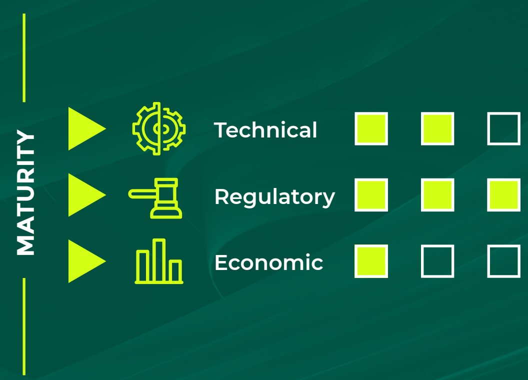
- Technically feasible with minor further technical development and standardization needs[1]
- The power grid is a complex system where the market is partly decoupled from the physical delivery. Hence, heuristic forecasts or complex physical simulation models are needed to determine the CO_2 emissions of the current and future energy mix

Regulatory

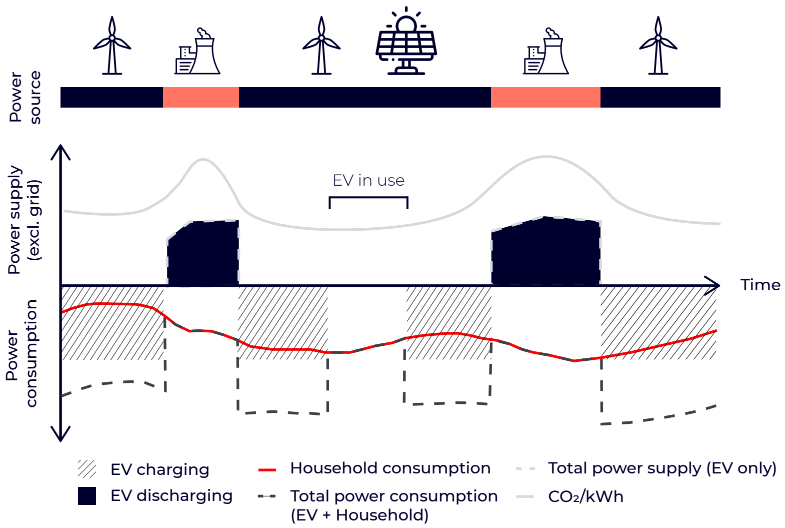
- Low regulatory barriers as as no power flows into public grid

Economic

- With increased share of Renewable Energy Sources (RES) in the energy mix, the correlation between low CO_2 emissions and low prices will become stronger, improving the economic benefits of the use case
- Increasing pressure on organizations to reduce their environmental footprint makes this use case attractive to meet sustainability goals, especially for large EV fleets



VISUALIZATION (simplified depiction)



ASSESSMENT

Target customer

Individuals or organizations aiming to reduce their environmental impact; potentially relevant to achieve sustainability targets

P3 observations & trends

- Environmental concerns as primary motivator; economic rationale only secondary
- Limited relevance as cost-optimized charging often already has a high correlation with CO_2 emissions

(1) For reference, see use case V2H | Self-Consumption Optimization on page 7.

USE CASE ONE-PAGER

V2H/B | ENERGY TARIFF OPTIMIZATION (BEHIND-THE-METER)

DESCRIPTION & CUSTOMER VALUE PROPOSITION

For customers with a time-based energy tariff, such as a dynamic or static Time-of-Use (ToU) tariff, bidirectional charging allows the vehicle's battery to be used to bridge periods of high electricity prices. This helps reduce energy costs by purchasing electricity when prices are low and storing it for later use in the home network when prices are higher. The vehicle's battery functions similarly to a conventional stationary home battery storage system, optimizing energy usage and cost savings, provided that the EV is at home and plugged in. This setup can also be integrated with a PV system for enhanced efficiency. This use case can also be extended to non-residential buildings such as factories. The use case execution is subject to the restriction that the EV has to be available for supplying the household during times of high electricity prices.

Customer value proposition: Saving energy costs

STATUS QUO & MAIN CHALLENGES

Technical

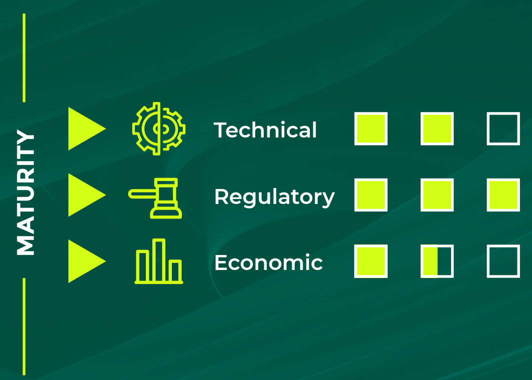
- Technically feasible with minor further technical development needs and need for standardization[1]
- Low household demand resulting in low E2E efficiency due to low discharging power (<1 kW)
- Smart meter needed
- Requires the electricity supplier to be able to carry out high-resolution billing
- Purely market-oriented signals lead to high simultaneities at times of low electricity tariffs and thus high network loads

