GAMES POLICY BRIEF

ENERGY-MOBILITY SECTOR COUPLING THROUGH SMART AND BIDIRECTIONAL VEHICLE CHARGING

Status Quo and Outlook on Policy, Market and Technology Framework Conditions

VERSION 1.0

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05 April 2023

INTERNAL REFERENCE

Deliverable No.:	D4
Deliverable Name:	Policy Brief
Lead Participant:	e7
Work Package No.:	WP5
Task No. & Name:	T5.1
Document (File):	GAMES Policy brief_final
Issue (Save) Date:	2023-04-05

DOCUMENT STATUS

	Date	Person(s)	Organisation
Author(s)	28-10-2022	Guntram Pressmair	e7
	13-01-2023	Guntram Pressmair	e7
	27-02-2023	Guntram Pressmair	e7
	20-03-2023	Guntram Pressmair	e7
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Verification by	24-03-2023	Jalomi Maayan Tardif	SUPSI

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FUNDING

This project has been funded by partners of the ERA-Net Smart Energy Systems and Mission Innovation through the Joint Call 2020. As such, this project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 883973.

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About ERA-Net Smart Energy Systems

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Co-creating with partners that help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

Beyond that, ERA-Net SES provides a Knowledge Community, involving key demo projects and experts from all over Europe, to facilitate learning between projects and programs from the local level up to the European level.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Description
AC	Alternating current
ACEA	European Automobile Manufacturers´ Association
AFID	Alternative Fuels Infrastructure Directive
AFIR	Alternative Fuels Infrastructure Regulation
aFRR	Automatic Frequency Restoration Reserve
APCS	Austrian power clearing and settlement
APG	Austrian power grid
BEV	Battery electric vehicle
BRP	Balancing responsible party
CAN	Controlled area networks
CCS	Combined charging system
CEER	Council of European Energy Regulators
CEC	Citizen Energy Community
CPO	Charge point operator
DA	Day-ahead
DC	Direct Current
DR	Demand response
DSF	Demand-side flexibility
DSO	Distribution system operator
EEX	European Energy Exchange
EMD	Electric market design
eMSP	Electromobility service provider
ENTSO-E	European Network of Transmission System Operators for Electricity
EPBD	Energy Performance of Buildings Directive
EPEX	European Power Exchange
ERA-Net SES	Networking the European Research Area Smart Energy Systems
EU	European Union
EV	Electric vehicle
EVI	Electric Vehicle Initiative
EXAA	Energy Exchange Austria
FCR	Frequency containment reserve
GHG	Greenhouse gas
GW	Gigawatt
GO	Guarantees of Origin
ICE	Internal combustion engine
ID	Intraday
IEC	Israel Electricity Corporation
IGCC	International Grid Control Cooperation

ISO	Independent System Operator
kW	Kilowatt
kWh	Kilowatt-hour
LIB	(Lithium-ion-batterie
LMO	Lithium manganese oxide
LFM	Local flexibility markets
mFRR	Manual frequency restoration reserve
MW	Megawatt
OCPP	Open charge point protocol
OEM	Original Equipment Manufacturer
PHEV	Plug-in hybrid vehicle
PV	Photovoltaics
REC	Renewable energy community
RED II	Renewable Energy Directive II
R&I	Research & Innovation
RES	Renewable energy source
RR	Replacement reserve
SEI	Solid electrolyte interphase
ToU	Time-of-use
TSO	Transmission system operator
TRE	National tertiary control
TW	Terawatt
UK	United Kingdom
V2B	Vehicle-to-building
V2G	Vehicle-to-grid
V2H	Vehicle-to-home
V2X	Vehicle-to-everything
ZEV	Zusammenschluss zum Eigenverbrauch

POLICY BRIEF

Mobility is a basic need for people. With increasing electrification of the mobility sector, careful sector coupling of mobility and the electricity system is getting more important. It can be considered an urgent need, in order to ensure reliability of our future energy system, but also as a chance to increase its efficiency as a whole. Against this backdrop, this policy brief analyses the status quo on **policy, market and technology** framework conditions for smart and bidirectional charging of electric vehicles (EV). Also, key **recommendations** for all kinds of decision makers are formulated, aiming at overcoming existing barriers. The following policy brief summarises the main findings and recommendations and the subsequent annex reports all analyses in full detail.

The rise of e-mobility

Electromobility is on the rise. A growing number of states announced their intention to phase out internal combustion engines (ICE) and support the ramping up of EVs instead. Every second newly registered vehicle in 2030 could be an EV. EVs have lower emissions overall, compared to ICE vehicles. Consequently, electromobility is internationally recognized as a necessary measure to address various problems of our time (e.g., global warming or air pollution). China has made a major contribution to the shift towards electromobility. However, Europe is a key actor as well. The European EV market is expected to be the second largest in 2030, after China and ahead of the United States.

Electric vehicles as a flexibility resource

EVs can be described simply as vehicles with an electric engine and a battery. They need to be charged and therefore interact with the electricity grid. Crucial components are the batteries, which can be seen as flexible energy storage component. Today, EVs do not pose a challenge for the power system. However, the combination of an increasing EV stock and uncoordinated charging can lead to **significant problems for power grid stability**. To address the difficulties for the grid, it is possible to **manage the charging process**:

Smart charging enables adjusting the power level and the timeframe of the charging process. The charging parameters are dependent on external (price) signals. E.g., an EV can be slowly charged overnight, when electricity prices are low.

Bidirectional charging is an enhancement of smart charging. Bidirectional charging allows energy to flow back . E.g., not only from the grid to the battery, but also from the battery back to the gird (vehicle-to-grid - V2G).

EVs can be used as **mobile and flexible energy storage facility** and together with smart- and bidirectional charging, EVs enable promising opportunities for their owners and the electricity system. The intelligent application of the charging process can provide **environmental and economic benefits** for the grid functioning, consumers and all the involved actors of the energy system, such as:

- Reducing the total peak power demand (“peak shaving”)
- Flexibility and ancillary services to the electricity grid
- Integration of fluctuating renewable energy into the power system

In general, smart- and bidirectional charging help maintaining **grid stability by providing flexibility**. EVs provide power when there is a lack of renewable energy supply and charge when there is an excessive amount of renewable energy. Simulation studies indicate that the flexibility provided by EVs has the potential to contribute to the electricity system functionality. See Annex A & B for more details.

The policy framework

The European Union (EU) has decided to phase out fossil fuel-based ICEs and instead subsidize low carbon-based engines (primarily EVs). As a result, fundamental expansion targets have been formulated for the member states. In the EU, there is no single set of regulations, but rather several different European directives, regulations, and initiatives that all have some influence on EVs and EV charging. Regarding smart and bidirectional charging, all publicly accessible charging stations in Europe will have to be digitally connected and capable of smart charging and, where appropriate, bidirectional charging.

Table 1: EV charging policies of selected countries

Country	EV charging policies
Austria	Subsidies for EVs and charging infrastructure. First steps towards smart- and bidirectional charging, e.g.,: right-to-plug, redesign of network tariffs towards more flexibility, charging station data regulation, research on bidirectional charging and an electromobility coordination centre.
Switzerland	Many cantons subsidize electromobility. Public-private initiative “Roadmap Elektromobilität 2025” including measures regarding bidirectional charging e.g.: test projects, development of affordable charging solutions or further research on possible stakeholders.
Israel	Electromobility is subsidized. No regulatory framework regarding EV charging yet. However, authorities have issued policy guidelines in 2022: expansion of charging stations as priority. The Electricity Authority does not require smart charging capabilities in charging stations yet.
Norway	Generous subsidies (EVs and charging infrastructure). A dynamic market for charging has developed. Wide availability of dynamic time-of-use tariffs. Bidirectional charging has been identified as profitable business model.
United Kingdom	Charging infrastructure build-up has largely been market-led. UK early adopted a policy to mandate smart charging functionality (2018). In July 2021, the government released a further smart charging strategy.

Regulatory barriers that impede the successful integration of EVs into the power system have been identified. Currently, knowledge about EV charging comes mainly from various pilot projects and interviews with experts and energy system stakeholders:

- **Regulatory framework**: the individual actors in the power system are unclear about their specific roles with regards to smart- and bidirectional charging
- **Coordination**: EV integration into the power system is based on rapid exchange of various real-time data. However, the different players in the power system do not know exactly what, how and with whom to communicate
- **Standardisation**: in addition, actors need standardized interfaces to communicate and exchange data
- **Market design**: moreover, players need a liquid flexibility market, meaning that markets need to be profitable, enabling valid business models for market participants

Smart and bidirectional charging require the energy system as well as the entire EV ecosystem to work together. In 2030, EV charging could be a **large and profitable market**. However, many market segments are still at an early stage and will take years to develop. See Annex C for more details.

The market framework

Unleashing the flexibility potential of EVs requires an effective integration of EVs into the electricity market design. For this policy brief, relevant flexibility markets have been analysed for participation of EV fleets. See Annex D for more details.

Table 2: Overview of potentially relevant flexibility markets

Ancillary services	Ancillary services include various explicit flexibility products which are procured to ensure system and grid stability. The most relevant ancillary services market for EVs to participate would be the **balancing market** for frequency regulation. Minimum bid sizes are typically very high and there are also market coupling mechanisms emerging for all types of balancing products. A relevant concept in the future would be **local flexibility markets**, procuring flexible resources for local congestion management at Distribution System Operator (DSO) level. EVs as distributed assets with relatively high-power capacity in the low voltage grids could make a significant difference on such markets. Austria and Switzerland both have established organised markets for ancillary services. However, in Austria strict prequalification requirements and in Switzerland high minimum bid sizes are barriers for EV participation. In Israel comparable markets are still under development with ongoing liberalisation.

Wholesale markets	Compared to other flexibility markets, wholesale markets are the most liberalised and organised markets for electricity. The major marketplaces for trading electric energy as a commodity in Europe are European Energy Exchange (EEX) (long term) and European Power Exchange Spot (EPEX) (short term). **Minimum bid sizes** are relatively small, but **arbitrage margins** might be also too small for successful EV business cases.
Retail market	The retail market is fully liberalised in Austria, whereas it is still closed for households in Switzerland. Israel has introduced so-called virtual suppliers, who are authorized to purchase energy from the system operator and sell it to consumers at a competitive price. **Dynamic pricing contracts** leveraging flexibility are still scarce, but there are some commercial offers already in Austria. However, smart meter roll out is required for such contracts. In Israel, for instance, smart meters need to be purchased at the cost of the consumer, which is a significant barrier for dynamic pricing.
Energy communities	Energy communities are a concept introduced by European directives. Hence, it is currently only fully implemented in Austria. However, flexibility can only be leveraged if flexible assets can be **controlled remotely based on real time generation and consumption data**, which has hardly been implemented so far. In Switzerland, energy communities at the level of buildings are already possible and Israel is running some pilot projects on energy communities.

The technological framework

The integration of electric vehicle battery capacity into an electric grid is based on a number of technical standards, which need to be implemented to facilitate the development of corresponding applications. For the full analysis of the technological framework one can refer to Annex E.

On the physical level, this refers to **standardized charging connectors**. Although the Type 2 connector, with the combined charging system (CCS) extension is widely used in Europe, it is not mandatory and some competing systems continue to exist. Even more important than the connector standards are **communication standards between vehicle, charging equipment and a control entity**, which support all previous communication requirements and additionally, communication necessary for smart charging and vehicle to grid applications.