Regulatory

- Low regulatory barriers as no power flows into public grid
- Use case is based on an electricity supply contract with dynamic tariffs in accordance with § 3 No. 31d EnWG
- Explicitly desired by German legislation:
  - Since 2022, all electricity suppliers that are supplying more than 100,000 end consumers over a year are obliged to offer dynamic tariffs (cf. § 41a EnWG)
  - Beginning in 2025, all energy suppliers in Germany will be required to offer dynamic tariffs

Economic

- Saving potential depends on price margins of the dynamic tariff, price delta between dynamic and household electricity price and household electricity consumption
- At current price levels for bidirectional hardware, investment costs are unlikely to be covered by electricity savings alone



ASSESSMENT

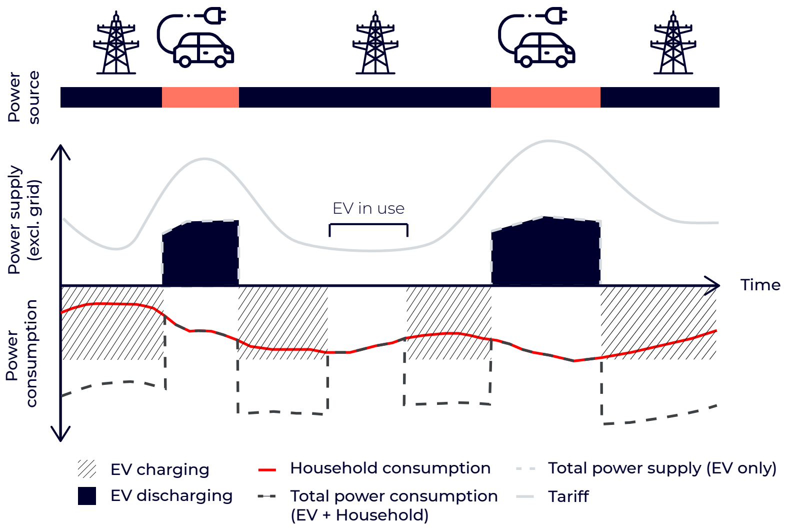
Target customer

Individuals that have high flexibility in shifting their charging/ discharging processes based on price signals, particularly attractive for users without PV

P3 observations & trends

- Energy tariff optimization for stationary batteries is currently entering the market, opening the door for V2H applications
- Different tariff structures enter the market for which the communication of the benefits will be key

VISUALIZATION (simplified depiction)



(1) For reference, see use case V2H | Self-Consumption Optimization on page 7.

USE CASE ONE-PAGER

V2G | ARBITRAGE (IN-FRONT-OF-THE-METER)

DESCRIPTION & CUSTOMER VALUE PROPOSITION

Charging and discharging processes are managed based on active trades on wholesale electricity markets. The electric vehicle charges when electricity prices are low and discharges back into the public grid when prices are high, leveraging the arbitrage business model. As market prices fluctuate due to the increasing share of volatile renewables, this strategy offers significant revenue potential. The household's energy consumption remains unaffected by this use case. Several EVs and/or other assets are pooled by aggregators who carry out the marketing activities in exchange for a revenue share.

Customer value proposition: Generating revenue through energy market trading

STATUS QUO & MAIN CHALLENGES

Technical

- For high-resolution billing, a smart meter is needed. Typically, a home energy management system (HEMS) is used to process boundary conditions such as planned departure time and target State-of-Charge (SoC)
- An aggregator is needed to reach the necessary minimum capacity for participating in electricity exchanges
- Depending on market behavior, arbitrage can result in a significant increase of full load cycles, putting strain on the vehicle's battery and power electronics. It is likely that OEMs will either limit bidirectional charging (e.g., in terms of hours or kWh) or include bidirectional charging use in their warranties to avoid battery guarantee claims
- With an increasing number of bidirectional EVs, purely market-oriented charging behavior can lead to high simultaneity and cause significant strain on the grid, potentially leading to grid bottlenecks

Regulatory

- Approval of the metering concept by the system operator is needed to ensure a clear and transparent structure for metering and settlement
- The use case can be integrated as an annex to the electricity supply contract