The most promising standard is the one designated **ISO 15118**. This standard defines a communication system which enables internet-protocol-level communication between a vehicle and a charging station. The physical information exchange is conducted via powerline-communication, or wireless communication. The future version ISO 15118-20 also supports plug-and-charge, which enables vehicles to charge at any charging station, with authentication and billing conducted via secure vehicle certificates in the background.

Another widely adopted, but not mandatory, standard is the **open charge point protocol (OCPP)** which enables charging stations of different suppliers to communicate with a central control system. The OCPP Version 2.0 supports ISO 15118, which enables a large range of applications.

The transfer of energy from the vehicle to the grid is a function that needs to be provided by the **vehicle manufacturer**. However, a mandatory communication standard for smart charging, without bidirectional charging, is recommended. With the same standard, bidirectional services will be easily implemented, when demand by the customers arises.

Battery degradation can be kept to a minimum if favourable charging and discharging conditions are met. It has been found that both "fast" charging and discharging with high power levels are harmful for lithium-ion batteries. Another often overlooked fact is the dependence of battery temperature while charging and discharging on its life expectancy. Therefore, charging and discharging at maximum rates below 0.5 C and between 10° and 30° Celsius is optimal.

This suggests using vehicle to grid capabilities for as a base power shifting, avoiding fast charging high power charging stations, and installing charging stations mainly indoors where temperatures are stable and optimal.

An interesting synergy effect is the possibility of preconditioning electric vehicles while connected to the grid, to save energy for cabin climatization and maintaining optimal battery conditions concerning state of charge and battery temperature.

Recommendations

Major conclusions of this study are the recommendations for unleashing the flexibility of EVs through smart and bidirectional charging in large scale. As an addressee the authors want to target policy makers, authorities, energy market regulators, and industry interest groups at all levels.

General recommendations include:

- **Policy agenda and decision making:** the industry requires clear and long-term political objectives to be able to plan and invest.
- **Incentives for owners and awareness raising:** it is necessary to inform the public about the possibilities of smart- and bidirectional charging and to motivate people to participate in innovative charging contracts.
- **Fostering applied research:** Pilot projects are necessary to quickly identify realistic opportunities and practical barriers.
- **Stakeholder communication:** Stakeholder conferences can raise awareness among key players and identify potential conflicts of interest hampering market uptake.

More specific recommendations are listed in the following tables, presenting **legal** measures, recommendations regarding **market design** and **standardisation**. The tables also show what is the appropriate policy level and in which national context the recommendations apply. The "x" indicate, if the recommendation is targeted towards a certain country (or the EU as an institution). If a recommendation does not apply, this means that it has already been implemented or preconditions have not yet been met.

Table 3: Legal recommendations

Recommendation	Description	Applicable for policies of			
		EU	CH	AT	IL
Make **smart charging the default** everywhere	This requires making dynamic electricity contracts a default for EV charging contracts and also minimum standards for charging station connectivity.	x	x	x	x
Guarantees of Origin (GOs)	Implement practical regulations on how GOs for renewable energy can be managed in case of V2G applications.	x	x	x	x
Eliminate **double taxation and double network charges**	For EVs serving as a battery storage in V2G mode.	x	x	x	x
Eliminate **net metering** rules	They are phasing out throughout Europe, but are a major barrier where they exist.	x			x
Accelerate the deployment of smart meters on a large-scale	With standardised functionalities to ensure interoperability. The sampling frequency must be in accordance with the flexibility trading settlement period.		x	x	x
Clarify **taxation** issues for profits **of energy communities**	Applicable only where energy communities are already in place.	x		x	
Accelerate the overall expansion of the charging station infrastructure	Make sure that there are enough charging stations, especially on motorways and important traffic junctions.		x	x	x

Table 4: Market design recommendations

Recommendation	Description	Applicable for policies of			
		EU	CH	AT	IL
Market liberalisation	Increase the **accessibility to the electricity market** for different private individuals and entities. This includes also opening markets for system services.		x		x
Dynamic electricity contracts	Enforce existing requirements and introduce new incentives for suppliers to offer **dynamic electricity contracts.**	x	x	x	x
Local flexibility markets	Implement large scale trials of **local flexibility markets** for offering flexibility services towards DSOs.	x	x	x	x
Modify regulatory frameworks to **encourage DSOs** to implement smart and flexible solutions at local levels	Remove regulation which hinders aggregation and flexibility procurement. Revise tariffs to include both a (higher) capacity and an energy charge. Define new DSO tasks (active grid operation and data management). Shift towards a total expenditure framework, where the DSOs need to minimize their operational expenditure.	x	x	x	x
Establish **energy communities**	Establishing a common international definition of the different types of energy communities, followed with the implementation of a legal framework that supports them in countries where this has not been done yet.		x		x
Incentivise **energy communities to offer flexibility services**	Simplify market access for energy communities. Support community energy management. Enable mechanisms for large companies to participate in energy communities. DSOs should provide smart meter readings in real time through an interface that does not require additional hardware.	x		x	

Ease **prequalification criteria** on the balancing market	Further reduce minimum threshold of bids. Enable group prequalification for aggregated pools of Demand-Side Flexibility (DSF). Allow stochastic redundancies for large pools of DFS instead of pure technical proven redundancies	x	x	x	
Introduce clear mechanisms for **independent aggregation**	Clarify compensation mechanisms. Allow independent aggregators to act without prior approval of the balancing responsible party (BRP) .	x		x	x

Table 5: Recommendations regarding standardisation

Recommendation	**Description**	**Applicable for policies of**			
		EU	**CH**	**AT**	**IL**
ISO15118	Introduce ISO15118 as a standard communication interface for new EV models, enabling bidirectional communication by default.	x			
Open Charge Point Protocol (OCPP)	Make OCPP a requirement for newly installed charging station.	x	x		x

Novel business models

Based on the findings so far, a business model making use of EVs' flexibility can be characterised by the following 4 determinants:

- **Fleet:** GAMES generally considers **carsharing fleets** and **corporate shared fleets**. We expect that fleets with a central fleet manager are the best starting point for business models targeting the flexibility of EVs, rather than fleets of privately owned cars without any fleet management. The manager is in a good position to also enforce a charging strategy for the whole fleet. Also, a commercial fleet manager is interested to find an optimal trade-off between generating revenues from flexibility services and reducing battery degradation. In the case of private EV owners this trade-off might be biased due to their limited knowledge. The "shared" aspect of a fleet is not necessarily a precondition to use it as a flexible resource. This means that also fleets of individual car users could serve as target segments in such business models, but only if there is a central fleet manager that can control the charging process.

- **Charging mode:** we expect that the main proportion of flexibility can be activated through the implementation of **smart charging**. It still remains unclear what is the additional flexibility potential that can be reached through **V2G**. Hence, this is also a question that is investigated in the quantitative modelling tasks of GAMES.
- **Business:** there is a **broad range** of business actors that have a potential interest in entering the market with novel business models featuring smart charging and V2G. Relevant players include car manufacturers, charging service providers, energy suppliers, aggregators, and energy communities
- **Flexibility service:** out of the whole range of services only a few can be considered reasonable for the case of EV fleets. The most promising flexibility services include:
  - **Balancing services** for the transmission system operator (TSO)
  - **Peak shaving** for the DSO
  - **Portfolio optimisation** for BRPs
  - Collective self-consumption optimisation for **energy communities**

ANNEX A – BACKGROUND: E-MOBILITY AND THE ENERGY SYSTEM

This section gives an overview of the current global trends on the uptake of electric vehicles and discusses their interaction with the electricity system.

A1 The rise of e-Mobility

Global development

Electromobility is on the rise. The idea of replacing the internal combustion engine with an electric drive is internationally recognized as a necessary measure to address various problems of our time. These problems include, among others, climate change, air pollution or oil import dependency. The following paragraphs are based on the current "Global EV Outlook 2022" published by the International Energy Agency (IEA) (1).

A key component of this transformation is the rapid expansion of the global EV fleet. A growing number of countries announced their intention to phase out fossil fuel based internal combustion engines vehicles and support the ramping up of EVs instead. Today, many have ambitious vehicle electrification targets for the coming decades. To achieve the common goal, many countries rely on international cooperation. For example, the Electric Vehicles Initiative (EVI) was established in 2010, a multi-governmental policy forum with the aim of helping governments to accelerate the transition towards electromobility. Not only western countries are represented in this cooperation, but also major players such as China and India. In addition, global automakers have plans to electrify their fleets that go further than policy targets. They consider electrification as an opportunity to capture market share and increase profits.

Consequently, the global EV market is dynamic. Global sales of EVs doubled in 2021 from the previous year to a new record of 6.6 million. In 2019, about 2,5% of global car sales (all road transport modes excluding two/three-wheelers) were electric, however the market share increased to about 9 – 10% in 2021. The total EV stock was about 18 million in 2021 and is estimated to reach between 200 and 350 million in 2030. According to various scenarios set up by the IEA, the sales share of EVs is forecast to reach between 20 – 33% in 2030, but even 60% could be possible. To classify the previous numbers, the total global road vehicle fleet is predicted to be around 2 billion in 2030. This means that EVs will make up around 10 -17% of the total fleet in 2030.

The previous expansion was based on multiple factors. However, sustained political support was the main driver. Public spending on subsidies and incentives for EVs doubled and reached about $30 billion in 2021. On the other hand, the public is becoming increasingly aware of the need for a mobility turnaround.

The Peoples Republic of China has made the major contribution to the accelerating growth and is expected to continue leading EV sales in 2030. More EVs were sold in China in 2021 (3.3 million, which represented 16% of total Chinese vehicle sales) than in the entire world in 2020. This is explained by the smaller size of Chinese EVs and by a minor price gap (due to lower development and manufacturing costs).

By contrast, EV sales are insignificant in many emerging and developing economies, where the few available models remain unaffordable for most of the people. In Brazil, India and Indonesia, fewer than 0.5% of all road transport vehicle (excluding two/three-wheelers) sales are electric.

The expansion of electromobility is not without complications. Huge problems have arisen in recent months and years. The most important one is insufficient access to necessary raw materials, which are required for the essential battery production. The pandemic and the increase in EV sales have placed great pressures on the battery supply chains. Prices of raw materials such as cobalt, lithium and nickel have surged and Russia´s invasion of Ukraine has created further problems. Unprecedented battery demand and a lack of structural investment in new supply capacity are key factors as well. In general, the production capacities for batteries are distributed very unequally worldwide, which can result in one-sided dependencies. For example, 70% of battery production capacity announced for the period to 2030 is in China.

European development

Europe is a key actor in electromobility. The quick expansion of electromobility and charging infrastructure has been declared a high-priority goal in the European Union and non-EU countries. Some countries such as Norway, Sweden and the Netherlands have already done very successful pioneering work.

In Europe, sales grew by 65% and reached 2.3 million in 2021. Overall, EVs accounted for 17% of Europe´s car sales in 2021. Different scenarios calculate with an EV sales share between 35% and 50% in 2030. The total electric vehicle stock in Europe (EU27, Norway, Iceland, Switzerland, and United Kingdom) is projected to reach 50 – 60 million by 2030.

Emission standards for electric vehicles in the European Union are expected to promote adoption across vehicle models and maintain Europe´s position as one of the most advanced EV markets in the coming years. In absolute numbers, Europe currently has a lead over the U.S.A. Furthermore, a direct comparison to China shows that Europe has achieved a higher EV-per-capita rate. Overall, the European electric vehicle market is expected to be the second largest in 2030, after China and ahead of the U.S.A. (1).