Economic

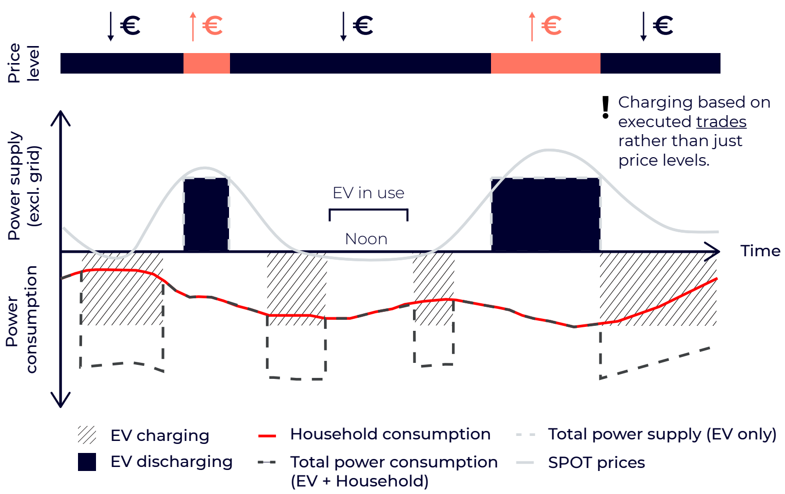
- Volatile business case as of today since electricity stored in bidirectional vehicles is currently not exempt from grid fees, taxes, levies, and surcharges, and revenues need to be shared amongst stakeholders[1]
- Revenue potential depends on the price delta between energy procured and sold. With increasing share of RES and corresponding volatility in electricity prices, revenues from the arbitrage business model appear to be secure. However, the flexibility offered by bidirectional EVs can have a smoothing effect on electricity prices. With increasing penetration, the revenue potential per EV therefore decreases
- Generally, the V2H use case of self-consumption optimization is more economical than trading as of today. Due to the high seasonal dependency of PV generation, it is worth combining the V2H use case with V2G use cases such as arbitrage

MATURITY

Technical	■	■	□
Regulatory	■	■	□
Economic	◧	□	□

Due to double taxation issue, grid fees and metering costs under current regulatory framework in Germany.

VISUALIZATION (simplified depiction)



ASSESSMENT

Target customer

EV owners who are able to plug in their vehicle for long periods of time

P3 observations & trends

- Potential for new business models, e.g., new (smart) energy tariffs to share trading revenues with the EV owner
- Different (innovative) metering solutions will be implemented
- Publicly discussed adjustments to the legal framework will significantly impact profitability
- Giving the surge of players entering the short-term energy markets, it is essential to closely monitor market saturation to safeguard trading profits and, consequently, the overall business case

(1) See system architecture page 15.

USE CASE ONE-PAGER

V2G | FREQUENCY SERVICES

DESCRIPTION & CUSTOMER VALUE PROPOSITION

A fixed proportion of the electric vehicle's battery capacity is "leased" to an energy service provider for system services. This function involves increasing and decreasing the charging and discharging capacity to participate in the balancing power market. Customers can take part in the primary, secondary, and tertiary reserve electricity markets, each with different technological requirements and monetization concepts. By offering energy and power capacity to the provider under specified conditions, the reliable provision of this capacity is remunerated accordingly. Bidirectionality enhances this service by doubling the flexibility offered.

Customer value proposition: Financial rewards for providing flexibility services

STATUS QUO & MAIN CHALLENGES

Technical

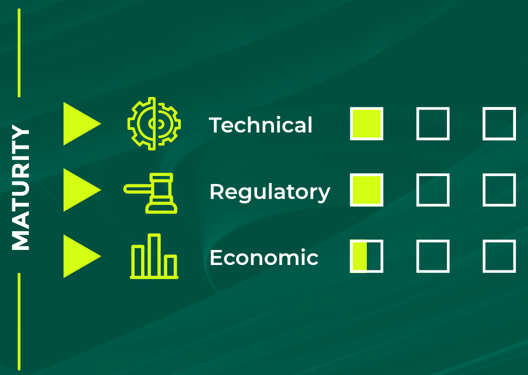
- Technically feasible if all systems and interfaces are compatible[1]
- Interfaces to the public grid must be clarified
- To guarantee that capacity can be provided, the aggregator must maintain a buffer by either having a larger EV fleet or other pooled assets

Regulatory

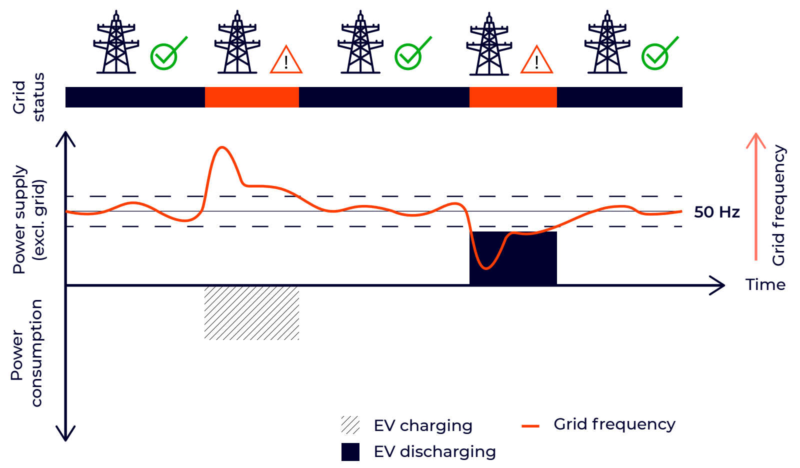
- Standards for provision and retrieval of capacity are yet to be specified for bidirectional EVs
- An extensive prequalification process is required for assets to provide frequency services.
- Initial guidance on the prequalification process for mobile storage systems has been provided by the German TSOs, indicating that, in most cases, only the local charging infrastructure requires qualification[2].