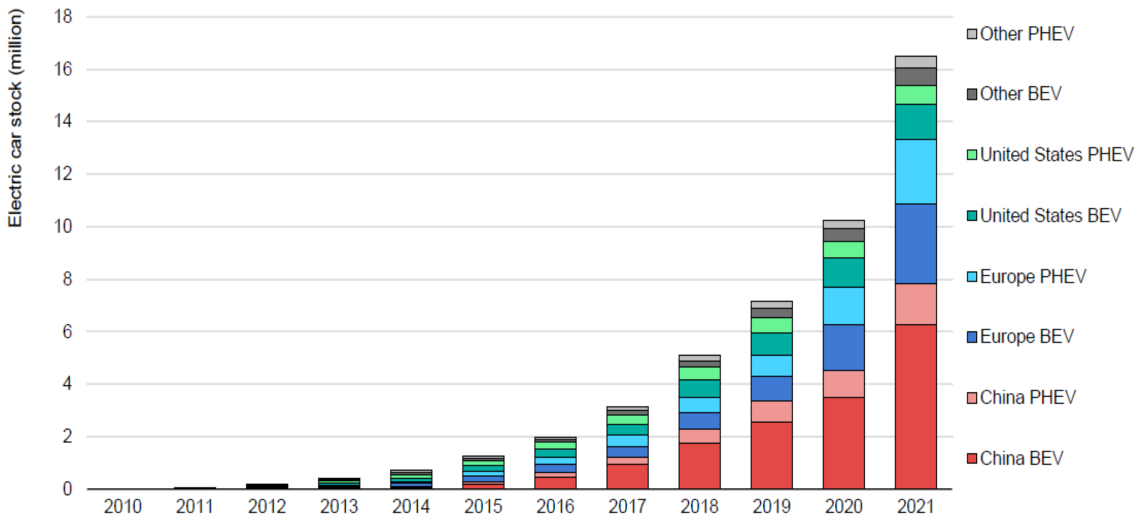

Figure 1: Overview: development of the global electric car stock 2010 – 2021 (in million). BEV = battery electric vehicle, PHEV = plug-in hybrid electric vehicle (2).

A2 Charging management: smart and bidirectional charging

EVs can be described as vehicles with an electric engine and a battery. Usually, they are divided into two categories: battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV). BEVs are powered solely by an electric motor and a plug-in battery. PHEVs contain an additional internal combustion engine (ICE) to allow more flexibility. PHEVs can be charged using electricity and BEVs need to be charged regularly. A crucial characteristic of EVs is therefore their interaction with the electricity grid.

EVs are typically charged at different locations, with different power levels and consequently at different speeds. Charging speed is one of the most important key figures to describe the charging technology. One possible classification is as follows: Slow charging (1 – 8 h & 3,7-22 kW), Fast charging (15 – 30 min & 50 kW) and Ultrafast charging (3 – 8 min & 150-350 kW). Slow charging is usually done via alternating current (AC) charging infrastructure and fast charging via direct current (DC) charging infrastructure. Charging infrastructure is also divided into public charging and private charging. EVs can be charged at low power while parked for a couple of hours, for example at home or at work. Users can combine parking and charging needs, thus slow charging will take place on an opportunity-basis. To support long-range travel, EVs require a wide-spread network of fast charging stations with high-power capacity. In 2030, private charging will cover the highest percentage of charging needs (over 70%). The rest will rely on a diffused publicly accessible charging infrastructure, either on private areas or on public streets.

Some forecasts assume that there will be around 135 – 235 million charging stations worldwide by 2030. The cumulative installed power capacity of those charging points is calculated to be about 0,6 – 1,1 terawatt (TW) globally, with 400 – 740 TWh of electricity consumption. Today, EVs do not pose significant challenges for the power system, because their share in total electricity consumption is relatively low. In Europe (2019), EVs represented only 0,2% of total energy consumption. Nevertheless, this rate will increase to 4 – 6% by 2030. In advanced economies, the increased demand probably won’t cause relevant problems, due to future energy efficiency improvements. However, the combination of a rapidly increasing EV stock and uncoordinated charging has the potential to cause major problems for the stability of the power grid, even in advanced- and especially in developing economies (3).

Smart charging

In the conventional charging process, absorbed power is given by the technical capability of both the charging station and the EV. It is simply the maximum power that both components can handle. Therefore, charging will occur in the shortest possible time and with the highest possible power absorption. Especially when the vehicle connection time is long, there is scope to modify this logic. With the appropriate charging infrastructure, it is possible to control the charging process. This is basically done by adjusting two parameters: the charging power and the charging time scheduling.

First, to enable real-time control of the charging power, charging stations can be equipped with communication and control systems. This process is also called power profile control. It allows the energy absorption to be modified.

Second, the charging time scheduling can be managed. The simplest way to do this is to connect the EV to the grid at certain times, for example, in middle Europe, at noon and not in the evening (hours of peak demand). However, intelligent communication and control systems enable to automatically control the charging process while the EV is still connected to the grid.

By combining the power profile control and the time scheduling, the charging process can be significantly improved. This approach is commonly known as smart charging.

Bidirectional charging

Smart charging can be further enhanced when considering bidirectional charging (two-way-charging). Essentially, bidirectional charging allows energy to flow in both directions, to and from the vehicle battery. This form of bidirectional charging is known generally as V2X, where X can be, for example, either a home energy system (V2H / Vehicle-to-home) or an electric grid (V2G / Vehicle-to-grid).

Both smart charging and V2G enable EVs to limit peak power demand or to provide other flexibility services, such as ancillary services or management of grid congestions. To fully exploit this potential, the engagement of EV owners, and their aggregation, is necessary. They need suitable incentives to make their car batteries available as flexible energy storage. Dynamically adapting grid tariffs in combination with easily understandable price signals are mentioned as possibilities. To allow this, the massive rollout of smart meters performing minimum hourly/quarter-hourly metering represents a fundamental pre-requisite, as well as the related data management system. Today, V2G solutions could provide attractive flexibility capacity, but require significant investments and system adjustments (4).

ANNEX B – FLEXIBILITY POTENTIAL OF ELECTRIC VEHICLES

The previous chapter identified key characteristics of EVs:

- EVs adoption will increase sharply worldwide
- EVs must be regularly connected to the electricity grid to charge their batteries
- The batteries can be used as a mobile and flexible energy storage

Consequently, the different opportunities to the grid provided by EVs are promising. The intelligent application of bidirectional charging can provide environmental and economic benefits for consumers and all involved actors of the energy system. This chapter presents a closer look at the potential flexibility EVs could provide to the electricity system, and the possible value of this flexibility.

First, we will look at what flexibility in the energy system means. The following definitions will help.

„Flexibility expresses the extent to which a power system can modify electricity production or consumption in response to variability, expected or otherwise. In other words, it expresses the capability of a power system to maintain reliable supply in the face of rapid and large imbalances, whatever the cause.“ (5)

-International Energy Agency-

We define flexibility as "modifying generation and/or consumption patterns in reaction to an external signal (such as a change in price) to provide a service within the energy system". (6)

-Ofgem-

Energy system flexibility is therefore the ability to adjust supply and demand, to achieve energy balance. It also helps to keep the flows of energy through the networks within safe limits. Different systems can provide flexibility over different timescales due to their different levels of inherent storage and flexibility. For example, coal and crude oil stocks can be seen as different types of energy storage, but also one or a fleet of EVs. EVs are primarily integrated into the electricity system, which is embedded in the entire energy system (7).

B1 Mobility trends and flexibility potential

The degree of system flexibility enabled by EVs depends not only on their number, but also on the way they are used and charged. According to the International Renewable Energy Agency (IRENA), cars in general (including EVs), are parked for about 95% of their lifetime. If a typical EV drives 15 000 km/year, it needs about 3 000 kwh/year. Even with a slow charging speed (e.g., 3,7 kW), the total time needed to charge the necessary total yearly energy is about 10% of the time the car stands idle. EVs can be charged in a fraction of their parking time, which gives a generous window of opportunity for flexible services. However, flexibility can be lower, for example when the vehicle is parked but not plugged in. The stationary time is decisive for the contribution to grid flexibility as well. The longer the EV is connected to the grid, the more flexibility services it can provide. For example, taxis or buses that travel a high daily distance have less immobilisation time, in contrast to single average private EVs .

Today, the EV fleet is still limited, and the cars have relatively small batteries in terms of kWh. Therefore, their aggregated energy storage capacity today is marginal and the flexibility that EVs could provide to the grid is small. However, EVs are expected to gradually become cheaper over time, due to falling battery cost and government policies. In addition, battery packs will increase from the current 20 – 30 kWh to 40 – 60 kWh. Thus, in 2030, the availability of flexibility will have grown with the number of EVs. Future batteries with a larger storage capacity (longer rides) will, on the one hand, offer more direct flexibility, but on the other hand increase their appeal and contribute to the purchase of more EVs. Technological advances in the charging infrastructure will also contribute to greater flexibility. According to IRENA, vehicles and charging stations will most likely have smart charging options including discharging as a common feature. Above all, a series-produced EV with standardised V2G capability could greatly lower the entry cost to customers and is seen as a significant future contribution to grid flexibility.

Between 2030 and 2050, this picture could change substantially. First, EV demand will eventually be saturated, and sales will decline. Second, people´s mobility behaviour is likely to shift from privately owned vehicles towards mobility services and car sharing, which is due to increasing digitalization and urbanization. The development could move away from privately owned vehicles towards mobility services and car sharing. This trend is expected to continue progressively due to digitalization and increasing urbanization. Consequently, EVs will be used more efficiently and fewer will be needed overall. In addition, the reduced number of EVs will probably be parked idle for less time. Thus, the flexibility potential will also be reduced (8).

B2 Quantification of flexibility potential in Europe

The EU is currently facing major challenges regarding its energy system. On the one hand there are current difficulties with maintaining cheap energy supply, and on the other hand the energy system is to be restructured towards a green and zero emission system. To achieve a sustainable energy mix that is affordable and secure, new and intelligent solution are needed. Demand-side flexibility (DSF), the ability of end-users to change their consumption and generation patterns based on external signals, has been identified as part of the solution. According to a study published by “SmartEN” (9), a total of 164 Gigawatt (GW) upward flexible power and 130 GW of downward flexible power was estimated in a simulated model calculation for the year 2030. Upward DSF means increase of generation or decrease of demand. Downward DSF means decrease of generation or increase of demand. In addition, a total activated flexibility of 397 TWh of upward DSF and 340,5 TWh of downward DSF was estimated. A full-DSF activation scenario unleashes the flexibility from buildings, EVs, and industry. The simulated combined potential of different DSF technologies in the EU by the year 2030 is well worth mentioning. For example, the following benefits were calculated: 15,5 TWh (61%) less renewable energy curtailment, 37,5 million tonnes less annual Greenhouse gas (GHG) emission, security of supply, €11.1 – 29.1 billion (27%-80%) less annual grid investment needs or €71.1 billion (64%) cost reduction for consumers per year on electric consumption. In total, the authors calculated over €300 billion of indirect annual benefits to people, communities, and businesses. Smart charging and V2G as DSF technologies were considered by "SmartEn" in their study. This allows us to estimate the amount that EVs can contribute in a full-DSF activation scenario. Smart charging and V2G combined make up a significant proportion of the available flexible power:

Share of flexible power (V2G plus smart charging)
45,38% of total upward flexible power and 32,20% of total downward flexible power.

Share of total activated flexibility (V2G plus smart charging)
32,07% of total activated flexibility and 38,19% of total activated downward flexibility (10).