Economic

- Limited market size: for frequency control reserve (FCR) , around 200,000 EVs would be sufficient[3]. Hence, the number of users that can benefit from the use case is finite. The additional financial burden of taxes, levies and surcharges on electricity temporarily stored in bidirectional EVs further decrease the use case's economic attractiveness. The first signs of market saturation are evident in other countries, such as the UK
- Due to the hard-to-predict price developments on the relevant markets, the revenue potential unsure
- Market models and conditions (e.g., minimum hours the EV must be accessible) as well as renumeration are not yet well defined



VISUALIZATION (simplified depiction)



ASSESSMENT

Target customer

EV owners and fleet operators who are able to plug in their vehicle for long periods of time

P3 observations & trends

- Potential for new business models, e.g., new (smart) energy tariffs to share trading revenues with the EV owner
- Different (innovative) metering solutions will be implemented
- Smaller market compared to wholesale market due to limitations on flexibility needed and competition to other flexibility sources (e.g., stationary batteries)
- Market saturation will be reached quickly.

(1) For reference, see use case V2H | Self-Consumption Optimization on page 7.
(2) regelleistung.net (9/2024) Leitfaden für die Präqualifikation von Elektrofahrzeugen und anderen nicht-ortsfesten Anlagen
(3) FfE (2024): Bidirektionales Laden – Anwendungsfälle aus Nutzersicht. Studie im Auftragdes ADAC e.V.

USE CASE ONE-PAGER

V2G | OTHER ANCILLARY SERVICES

DESCRIPTION & CUSTOMER VALUE PROPOSITION

There are many other less common ancillary services that can be offered by bidirectional electric vehicles. In particular:

- Congestion management (Redispatch 2.0 / 3.0)
- Local flexibility (§ 14a EnWG, etc.)
- Voltage control
- ...

Customer value proposition: Financial rewards for providing flexibility services, and a stable grid

STATUS QUO & MAIN CHALLENGES

Technical

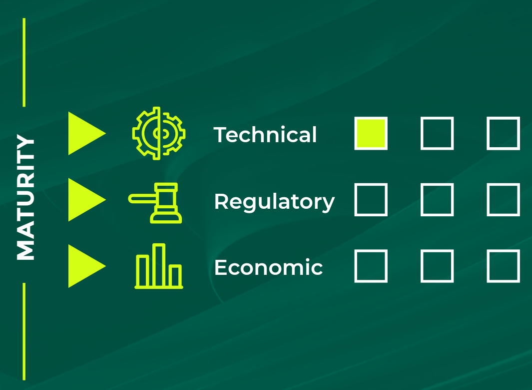
- § 14a EnWG: control via SMGW. Controls might happen unforeseen, which conflicts with the optimized charging schedule of the smart energy provider
- DSOs often lack the required digitalization needed to meet the requirements of the local flexibility mechanisms

Regulatory

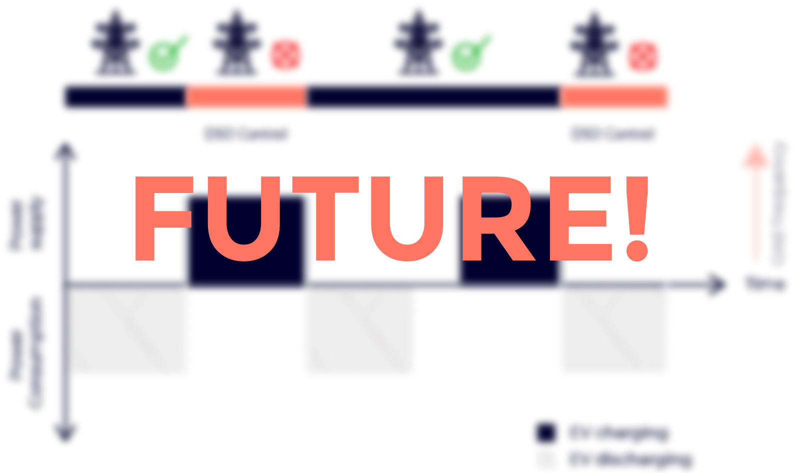
- § 14a EnWG: currently only for unidirectional use cases
- Under investigation, as they highly depend on the direction of Redispatch 3.0