Visualisation of flexibility potential in Germany

The German e-mobility start-up LADE has developed an interactive visualization tool that illustrates the concrete contribution V2G can make to CO_2-free power generation (10). Based on real data from the Federal Network Agency, the simulator presents what the implementation of V2G could look like for Germany. It shows the total power consumption in Germany as well as the power generated using wind and solar energy. In addition, concrete expansion targets for renewable energies and the number of EVs can be simulated.

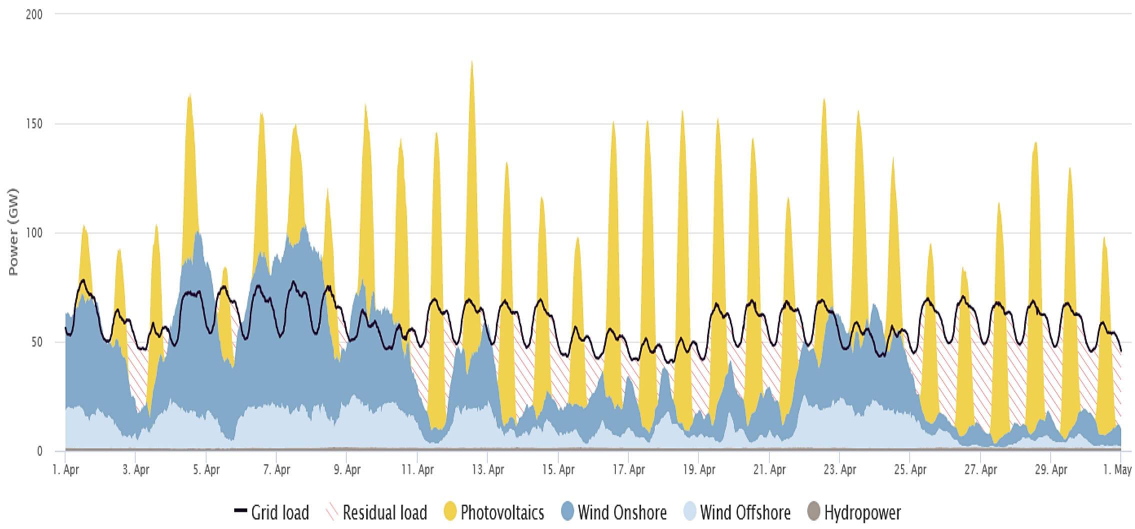

Figure 2: Total power consumption in Germany and the power generated using wind and solar energy. Illustration without V2G technology applied.
Setup: April 2022 & renewable expansions goals for 2030 enabled (11).

Figure 2 shows the power consumption or grid load in Germany in April 2022 as a dark line. In this simulation, the expansion targets for renewable energy in 2030 have already been achieved. This means a doubling of the installed onshore wind capacity, a quadrupling of the installed offshore wind capacity and a quadrupling of the installed photovoltaic capacities. In addition, 15 million EVs are available in

Germany, which roughly corresponds to the current goals of the German government. We notice that power consumption is largely covered by renewable energies and that there is a significant surplus of solar energy on a regular basis. However, there are also periods where renewable energy is not sufficient.

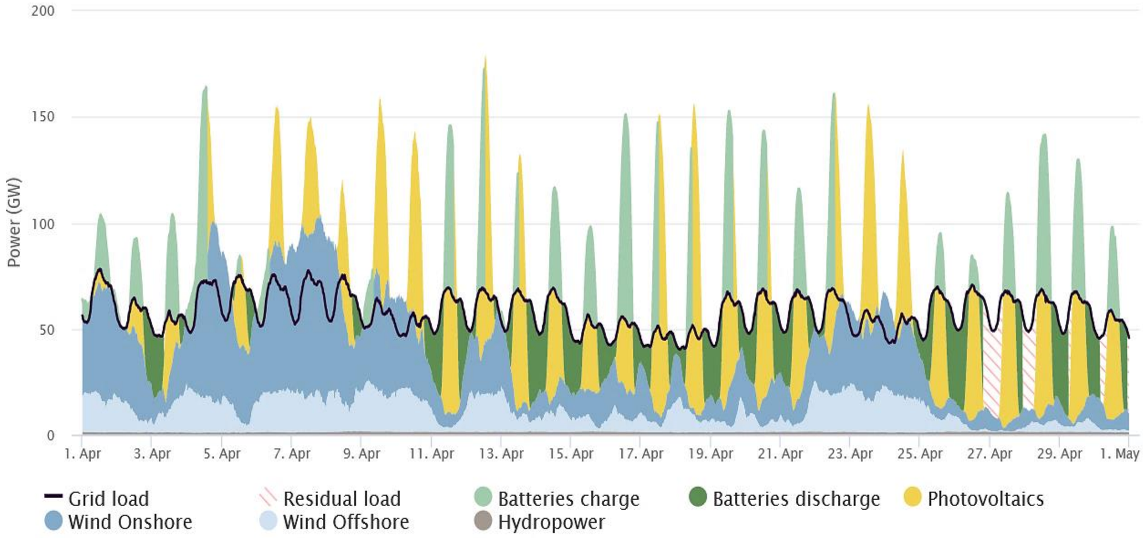

Figure 3: Total power consumption in Germany and the power generated using wind and solar energy. Illustration with V2G technology applied.
Setup: April 2022 & renewable expansions goals for 2030 enabled (11)

Figure 3 also illustrates April 2022 and we recognize the same amount of generated renewable energy. In this scenario, however, V2G technology is implemented. Consequently, the regular surplus of renewable energy is stored in the EVs batteries and later used to fill in the gaps. For April, this results in the following effects:

- 4.1 million tons less CO_2-emission
- €1,223 billion savings
- 14,69% higher renewables share

If Germany achieves its expansion targets, it might be possible to provide about 95% of the electricity supply using the sun, wind and EVs (11).

Benefits of flexibility

As already mentioned, smart and bidirectional charging can offer many benefits, especially for the power grid. The following has been confirmed in the literature:

Effective EV charging management strategies can **support grid stability** in combination with a high EV penetration rate. Smart charging can optimize the timely electricity demand from the grid to avoid network constraints, such as network congestion. It enables **peak shaving** and provision of **ancillary services** as well. For example, many studies have shown that with the help of an appropriate number of EVs and the use of smart charging, the peak loads in the grid can be noticeably reduced. In addition, V2G assists in flattening the voltage profile of distribution feeders and reduces line currents and large load variations at distribution transformers. A V2G-capable vehicle can offer other power quality services. . Moreover, V2G can enable ancillary services, such as voltage- and frequency control and provide an alternative to spinning reserve. Consequently, V2G can improve the performance of the electricity grid in terms of efficiency, stability, and reliability. In general, smart charging and V2G aid to maintain grid stability. EVs provide power when there is a lack of renewable energy supply and charge when there is an excessive renewable energy supply in the grid.

Along with the benefits offered to power grids, smart and bidirectional charging also have the potential to bring **financial advantages**. These include, for example, minimizing of energy generation cost, minimizing of running cost or benefits maximization for aggregators. Furthermore, charging management could defer or completely avoid investment in transmission and distribution network assets, such as power lines and transformers. Also, managed charging reduces network costs for all connected customers as well as charging costs. Furthermore, smart charging helps to reduce charging costs by about 6%. Moreover, managed charging of EV fleets can achieve 20% reduction in annual electricity cost and 48% reduction in battery aging cost (battery aging cost represents the cost of replacing the battery spread over the battery lifetime) (11).

In Great Britain, V2G technology has been identified as promising technology and its potential has been extensively investigated. A current (2021) analysis finds that aggregators could generate financial benefits of £700 - £1250 per V2G-enabled EV. Cost savings and direct revenues (for the aggregator) from providing grid services contribute to this. The long-term economic benefits have been assessed for a back-to-base fleet of 1 million commercial EVs. Simulation results show that V2G can unlock whole-system cost savings of £412-883 million per year. In contrast, unmanaged and smart charging scenarios are shown to result in increased system costs of £567-773 million per year and £102-150 million per year respectively, due to higher energy demand and limited flexibility. The value offered by an additional EV with V2G for system operation falls with larger fleet sizes. With only 50 000 V2G-enabled EVs, each new EV could reduce system operation cost by up to £12 000 per year. However, with 150 000 EVs on the system, the marginal value per EV is about £600 (12).

In the Sciurus project in the UK (United Kingdom), it was calculated, among other things, how much the owner would save in a year with a V2G-capable EV. The simulated annual revenue from V2G using tariff optimisation was £340 compared with an unmanaged charger. This income can be increased (up to £725) if other services provided by V2G-capable EVs are included: firm frequency response and dynamic containment. However, there are still technical problems in the application of these two. For comparison, smart charging can capture £120 from tariff optimisation (13).

Furthermore, smart, and bidirectional charging also help to achieve **environmental objectives**, such as reduction of CO_2 and greenhouse gas emissions. It has been calculated, for example, that smart charging, compared to uncoordinated charging, enables a reduction in annual CO_2 emissions of 5 – 10%. Another important effect of managed charging is the more efficient use of renewable energies. Since a potential surplus of renewable energy can be stored in the batteries, less of it is lost. This effect is particularly significant in the case of solar energy, where there is usually a daily unused surplus in the summer months (14).

ANNEX C – POLICY FRAMEWORK: STATUS QUO AND BARRIERS

This chapter provides an overview of different policies related to electromobility, smart- and bidirectional charging. The focus is placed on the EU, Austria, Switzerland, and Israel (partners of the GAMES project). In addition, a summary of the most important regulatory barriers regarding smart- and bidirectional charging is included.

C1 European policies

The EU has defined limiting global warming as an overarching goal and consequently wants to become climate neutral by 2050. To achieve the reduction targets, the European authorities have agreed on certain key policies. In the context of e-mobility, the following are particularly worth mentioning: improvement of energy efficiency, expansion of renewable energies and the phasing out of fossil fuel-based ICEs. As a concrete measure, it was decided that from 2035 only zero-emission vehicles (mainly EVs) will be allowed to be newly registered (15).

In 2020, the energy supply and transport sectors were the two largest emitters, accounting for 24,2% and 20,7% of total emissions, respectively (16). EVs as mean to decarbonize transportation, are therefore a central component of European climate policy. In general, policies concerning EVs and their charging are part of a broad and long-term transportation policy and climate strategy in Europe, with many different actors involved.

The original intention of the European EV charging policy was for the member states to build up their charging infrastructure in proportion to the growing number of EVs. For this reason, fundamental expansion targets have been formulated for the individual states, for example a certain quota of publicly accessible charging points per EV or a prescribed number of public charging points along the main traffic routes. However, the number of European charging stations is lagging the targets, and the necessary expansion rate is currently far too slow. (18) For example, to supply a planned number of around 43 million EVs (2030 in Europe) with the appropriate charging infrastructure, about 14 000 public charging stations would have to be deployed every week. In 2021, however, only 2000 were built per week (28). The focus of the EU was not only to ensure the necessary number of charging stations, but also on establishing an open and competitive market for all participants in the charging process. This includes several requirements, including non-discriminatory access to public charging stations, clearly communicated prices or competition among providers (17).

The EU has specified a strategic framework for achieving its climate goals, the "European Green Deal". It is a package of policy initiatives, which aims to set the EU on the path to climate neutrality by 2050. The "Fit for 55" package is a set of proposals to revise climate-, energy- and transport-related legislation and aims to translate the ambitions of the Green Deal into law (18).