Economic

- § 14a EnWG: savings through lower grid charges in exchange for allowing the grid operator to use contractually agreed flexibilities. The grid fee is independent of the actual use of flexibility (long-term flexibility commitment)



VISUALIZATION (simplified depiction)



ASSESSMENT

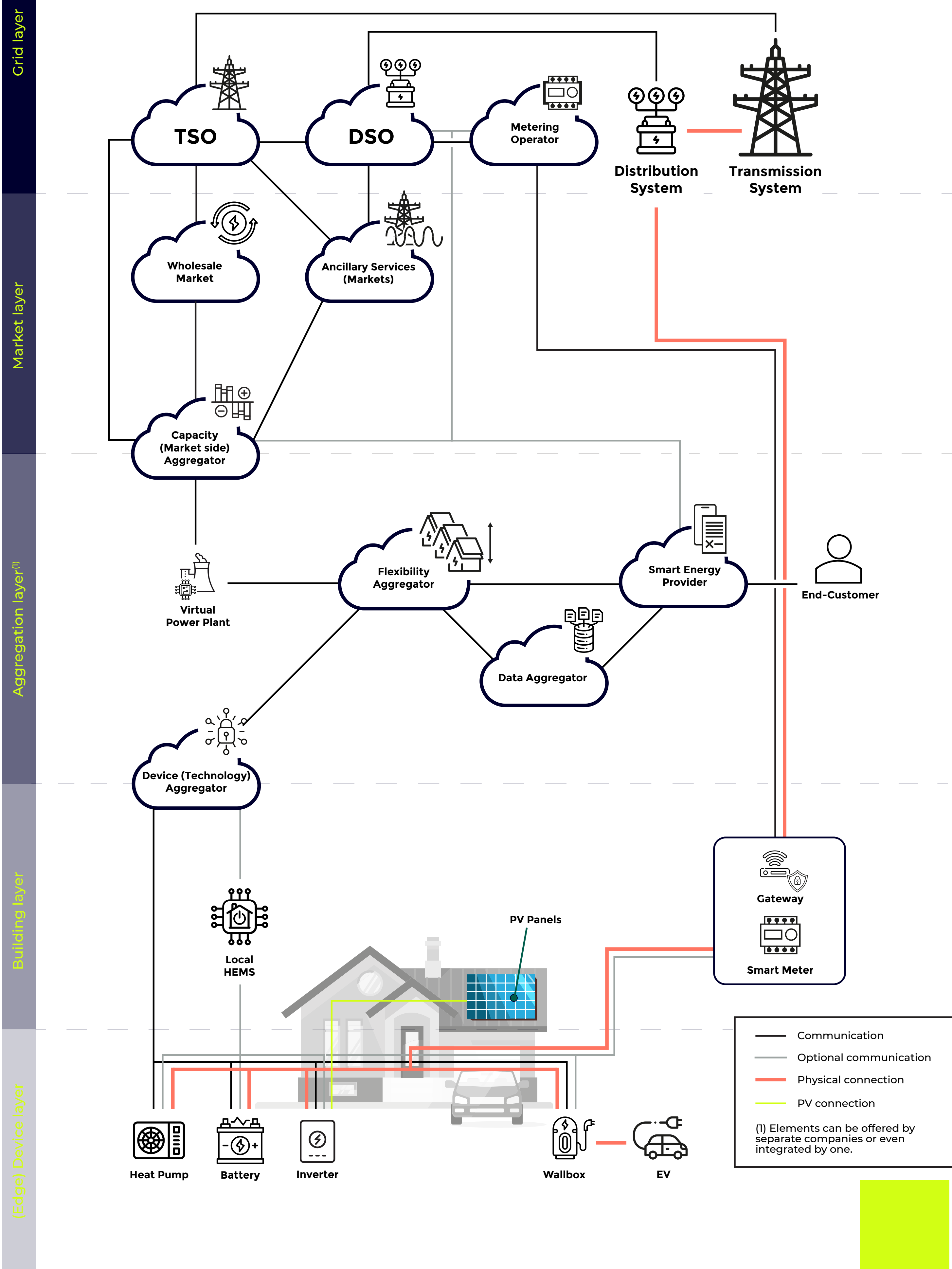
Target customer

- EV owners who want to generate additional revenue with their vehicle
- But, might be in-forced by law

P3 observations & trends

- Potential for new business models, e.g., new (smart) energy tariffs to share trading revenues with the EV owner
- Different (innovative) metering solutions will be implemented
- Real time TSO/DSO controls needed; first proposals are being implemented
- Market is much smaller than wholesale market (potential saturation)

SYSTEM ARCHITECTURE



WHAT WE OFFER

BRINGING SMART ENERGY TO LIFE

At P3, we combine strategic insights, technological expertise, and market intelligence to help you unlock the full potential of bidirectional charging for your organization. With our comprehensive approach — ranging from energy sector and grid expertise to turnkey software development — we support you at every stage.