As a result, there is no single set of regulations, but rather several different European directives, regulations and initiatives that all have a greater or lesser influence on EVs and EV charging. For example, the "Sustainable and Smart mobility Strategy", the “Clean Vehicles Directive”, the “Renewable Energy Directive II (RED II)” or the “Energy efficiency Directive” (19). Within this number of regulatory frameworks, the “**Alternative Fuels Infrastructure Directive**” **(AFID)**, the “**Energy Performance of Buildings Directive**” **(EPBD)** and the **RED II** are of particular importance for EV charging (20).

The **AFID** establishes a set of measures for the creation of an alternative fuel infrastructure (including charging infrastructure), while the EPBD outlines specific measures for the building sector, including the installation of charging points inside residential and non-residential buildings (19). The newest version of the AFID proposal- Alternative Fuels Infrastructure Regulation (AFIR) outlines three key requirements for Europe’s charging infrastructure: The charging network should be fair, open and accessible. In other words, there should be a sufficient number of freely accessible charging stations for everyone. In the EU, particular value is placed on the needs of potential users, the charging process should be quick and easy to understand. As opposed to a directive, a regulation is a legally binding instrument. Therefore, member states must create national policy frameworks for EV charging infrastructure, outlining their assessment, targets, and key milestones for the development. Regarding smart and bidirectional charging, all publicly accessible charging stations in Europe will have to be digitally connected and capable of smart charging. Smart charging stations should comprise a set of physical attributes and technical specifications that are necessary to send and receive data in real time, enabling the flow of information between market actors. Smart metering systems enable real-time data to be produced and allow smart charging in combination with smart charging stations. Therefore, member states shall encourage the use of smart metering systems. Furthermore, member states shall assess the potential contribution of bidirectional charging to the penetration of renewable electricity into the electricity system. This assessment is to be made and published every 3 years from June 2024. Based on the results, member states shall take the appropriate measures to adjust the availability and geographical distribution of bidirectional charging stations (17) (21).

The newest version of the **EBPD** directive also obliges member states to have smart charging-enabled charging stations and also bidirectional charging if appropriate. (22).

> “Member States shall ensure that the recharging points referred to in paragraphs 1, 2 and 4 are capable of smart charging and, where appropriate, bidirectional charging, and that they are operated based on non-proprietary and non-discriminatory communication protocols and standards, in an interoperable manner, and in compliance with any legal standards and protocols in the delegated acts adopted pursuant to Article 19(6) and Article 19(7) of Regulation (EU) …/… [AFIR].” *(23)*
>
> *-Proposal for a*
>
> *DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL*
>
> *on the energy performance of buildings (recast)-*

The EU introduced a series of provisions within the "Clean Energy Package" (2019) facilitating smart charging. These include the "**Electricity Directive** (EU) 2019/944" and the "**Electricity Regulation** (EU) 2019/943". Both acts aim to empower consumers by giving them more autonomy to benefit from the dynamism of market prices. The Electricity Directive introduced a requirement to put in place smart metering systems and obliged all electricity suppliers of a minimum size to offer dynamic electricity price contracts. It also contains provisions for aggregators facilitating the development of other flexibility services (22).

EU countries use various tools and instruments to introduce the widespread use of smart or bidirectional charging, such as:

- Tax benefits/exemptions for investments in charging infrastructure
- Tax benefits/exemptions for business models related to EV charging
- Tax benefits/exemptions for smart/bidirectional charging users
- Direct investments in public charging infrastructure
- Subsidies for investments related to electromobility or EV charging
- Subsidies for business models related to EV charging
- Purchase grants for low emission vehicles
- Local incentives (for example: free parking for EVs)
- Prescribed charging technology standards
- Command and control instruments
- Active acceleration of bureaucratic processes (faster approvals for charging stations)
- Campaign to promote electromobility (24)

For example, Germany mandates smart charging for private chargers to qualify for subsidies. Greece and Portugal mandate smart chargers for all publicly accessible charging points (25).

The main source of support for Research & Innovation (R&I) investments in smart EV charging at EU level is the "Horizon Europe Framework Programme". For example, the call "Clean and competitive solutions for all transport modes" of Horizon Europe has many actions related with smart EV charging, such as the "System approach to achieve optimized Smart EV Charging and V2G flexibility in mass-deployment conditions" (€25 million). (26)

C2 Corporate policies

Smart and bidirectional charging requires the entire EV ecosystem to work together. According to European Automobile Manufacturers´ Association (ACEA), charging operators and hardware manufactures should install and produce smart-charging stations, OEMs (original equipment manufacturer) suppliers are supposed to bring the V2G charging technology to the market, and grid players and energy producers need to build the capabilities and promote business models to increase the use of smart and bidirectional charging (27).

Companies act to maximize their profits, but usually have to adapt their business models to state regulations or to overarching social goals (e.g. the reduction of carbon emissions). The automotive industry, for example, has recognized the need for a shift to electromobility. As a result, many major manufacturers (e.g., Renault, Fiat, Volkswagen Europa) have announced to fully switch from ICEs to alternative drives by 2030 (28). Moreover, 44 well-known companies (e.g., Siemens, Unilever or PepsiCo) even demanded from the EU-Commission that from 2035 only zero-emission trucks may be newly registered. This step would give companies investment and planning security (29).

In the US, Europe, and China, the profit pool (the total profits earned at all points along the value chain of an industry) for the EV charging sector is likely to grow to between €8 billion and €13.5 billion by 2030. EV charging will be large and profitable markets, in which smart energy services will represent about one third of the total profit pool by 2030. However, many market segments are still at an early stage and will take years to develop, so decisions and investments today will play a significant role in determining the long-time winners. Companies interested in the EV charging market face three key decisions about where to compete: the charging location (home, work, destination, or transit), the part of the value chain, and the region. The largest profit pool for home and work charging will likely be linked to next-generation smart energy services, including V2G. Companies that succeed in the growing market for home and work charging will be best positioned to compete.

There are several distinct business models in the emerging EV charging ecosystem. The simplest model is one focused purely on hardware or software. Others bundle different elements of the charging value chain. Charging solution providers, for example, combine hardware, planning, and installation. Charge point operators (CPO) install and operate charging stations. Capital markets currently award a higher value to integrated business models. They place a lower value on pure hardware providers, assuming that over time, equipment is likely to become a lower-margin commodity business. Participants in the new charging ecosystem include automakers, oil and gas firms, electricity companies, equipment manufacturers, software firms, charge-point operators, retailers, infrastructure funds, and start-ups. Many companies have formed partnerships to deliver an optimal customer experience, ensuring that charging apps, networks, and payment systems work reliably in every location.

Leading companies in the US, Europe, and China already are developing consortia to provide a broad array of solutions, including home, transit, and destination charging, as well as smart home applications and solar power. Dealers are teaming up with installers, smart home providers are working with charging services, and cities are collaborating with oil and gas companies and utilities. Large consortia allow members to share the capital expenditure on infrastructure and generate profits faster in a nascent market. For example, “Ionity”, a joint venture of global automakers including “BMW Group”, “Ford Motor Company”, “Hyundai Motor Group”, “Mercedes-Benz”, and “Volkswagen Group”, aims to accelerate the development of a fast-charging network along Europe’s major highways.

To succeed, alliances must keep the customer at the centre of the offering and ensure a positive user experience. Several companies have managed to do both those things despite doing it alone. For instance, automaker “Tesla” has created a proprietary charging ecosystem, including wall connectors for home charging and storage, solar panels for the roof, a global network of highway superchargers, and destination charging sites. In addition to providing all the infrastructure, the company ensures that its charging universe is seamlessly interconnected (30).

C3 Policies in Austria

As an EU member state, the current government in Austria is committed to the European goal of climate neutrality. The Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology has announced even more ambitious targets: climate neutrality by 2040, which also means a zero-emission transport sector (31).

The Austrian government has long provided subsidies for the purchase of EVs and investment in EV charging infrastructure. EV subsidies are funded through a public-private partnership between vehicle importers and the government. Subsidies are provided for up to a maximum of 30% of the eligible purchase cost. In addition, the government plans to further expand and upgrade the charging infrastructure in co-operation with private sector suppliers. (32)

At the federal level, there a are only a few legal measures to promote the charging infrastructure and there are no legal obligations to expand the charging infrastructure. Due to the federal system in Austria, many laws are implemented at the state level, for example the European EPBD. At the same time, more and more federal states are incorporating improvements to promote the charging infrastructure into their building's regulations (33).

In 2022, electromobility was funded with €167,2 million. The purchase of an EV by private individuals was subsidized with €5 000, private wall charging stations (wallbox) with €600 and company or public fast charging stations with up to €30 000 (34).

Austria has made notable progress in increasing the share of EVs. The combined share of BEV and PHEV in new vehicle registrations was 2,02% (7154 EVs) in 2017 and increased to 20,02% (47992 EVs) in 2021. In September 2022, 139 351 electric vehicles were on the roads, which corresponds to about 2,7% of the total vehicle fleet. In July 2022, there were a total of 11 730 publicly accessible normal charging and 2 061 fast charging points throughout Austria. This roughly corresponds to the EU target of one charging station for every 10 EVs (35).

Austria has also set itself the goal of obtaining 100% of its power supply from sustainable energy sources by 2030. EVs in combination with smart and bidirectional charging can be a crucial support. During a project in Austria, 1665 people with a professional connection to the topics of energy and electromobility were asked about their assessment of smart and bidirectional charging. It turned out that the topic has not yet reached the important decision-makers. A multitude of questions regarding the application of smart and bidirectional charging, system effects and the actual added value were unclear for the majority of actors (e.g. network operators, fleet managers or end users). Currently, many relevant laws, regulations, directives, norms and standards in the field of energy and mobility are not on a national level but set at European level. These are still insufficiently on the new possibilities of smart and bidirectional charging (36).

In December 2022, The Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology published an immediate action program dealing with the use of renewable energies in mobility, the "Sofortprogramm: Erneuerbare Energie in der Mobilität". The plan provides a strategic framework and measures to achieve the Austrian goal of zero-emission transport as well as to meet the European targets through the "Fit for 55" package. With the help of stakeholder workshops, 40 measures were developed, some of them relate to smart and bidirectional charging. Furthermore, a focus was placed on the integration of e-mobility into the power grid. The following measures relate to smart and bidirectional charging:

Right-to-Plug: The "Wohnungseigentumsgesetz" (Home Ownership Act) was amended, and a so-called right-to-plug was implemented. The right-to-plug is the right to the installation of a slow-charging system at an owned parking space, without having to go through complicated approval hurdles.

E-mobility and network tariffs: To enable more flexibility on the electricity market, certain market mechanisms must be reorganized in Austria. Consequential, electricity network charges/tariffs are to be redesigned to encourage the use of flexibility services. For example, in the form of interruptible tariffs. This means, the charging process of EVs should be able to be interrupted in exchange for a reduced rate tariff. This should enable EV users to participate in the electricity market.

Charging station data regulation: Statistical and dynamic data (e.g., price information) are defined in a new ordinance, which are entered into a charging station directory via the Austrian regulator E-Control. The charging station directory has a standardized interface, which means that data can also be made available to service providers and third parties.

Charging tariff calculator: E-Control is developing a calculator to compare charging tariffs. This should be an effective measure for more price transparency and comparable charging prices in Austria.

Electromobility subsidies: Private individuals, companies, regional corporations and associations can apply for several subsidies for EVs or charging infrastructure. The respective subsidies are updated continuously. For example, there is a funding program that supports companies in switching their fleets to emission-free commercial vehicles. Support is also provided in setting up a suitable charging infrastructure. €455 million are earmarked for this program by 2026.