Bidirectional charging is a complex challenge with diverse technical, regulatory, and operational requirements. We are here to navigate you through this evolving landscape, identify key business opportunities and align them with your strategic goals. From analyzing and prioritizing use cases to developing an individualized roadmap and scaling implementation, P3 delivers a pragmatic, results-driven approach that ensures success from concept to completion.

We are the first to pilot new technologies and share first-hand insights with our clients. For a glimpse into the reality of bidirectional charging, keep reading and join Markus Hackmann on his journey to a Vehicle-to-Home system.

END-TO-END ENERGY & MOBILITY CONCEPTS

#STRATEGY – CONSULTING
#TECHNOLOGY - CONSULTING

OUR PORTFOLIO IS BASED ON FOUR CORE COMPETENCIES:

ENERGY MARKET & GRID EXPERTISE

- Grid studies & sector coupling strategies
- Income optimization for decentralized energy assets
- Greenfield project planning & execution

TURNKEY SOFTWARE DEVELOPMENT

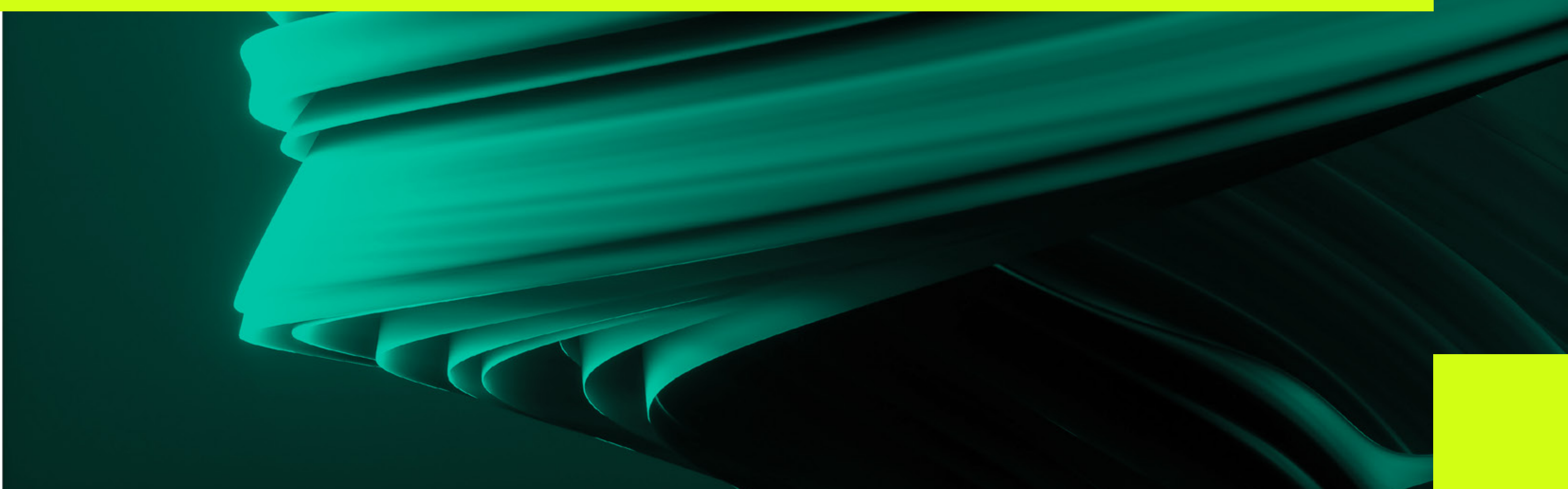
- HEMS solution development
- Vehicle API & charging station integration (OCPP & OCPI)
- Charging scheduling algorithms & End-to-End VPP solutions

TECHNOLOGICAL COMPETENCIES

- Technical & regulatory compliance for smart energy products
- PtX project design & execution
- Procurement assistance & benchmarking
- Testing in P3 Energy Lab

STRATEGIC CAPABILITIES & MARKET INSIGHTS

- Technical due diligence & risk management
- Investment benchmarking & go-to-market strategies
- Supply chain management & product development



EXCURSUS

WHAT V2H REALLY LOOKS LIKE

Interview partner

MARKUS HACKMANN

Markus Hackmann, Managing Director at P3 Group, has been shaping e-mobility for almost 20 years. In 2023, he was one of the first to install a fully functional Vehicle-to-Home set-up at his home in Osnabrück. His experience provides rare, real-world insights into one of the most promising – yet still emerging – secondary use cases for electric vehicles.

Markus, you were one of the first people in Germany that installed a Vehicle-to-Home (V2H) set-up at your home. How did you first hear about this V2H technology?

I first heard about the Vehicle-to-Home solution of E3/DC at the Intersolar in 2023. Shortly after, I read about it in the PV magazine. From that point onwards, I was convinced that this is the technological future of e-mobility.

What convinced you to take the leap as an early adopter?

At P3, we like to test products first-hand. This way, we can share our experiences with our clients and tell them our honest and well-founded opinion on new technologies and solutions. Personally, having had years of experience in e-mobility, I knew that I wanted to pilot the V2H system. My wife was skeptical at first, but, used to me being a tech nerd, went with the idea. Onvace I explained it to her, she actually thought it was quite cool.

What were your expectations when you decided to install the system? Have they been met?

I knew that the technology, being in an early Research & Development state, would be expensive. What I did not expect, however, was how long it would take me from installation to finally being able to feed energy back into my home. This has actually become a running joke in the community. I was lucky enough to give several presentations throughout the journey, each time hoping to finally be able to share results. And each time, I had to put off the audience with another teaser. In the end, it came down to my VW not having the right software update. I reached out to VW, my dealership, and E3/DC regarding the software update. After some time and a bit of networking, a colleague was able to connect with the right contact at VW. Nine months later, the update was finally installed. In the end, it all worked out – some solutions simply take time.

What does day-to-day life with a V2H system look like?

It took my wife and I a couple of weeks to learn our way around the technology. The first few times, we had some technical issues – we couldn't disconnect the plug, the SoC was lower than expected in the morning, I found out that the car has to stay within an SoC range between 20 – 80% to work. I had to learn how to adjust the settings both in my car as well as at the home battery so that the system components work smoothly together.
By now, we have found a rhythm that works well. During the summer months, I don't use bidirectional charging at all. Part of my overall system is a home battery which is large enough to store any surplus solar energy, allowing me to be 100% independent from the grid around 5 months per year. By contrast, during the winter months there is so little sun that there's barely any solar energy worth storing in the EV battery. Where V2H becomes interesting is in the transitional periods during spring and fall. Months like March, April and October are ideal for using bidirectional charging to increase autarky.

> ***I was convinced: This is the technological future of e-mobility.***

Which benefits have you noticed - and have you encountered any issues, limitations, or unexpected surprises?

For any energy nerd such as me, it is fascinating to see that I can extend my autarky period by several months using my EV battery as an additional storage system. But, as with any technology, there are drawbacks. Firstly, if it's cold, up to 20 kWh easily are withdrawn from the EV battery overnight to power the household – that's about 100 km in range, so quite significant. Secondly, the intelligence behind the charging and discharging processes is far from perfect. Today, the car is often charged early in the morning, even though the sun is about to come out. This is actually a case where I see potential for an AI application in the future.

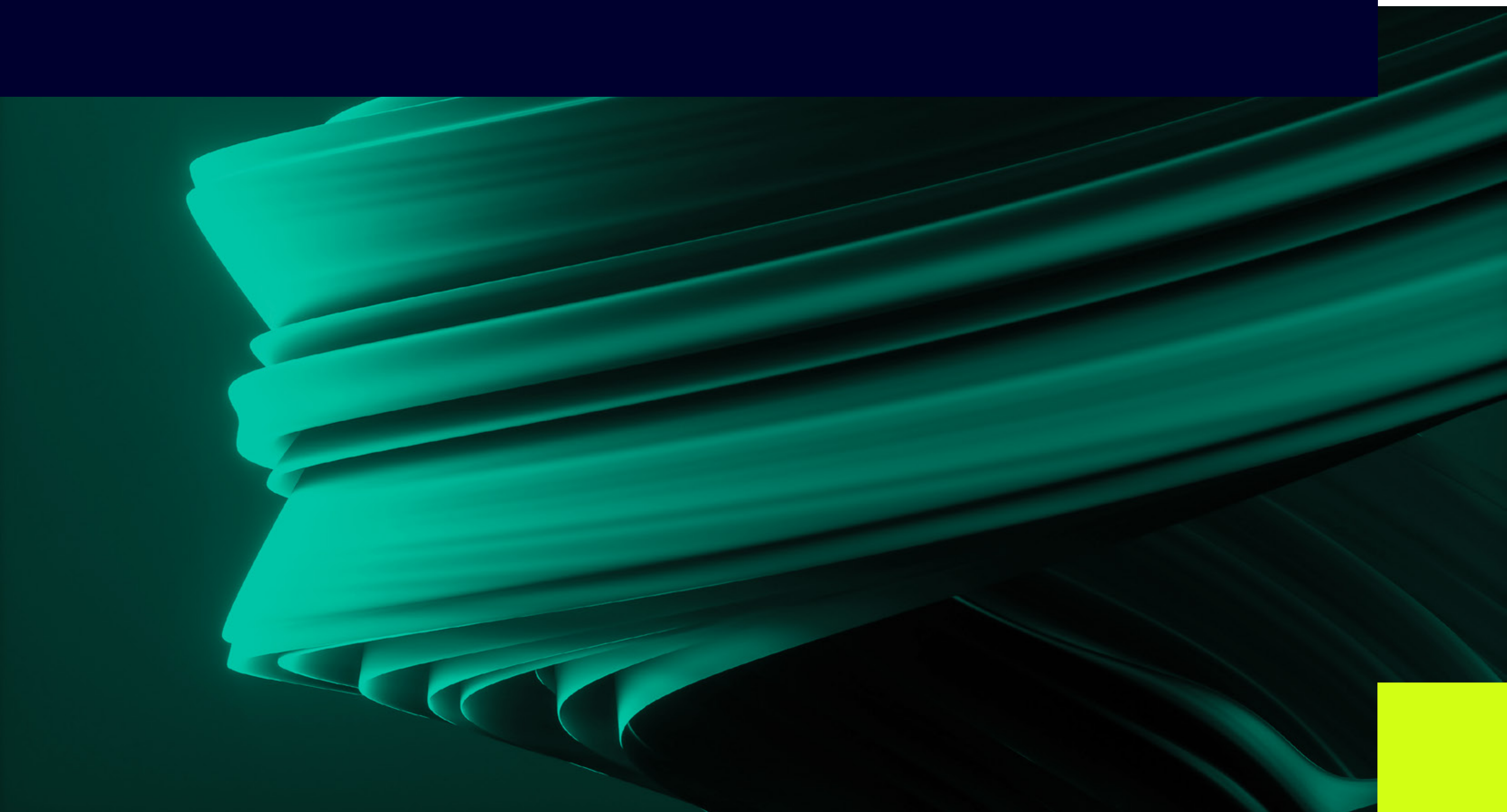
How do you see the long-term economic case for V2H – is it worth it today or mostly a bet on future value?