Research: A study will examine what legal, technical, and organizational framework conditions and questions regarding bidirectional charging and V2X applications exist. Recommendations for action are to be derived from the study to achieve the greatest possible value from these applications.

Electromobility coordination centre: A central Austrian office will be established, which will serve as a coordinating network and competence centre. The centre is intended to be the central hub for Austria´s electromobility agenda (37).

C4 Policies in Switzerland

In 2017, Switzerland ratified the Paris Agreement and announced a 50% reduction of GHG emissions by 2030 (compared to 1990 levels). In addition, the country is aiming for net zero GHG emissions by 2050 (38). In this regard, significant progress has already been made towards the expansion of electromobility. The combined share of BEV and PHEV in new vehicle registrations was 4,1% in 2018 and reached 22,5% in 2021 (39). In 2022, 110 700 EVs were registered, which corresponds to about 2,3% of the total vehicle fleet (40). A total of 9738 public charging stations were available in 2021. 8% of them had a power level of more than 100 kW.

Overall, Switzerland has one of the best and densest charging networks in Europe. According to "Swiss eMobility", this is due to the active and unsubsidized market players. In addition, more and more people are ready to choose an EV as their next vehicle. In Switzerland, cantons in particular are responsible for promoting low-emission and energy efficient vehicles. Many of them subsidise electromobility. However, the scope and funding conditions are fundamentally different. Five cantons grant purchase grants for vehicles, six cantons for private and/or public charging infrastructure. Also, the motor vehicle taxes differ significantly (41). At the national level, EVs (not plug-in hybrids) are exempt from the automobile tax of 4% of the vehicle price. Moreover, there are no taxes on electricity as fuel (42).

In 2021, the public-private initiative "**Roadmap Elektromobilität 2025**" was designed, which identified three interim targets for the further expansion of electromobility. This initiative is the successor to the "Roadmap Elektromobilität 2022", whose goals have been achieved. The new goals for 2025 are: First, the share of EVs in new registrations should rise to 50% by 2025. Second, the number of public charging stations should increase to 20 000. Third, user-friendly and grid-friendly charging options should be available in all charging situations, including at home, by 2025. To reach the goals (especially the second and third), 56 organisations and entities (including the automotive-, electricity-, real estate-, and vehicle-fleet industry as well as the federal government, cantons, cities and municipalities) will research ways to best implement a nationwide electric vehicle charging network at service stations, homes, workplaces and on the road (39).

At the heart of the roadmap are cross-organizational "lighthouse measures", which address particularly relevant challenges: charging in apartment buildings, in the district, at the driving destination and the circular economy of drive batteries (43).

As part of the roadmap, 75 measures were drafted. Many of them relate to charging infrastructure and some to bidirectional charging. The measures affecting the charging infrastructure are diverse. Some aim to speed up the approval and construction of charging stations in different areas and locations (rural area, multi-party buildings, civil federal buildings or the hotel sector) and at the same time reduce bureaucratic hurdles. Others try to develop a Swiss wide suitable IT and data infrastructure (39).

For example, “Electrosuisse” recently put in operation a versatile charging park in Switzerland, with a total of 22 wall charging stations from various manufacturers and bidirectional charging stations. On the one hand, an adequate charging infrastructure is provided for visitors and employees, as well as for the company’s own EV fleet. On the other hand, training and further education for the industry are offered, as well as guided tours for those interested.

The Federal Roads Office enables all 100 federal motorway rest areas to be equipped with fast charging stations until 2030. In addition, the Federal Road Office will allow investors to set up fast-charging stations at areas near motorways (43).

The building, planning and environmental directors’ conference (BPUK) and the energy directors conference (EnDK) want to use their committees to advocate for simple processes for setting up charging stations and installing the necessary lines, as well as supporting the mutual exchange of knowledge between the cantons and the other levels of government. “ABB” is committed to developing cost-effective bidirectional charging stations to help spread the technology. By mid-2023, “Helion”, “sun2wheel” and “Solar Manager” will develop an affordable V2H charging solution. The measure of the “Tesla Owner Club Helvetia” determines the various stakeholders for a V2G solution and their needs, basics requirements, opportunities and risks. A catalogue of recommendations for the implementation of a V2G solution will be developed from the information obtained. The company “sun2wheel” is testing the effects on the power grid of various V2G application categories in a pilot project (39).

There are currently several other project in Switzerland that are intended to test the possibilities of V2G. Among other things, one deals with the question of how to enable a smooth exchange of data between the players in the power grid. Others test the economic potential of V2G and develop possible business models (44).

C5 Policies in Israel

Israel does not yet have any comprehensive regulatory framework regarding EV charging. However, with the increasing penetration rate of EVs, the relevant authorities (primarily the Electricity Authority and the Planning Administration) have issued some policy guidelines and are now formulating the due regulation. Following is a summary of the policy guidelines in Israel as of 2022. It is worthwhile noting however, that any policy guidelines as outlined here is likely to change in the very near future as the EV market share is growing.

The authorities that influence EV charging regulation are: the Electricity Authority, the Ministry of Transportation, the Electricity Company, the Housing and Construction Ministry, the Ministry of Environmental Protection, the Ministry of the Interior, the Smart Mobility Administration (formerly a unit withing the Prime Minister Office which was transferred to the National Economic Council) and the Tax Authority. Other stakeholders are local authorities, vehicle importers, public charging stations providers (such as Afcon (45), Sonol EVI (46), Gnrgy (47), Virtual fleet managers (such as Pointer (48) and Ituran), large corporations such as Microsoft who own large fleets and could benefit from smart charging options and flexibility services.

According to the Ministry of Energy, EVs are expected to increase the annual household demand for electricity by 3150 kWh which means a significant additional load on the power grid. Therefore, the expansion of charging stations infrastructure is high on the Ministry's working agenda (49).

The guidelines for installing EV charging stations are based on the European Commission documents COD 2016/0381. EV Charging stations are part of the public electricity infrastructure owned by the Israel Electricity Corporation (IEC) and governed by various national and local authorities and regulators. However, the stations are operated, as a rule, by private sector companies.

While the regulation for charging stations is lagging, the various ministries and government agencies do take action to remove barriers and to increase the EV market share while expanding the installed base of charging stations with the financial support of the Ministry of Energy.

Incentives that EV buyers currently receive in Israel include:

- The purchase tax on new cars in Israel is considerably higher than in other European countries, amounting to 83% for fuel combustion cars. In order to incentivize buyers to purchase electric vehicles the purchase tax on EVs was reduced to 10%. This tax is planned to increase to 20% in 2023 and to 35% in 2024 (50)
- Since 2015 employees that are entitled for leased company cars (only EV) receive a tax benefit of ca. 250 Euros/month (51)
- The cities of Haifa and Kfar Saba exempt EVs from parking fees for up to 2 hours in authorized parking zones across the city

Other supportive policy measures include:

- Between 2017 and 2022 the Ministry of Energy issued several calls for private companies and local authorities to install charging stations in public parking lots and residential buildings aiming at rolling out a total of 2500 stations across the country. To support this call, the Ministry allocated a budget of more than 30 million ILS (52). It is worth noting that the regulator (the Electricity Authority) does not require smart charging capabilities in charging stations, although this requirement might be introduced in the very near future
- Charging services pricing is not supervised and it is set by the power providers who install and operate the stations
- The installation of an EV charging meter in the parking space of residential buildings will be regulated in the near future based on the results of a pilot project undertaken by the Tel Aviv Municipality with the support of the Ministry of Energy (53)

- An amendment to the Electricity Market Law (1996), that passed in 2018, stipulates that providing electricity through a charging station will not require a permit

To accelerate the expansion of the installed public charging stations, the Planning and Construction Law stipulates that charging stations installed in public areas by local authorities or by a municipal corporation, do not require a construction permit. This exemption applies also to charging stations that are installed in private parking lots (54).

A range of amendments to the Construction and Planning regulations are being currently considered by the Planning Authority aiming at advancing the rapid deployment of charging stations.

C6 Other national policies

Norway

Norway is one of the world leaders in terms of electromobility. By February 2022, there were more than 470 000 registered BEVs in Norway and BEVs held a 64% market share in 2021 (55). In April 2022, EVs (BEV + PHEV) took 84,2% market share. Overall, 23,1% of the total passenger fleet in Q1 2022 were EVs (56). The Norwegian charging infrastructure is correspondingly well developed. In 2021 there were a total of 19 268 publicly accessible charging stations. (57)

Norway's policy makers have invested heavily in charging infrastructure since the late 2000. The deployment of EV chargers began at the local level and, since 2009, has been supported at the national level. In 2009, the government introduced a national subsidy policy aimed at promoting public charging near urban areas and along major highways.

Between 2010 and 2015, the country has spent a combined total of $15,5 million to support charging stations nationwide. Subsidies for normal chargers ranged from $1 000 to $6 000, while subsidies for fast chargers ranged from $10 000 to $45 000, which covered a large part of the installation costs. Norway also provided generous fiscal incentives to consumers to encourage EV adoption. For example, BEV purchases are exempt from registration fees, value-added tax, and annual license fees. In addition, there are other incentives in place including free access to public parking and bus lines (58).

Since EVs are already widespread in Norway, a relatively dynamic market for the charging process has also developed. Most EV users have a charging station at home, which mostly offers the possibility for smart charging. As a rule, customers opt for smart charging if it can reduce their energy costs (59).

Norway has a wide availability of dynamic Time-of-use tariffs for all consumers, not just EV users. Multiple smart charging services exists that can work with these tariffs (60).

The application of bidirectional charging with the help of V2G technology has also been identified as a potentially profitable business model in Norway. (61)

United Kingdom

The UK government has committed to phasing out the sale of new petrol and diesel cars and vans by 2030. As of January 2022, there were 28 375 public charging stations available in the UK. Infrastructure development has largely been market-led. Until recently, a limited number of regulatory instruments and incentives had been used. However, to keep up with charging demands, far-reaching proposals which will place obligations on public authorities, building constructors and others have been examined. The aim is to ensure an adequate charging infrastructure and appropriate consumer protection. (62)

The UK was an early adopter of a policy to mandate smart charging functionality (2018). In July 2021, the UK government released a smart charging strategy based on a two-phased approach. Phase 1 requires that new charge points, public or private, be smart chargers and be set by default to charge only at off-peak times. Phase 2 topics include the ability of consumers to switch operators, cybersecurity, and grid stability. (25)

C7 Regulatory barriers for smart and bidirectional charging

Electromobility is only at the beginning of the market ramp-up. The many possibilities that EVs can bring are accordingly new and unknown for all players in the energy system. This also applies to smart and bidirectional charging. Currently, knowledge about EV charging and related barriers comes mainly from various test projects and interviews with experts and energy system stakeholders. Major regulatory barriers have been identified that impede the successful integration of EVs into the power grid, such as discussed in (63) (64) (36).

Challenging new market design: Markets and regulations must reward flexibility; they have to reflect the value of flexibility options for the system. A functioning market model must therefore be ensured where flexibility can be traded with the prospect of profit. Open markets including wholesale markets and those specifically for flexibility services such as balancing, congestion management and voltage control are suggested as a possible market design. Cost-reflective time-sensitive consumer tariffs can incentivise drivers to charge at the optimum time for the entire system (65).