Today, it is mostly a bet on the future. Vehicle-to-Home system is very expensive and, to be honest, a little complicated. If you are a techie interested in energy autarky and don't have to worry about the financial investment, it is certainly interesting. Most people, however, can already achieve a lot with unidirectional charging at much lower costs. Bidirectional charging is then only the cherry on top.

Taking all this together: Would you recommend V2H to other EV owners?

You probably don't want to hear this, but: it depends! To the ones who really believe in e-mobility, have the necessary financial resources and want to make a difference with V2H and later on V2G, I would say go ahead. For everyone else, especially people that expect a positive business case, I'd recommend to wait until the technology is more mature. We anticipate more offers to enter the market at the end of this year, and, prospectively, costs will go down significantly to around a third of the price we have today – that's when we will have a real case for a broad customer base.

> ***"You can already achieve a lot with unidirectional smart charging - bidirectional charging is currently only the cherry on top."***

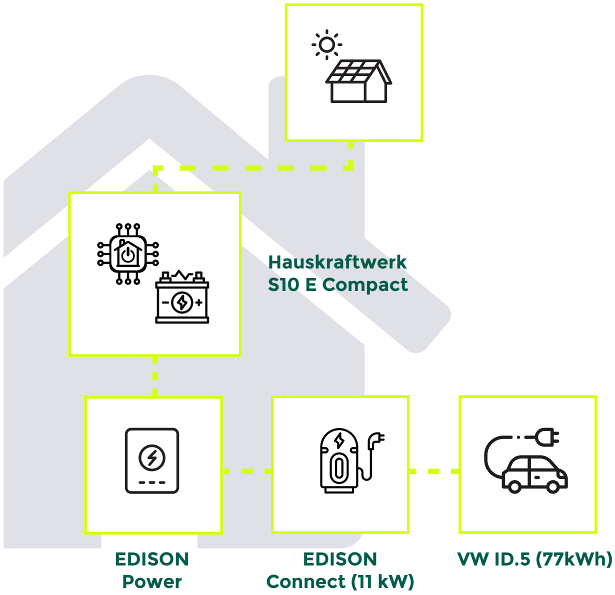


EXCURSUS

INSIDE THE TECHNICAL SETUP

Bidirectional charging with the E3/DC EDISON V2H system

With EDISON V2H, E3/DC offers a bidirectional DC charging solution for its home power station, consisting of the bidirectional DC charging station EDISON connect and the DC/DC inverter EDISON power. To ensure optimal performance, the system operates in combination with an E3/DC storage unit.
The electric vehicle is charged with solar power via the CCS plug and also returns the energy to the E3/DC home power station if needed. The integrated inverter hence uses the EV battery as a second DC power source next to the PV system, prioritizing self-sufficiency and energy efficiency.
The charging solution is tailored for multiple models from the VW ID. family and equal platforms, provided they feature a 77 kWh battery and run on software version 3.5 or later. Since January 2025, EV models from Ford can also be connected.



LET'S EXPLORE WHAT WE CAN ACHIEVE TOGETHER!

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