In the EU, there is no clear method adopted by the regulators for compensation for the offered flexibility services to the distribution system operators. Incomplete or vague regulations and immature flexibility markets at the distribution level are identified as barriers. The immaturity of distribution level flexibility markets is also reflected through lack of transparency and market priority rules among market participants.

Lack of dynamic pricing schemes has also been identified as an important regulatory barrier in Europe. However, an obligation to allow dynamic pricing for consumers is part of the Electric Market Design (EMD). This has been implemented, and was even already possible, in some EU member states but not all. In addition, dynamic pricing requires smart metering, which shows a slow roll-out in many member states (66).

Legal uncertainties: In Europe, a large number of relevant laws, regulations, guidelines, norms and standards in the field of energy and mobility are not based on national but set at European level. These are not sufficiently geared to the new possibilities of smart and bidirectional charging and impede the widespread use (67). Inconsistent laws with sometimes different and outdated goals, standards, definitions, and measures regarding smart and bidirectional charging represent a major barrier. For example, in the EU there are many different directives and regulations that affect EV charging (20). Additionally, in many European countries there is no clear and unambiguous legal basis for the charging infrastructure itself (68).

V2G-able EVs face difficulties regarding their connection requirements and legal status as flexibility providers. V2G-capable EVs need to comply with requirements both as producers and consumers. It must also be clarified in which legal form EVs can participate in the flexibility market as flexibility providers (69).

DSO regulation: Regarding smart and bidirectional charging, the specific roles and competencies of DSOs are not clear. Distribution grids are historically grid focused and unilateral directed. The grid is easier to operate if the energy flow is unidirectional and the loads and productions are easier to forecast and control. The original roles of the power grid actors were not designed for bidirectional energy flows (70).

Historically, DSOs operated radial grids with unidirectional power flows from the transmission grid to end-users. Main concerns (congestion and voltage issues) were addressed by investing in grid reinforcements. This approach was compounded by a regulatory framework that renumerated DSOs based on their capital expenditures, inciting them to invest in costly infrastructure instead of using operational measures. In the future, making the power grid more flexible will be a priority. This requires DSOs to concentrate on proactive grid operations and to develop new roles and responsibilities for grid operation and planning. Regulators need to work on providing DSOs with the incentives for innovation and cost-efficiency (71).

DSO managers have stated in interviews that they do not know in what form they can participate in a potential flexibility market, or whether they are allowed to provide flexible storage themselves (72). It is also not always clear whether a grid operator may purchase smart charging services. Furthermore, in the Netherlands and Sweden, it is vague if flexibility services of third parties can be procured by DSOs (73).

Overall, at the DSO level, it is unclear which markets, tariffs, auctions, or tenders will be feasible and provide the best solutions for flexibility provision. An additional barrier for establishing flexibility markets at DSO level is to find the optimal geographic scope. Each distribution line could potentially have different needs for load management. (74)

Standardisation: A functioning flexibility market within the energy system requires the coordination of different actors in real time. To meet the coordination requirements and to ensure investment security, a sufficiently high level of standardisation is required for various interfaces in the energy system.

For the UK, 50 global V2G projects were analysed, and similar results were obtained: Onerous interconnection requirements were flagged in interviews. Moreover, a challenge for providers is that interconnection standards are country specific. In the UK, the interconnection process was identified as one of the most complicated globally, taking about 6 months to connect (75).

V2G chargers' installation can imply additional administrative procedures that discourage their adoption by the user. As a result, connection requirements, classification and standardisation of V2G connections are not fully developed yet. For comparison, the connections of Vehicle-to-Home (V2H) and Vehicle-to-Building (V2B) have already been standardized (70).

Coordination: A market-based approach for flexibility services requires interaction between DSOs and TSOs . In addition, the interaction between DSOs and EV owners often requires the mediation of aggregators, which can cluster many EVs and manage their flexibility into tradeable services packages (70).

Cost-reflective time-sensitive consumer tariffs further increase the coordination effort. They require collaboration of regulatory bodies, TSOs, DSOs and energy suppliers (76). Lack of coordination between smart charging initiatives and the DSO can lead to congestions within the regional grid. If the data exchange is not sufficient, the DSO cannot plan properly. Furthermore, the data exchange requires certain cyber security standards (73).

Overall, there are obstacles to be overcome when it comes to exchanging data between different actors in the energy system. For example, there is no access to data from vehicle and battery manufactures regarding the suitability of car batteries for the use of smart and bidirectional charging and their impact on battery health (77).

Currently, data are mostly proprietary to car or charging points manufacturers, which means that management possibilities by third-party companies are limited, and users have reduced control of their data access. Such practices increase the risk of EV car manufacturers becoming monopoly actors (66).

Double energy tax: Double energy tax is considered a major barrier for bidirectional charging. The basic problem is that a bidirectional flow of energy may be taxed in both directions. Double taxation applies because storage services are classified as consumption from a tax perspective. This means that taxes are levied both when energy flows into the battery and when energy flows back into the grid. The double tax issue becomes more complicated as different tax rates apply to different charge points. This was observed, for example, in Germany, France and the Netherlands.

Electricity network tariffs: The European electricity market design provides that active customers should be subject to cost-reflective, transparent, and non-discriminatory network tariffs that count separately for electricity feed into the grid and electricity consumed from the grid. Furthermore the “Electricity Market Regulation 2019/943” defines that member state regulatory authorities shall consider time-differentiated transmission and distribution network tariffs. However, only two member states (France and Spain) have assured that double network charges are not possible for active consumers owning energy storage facilities. Moreover, only France and Norway have time-differentiated network tariffs that are cost-reflective. Double network charges are a barrier for bidirectional charging only. Lack of time-differentiated and cost-reflective network tariffs is a barrier for both bidirectional and smart charging (66).

Grid connection costs: In competitive tenders of public charging stations, prices often play a decisive role to win the tender. Therefore, operators may choose the lowest capacity connection to reduce costs and win the tender. However, the limited capacity affects the ability to enable smart charging (73).

To participate in some flexibility markets, settlement meters are required. Different meters are often required for different services. However, meters are often designed for much larger utility scale assets, resulting in proportionally high costs for V2G providers (75).

Netting rule: Only applies in the Netherlands and prescribes that energy consumed and produced by a household will be netted by the end of the year. If a household earns the same by selling excess energy as it saves by optimizing with bidirectional charging (using an EV battery as storage), then there is no longer any incentive to do bidirectional charging (73).

Small capacity service providers: Regulatory barriers have been identified as severe for small capacity service providers (such as aggregated vehicle fleets). These include the market participation and the lack of definitions for storage technologies. Small capacity service providers face two challenges: First, the minimum bid size, particularly at TSO-level markets, requires large-scale aggregation. For small capacity service providers, this is difficult to achieve at early uptake stages. Second, the large aggregation of many small assets multiplies the costs of a verification process (78).

Lack of support mechanisms: Investments by companies and individuals are essential to create charging infrastructure on company premises and private property that is necessary for smart and bidirectional charging. Currently, smart and bidirectional charging have no significant added value for companies and private individuals. There are already support mechanisms for switching to climate-friendly mobility, but these are not yet sufficiently geared to the requirements of companies when using smart and bidirectional charging and need to be adapted accordingly (79).

Policy framework: In Australia, regulatory regimes such as integrated system/energy plans suffer from a lack of long-term planning and goal setting for EV grid integration. In addition, there are few country-specific studies and EV-grid integration forecasts. The authors identified a lack of encouragement to design new electricity market mechanisms and tariff structures for promoting V2G as well (80).

In Israel, as a rule if a smart charging station is installed there is no need for any additional meter in parking spaces of residential buildings. However, sometimes EV owners do ask to install an additional meter in order to settle the payment aspect.

Charging stations that are currently rolled out often **do not comply with the open charge point protocol (OCPP)**. This is a problem in Israel, for example, and is a major barrier for enabling smart charging functionalities.

A general issue for using EVs as a battery storage providing system services is the mechanism of **Guarantees of Origins (GO)** for renewable energy. The problem arises, when certified renewable energy is charged by the EV and later discharged through V2G at another charging station (maybe also subject to another BRP). As a result, the energy discharged “looses” the certificate, as it is not possible to track how much is the share of renewable energy in the battery.

In summary, the following overall picture emerges: In many countries there is a lack of a comprehensive and purposeful regulatory framework regarding smart and bidirectional charging. The individual players in the power grid and in the energy, system don’t have clear specifications where to place themselves in a new flexibility market. They don’t have uniform specifications regarding technical standardization and there is a lack of understanding about future communication channels between the individual players.

ANNEX D - MARKET FRAMEWORK: STATUS QUO AND BARRIERS

Unleashing the flexibility potential of EVs requires not only technological standards and legal framework conditions, but also an effective integration of EVs as relevant players in the electricity market design. At first, this annex gives a brief overview of how EV flexibility can create value for the electricity markets by introducing some generic use cases. However, these use cases can only be implemented if the market conditions allow and incentivise them. Hence, as a next step on a European scale as well as in detail for the Austrian, Swiss and Israeli market, the following is analysed:

- **Flexibility markets**, where EVs' flexibility could be offered as a service or a product
- Concepts (national) of **energy communities** and how EVs can add value to them
- **Barriers for energy-mobility sector coupling** in the current market structure arising as a result

D1 Use cases for energy-mobility sector coupling

In general, the value EVs can add to the electricity system can be summarised in following use cases, most of them suggested by European Network of Transmission System Operators for Electricity (ENTSO-E) (3):

Reshaping the power load curve: The EV charging process can be shifted from peak to off-peak hours to avoid the need for additional and expensive power capacity (typically fossil-based). The time-shift alone of the charging process will have an important effect and with the help of V2G technology, the positive effect can be even increased. To shift charging from the evening to more suitable times, a change in users habits needs to be stimulated. This can be achieved through new tariff schemes (Time-of-use – ToU). Adaption of consumers towards such tariffs can be supported by "Behind the Meter" Services. EV batteries can be used to perform tariff optimisation, charging during low-price periods and then providing their energy for domestic loads during high-price ones.

Reduction of "Over-Generation" by renewable energy source (RES): Considering the increasing amount of RES generation expected in the next decades, over-generation and curtailment of green energy will become a relevant issue. EVs can schedule their charging process so as to fully match and hence exploit renewable generation availability. Also here, new tariff schemes (hourly / quarterly or potentially real time-based tariffs) together with "Behind the Meter" Services can enable this use case. As a result, this results in an increase of self-consumption by the prosumer or the community of prosumers.

Balancing services for transmission grid operation: EVs can be used to support the balancing of the transmission grid, keeping the frequency close to the reference.

EVs could modulate their charging profile according to the requests of the TSO and provide frequency-response.

Management of grid congestions: EVs can be used as distributed resource to reduce the risk of transmission grid congestions, so to minimise sub-optimal re-despatching. Widely distributed EVs offer the TSO important possibilities to effectively intervene in areas where congestions in lines and nodes typically happen. Similar this service can be offered towards the DSO to avoid overloads on distribution grids. EV charging can be shifted from evening peak hours to off-peak hours to avoid additional loads on distribution grids and limit electrical and thermal stresses. As a result, this can be a measure for grid investment deferral.

Voltage control in distribution grids: Bi-directional DC chargers can be used to perform voltage control on distribution grids. This would occur through reactive power control by power electronics equipment installed in the chargers. Voltage stability guarantees grid correct operation and is especially required when high shares of volatile RES are connected.

Electricity supply in emergency event or local blackout: Making use of bidirectional charging, EVs can also serve as a home battery in black out events. Note, that the charged energy is limited and hence only short local blackouts can be sustained. However, this might be a relevant motivation for end-users to make use of bidirectional charging.

Reduced costs of purchasing stationary batteries: An EV battery can be partly seen as an alternative to home battery storage. Stationary batteries currently do not pay off during their guaranteed lifetime. So bidirectional EVs can be used instead of such a battery to e.g., cover evening peaks etc.

D2 European Union

Flexibility markets

EU policies have always shaped the member states electricity market design since the first Electricity Directive 96/92/EC on common rules for the internal market in electricity has initiated electricity market liberalisation on a European level. Hence there are certain markets that go beyond national regulation and especially cooperation mechanisms to harmonise certain flexibility markets throughout EU member states.

Ancillary services

Regarding balancing markets for frequency control, there are following market coupling mechanisms, meaning that the products in these markets are jointly procured by TSOs from all participating countries *(81)*:

EU Frequency Containment Reserve (FCR) cooperation: market-coupling mechanism for primary control. It has been operational since 2020 and currently 8 countries are involved.

PICASSO: market-coupling mechanism for secondary control (Automatic Frequency Restoration Reserve - aFRR). It has been operational since 2022 and currently 23 countries are involved.

International Grid Control Cooperation (IGCC): involves 17 countries and performs imbalance netting of aFRR. Additionally, it is important to note that, similarly to IGCC, also the PICASSO platform performs an implicit netting of demands by considering positive and negative demands in the same clearing process. Hence, in the enduring solution, the IGCC will be substituted by PICASSO and will then cease to exist.

MARI: market-coupling mechanism for tertiary control (manual Frequency Restoration Reserve - mFRR). It has been operational since 2022 and currently 27 countries are involved.

TERRE: market-coupling mechanism for replacement reserve (RR). It has been operational since 2020 and currently 6 countries are involved.

Another type of ancillary services that has gained momentum in discussions on the European energy market design are so-called **local flexibility markets (LFM)**. According to Council of European Energy Regulators (CEER) (82), DSOs can meet their flexibility needs either through a rules-based approach, network tariffs, connection agreements or market-based flexibility procurement. The latter is considered the preferred option according to CEER. Hence, on LFMs, DSOs can procure flexibility services from demand side resources to facilitate DSO congestion management, voltage control, reliability enhancement and network deferral. The regulatory basis for such market-based procurement mechanisms has been provided by Article 3 of the electricity regulation (Regulation (EU) 2019/943), calling for incentives for DSOs, 'for the most cost-efficient operation and development of their networks including through the procurement of flexibility services'. Also, article 32 of the electricity market directive (Directive (EU) 2019/944) highlights the importance of the development of an adequate regulatory framework 'to allow and provide incentives to distribution system operators to procure flexibility services, including congestion management in their areas' (83). Consequently, there are a few pilot markets testing the LFM concept in operation (83):

- The NODES market platform and its applications in the local flexibility market projects of NorFlex (Norway), sthlmflex (Sweden) and IntraFlex (the United Kingdom)
- The GOPACS (Grid Operators Platform for Congestion Solutions) (the Netherlands), involving the Energy Trading Platform Amsterdam
- The enera Flexmarkt (Germany), a joint venture involving EPEX Spot
- The Piclo Flex UK flexibility tenders
- The ENEDIS flexibility tenders (France)

Wholesale market

Besides national energy exchanges, there major marketplace for trading electric energy as a commodity in Europe is the **European Energy Exchange (EEX)** based in Leipzig, Germany, is a major market for electricity futures. Short-term products (day-ahead, intraday) are traded on the affiliated European Power Exchange, **EPEX Spot** , based in Paris. It runs national auctions in 13 countries (Northern, Central and Western Europe) and also operates the Single Day-Ahead Market Coupling, a union-wide auction which integrates the day-ahead electricity markets of the 27 member states.

NordPool is the Nordic power exchange based in Oslo, Norway, serving an area similar to EPEX Spot.

Retail market

Based on the requirements from the EU directive on the internal market for electricity (Directive (EU) 2019/944) and its predecessors, the retail market in EU member states is required to be liberalised. More specifically, Article 4 states that customers are free to purchase electricity from the supplier of their choice.

Moreover, to foster the uptake of dynamic pricing schemes, Article 11 requires that every supplier that has more than 200 000 final customers has to offer dynamic contracts, whereas they are defined as contracts that reflect the price variation in the spot markets, including in the day-ahead and intraday markets, at intervals at least equal to the market settlement frequency.

However, not all of these requirements have been implemented and enforced in national regulation in many member states.

A European-wide analysis specifically for dynamic EV charging contracts has been conducted by the authors of (84). Dynamic time-of-use tariffs follow the day-ahead wholesale prices and therefore have hourly changing prices. In static time-of-use tariffs, prices are also lower for charging outside of peak hours, but they are defined far in advance, e.g., annually. Figure maps the availability of specific EV tariffs across Europe. The digits indicate how many EV-specific tariffs and services are on offer in a country, and the colours indicate the state of advancement of dynamic time-of-use tariffs for all types of (flexible) consumption.

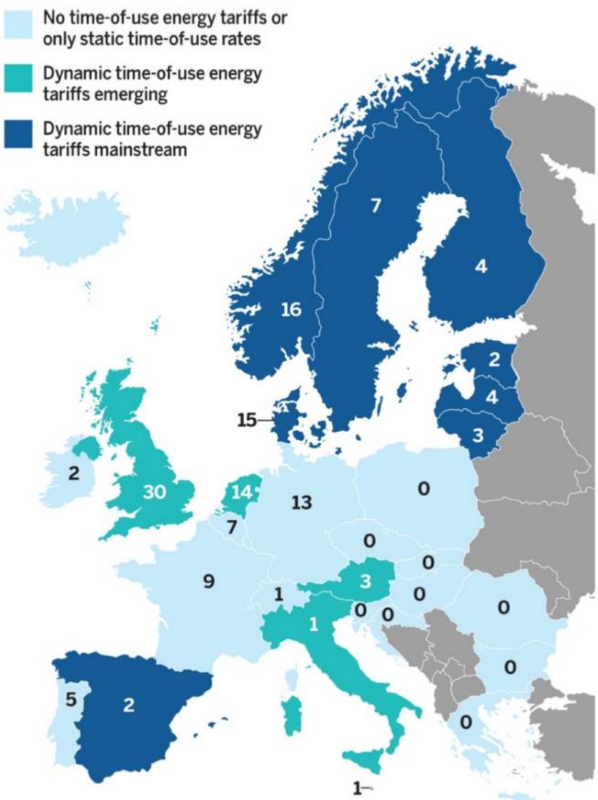

Figure 4: Number and distribution of smart charging tariffs and services across Europe *(84)*.

Energy communities

The concept of energy communities has been officially defined as part of the EU Clean Energy Package. The definitions of **citizen energy community (CEC)** in the electricity market directive (Directive (EU) 2019/944) and the **renewable energy community (REC)** in the RED II (Directive (EU) 2018/2001) are similar but have some distinct differences.

Both types of energy communities are organisations that are set up as a legal entity. They must be effectively controlled by their members, and their primary objective is to provide environmental, economic and social community benefits rather than financial profits. The key difference between CECs and RECs lies in the nature of the Directives from which they emerge. While CECs are formally recognised as a market actor, the text purely aims to create a level playing field for them in the energy market. RECs on the other hand are seen as a tool to promote the generation of energy from renewable sources and therefore have a pure focus on renewable and decentralised energy resources (85).

As a predecessor of energy communities, the concept of **collective self-consumption** can be mentioned. The RED II (Directive (EU) 2018/2001) defines jointly acting renewable self-consumers, which is are groups of renewable self-consumers who are located in the same building or multi-apartment block. This allows energy sharing within a building in a way that generation assets (such as rooftop PV) can be operated jointly by those self-consumers (85).

Barriers for energy-mobility sector coupling

Hesitant implementation of retail market liberalisation: Although, the electricity market directive has set out key principles for liberalising the retail energy market, including free choice of energy retailer, simple switching procedures, liberalisation is still pending in some member states. For instance, in Cyprus, the retail market is still a full monopoly. Especially relevant for enabling EVs as DSF resources, dynamic energy contracts are still very scarcely offered throughout the EU member states, even though there is a certain requirement for large retailers set out in the directive.

Scattered trials of local flexibility markets: There are already some operational pilot markets in parts of Europe that test the LFM concept. However, they feature different approaches in terms of product definition and market rules. A common framework for LFMs would be beneficial in order roll out these markets in all parts of Europe. This is seen as an important barrier for the uptake of EVs as flexible resources, because EVs are especially promising for DSO congestion management, considering there decentralised charging behaviour.

Conceptual barrier of energy communities: The main conceptual shortcoming of energy communities might be the restrictions for eligible community participants. Large companies are not eligible to participate or to have any decision authority within the community. This is mainly due to the idea that energy communities should be non-profit and grassroot organisations, meaning that they are organised bottom-up by the people. However, this is a major roadblock for unleashing the flexibility potential of energy communities. This is because EV fleets often represent a large company, such as commercial car sharing providers. They have a significant potential to offer their flexibility to energy communities at their distributed charging stations but cannot participate in such a concept.

D3 Austria

Flexibility markets

The Austrian electricity market has been fully liberalised in 2001, following the requirements of the EU directive on the internal market for electricity (Directive 96/92/EC and following Directive 2003/54/EC). For this liberalised market the Austrian regulatory authority "e-Control" has been established.

In the following paragraphs, all organised markets in which demand side resources can participate in Austria are discussed.

Ancillary services

To a certain extent, flexibility from demand side assets can be offered on the **balancing market**, operated by Austrian Power Grid (APG), the main Austrian TSO. The purpose of this market is to procure flexibility that can be dispatched to maintain a steady frequency of 50 Hertz in the network. There are three sub-markets, differentiated by the time horizon of flexibility activation (86) (87) (88):

Primary control (FCR): In this market, flexible assets are remunerated only for their availability, hence for the power capacity kept available during a contracted time period (4-hour interval). Activation of primary control assets is fully automatic and response time needs to be within some milliseconds. Also only symmetric offers are expected, which means that a contracted asset has to deliver the same capacity of upward as well as downward flexibility. This prevents a range of assets to participate in this market, but in general the market is open for participation of DSF, as a result of Austria joining the EU FCR Cooperation platform in 2019.

Secondary control (aFRR): There are two consecutive auctions for availability (power) and activation (energy). Offers accepted in the availability auction, also have to participate in the activation auction for a specific dispatch request. There are remunerations for successful bids in both auctions. There are products either for positive or negative flexibility. Activation is fully automatic. The market is open for DSF and since 2022, it is also part of the ENTSO-E PICASSO platform.

Tertiary control (mFRR): As for aFRR, there are separate power and energy auctions. Also, there are products either for positive or negative flexibility. Dispatch requests are communicated through automated messages, but assets can be activated manually. It is planned to connect the Austrian mFRR market to the ENTSO-E MARI platform in 2023.

Although the Austrian balancing market are open for DSF, they remain dominated by hydro and gas power plants. It is estimated that only about 10% of the capacities are covered by DSF, mainly form industrial loads.

Additionally, a relatively new market for ancillary services in which also demand side assets can participate is the so called, **"Grid Reserve" ("Netzreserve")**, introduced in late 2020. It is a market-based mechanism for procuring capacities for **TSO-level**

congestion management. It explicitly allows aggregators with a minimum pool size of 1 MW to participate. Both load and generation assets are permitted (89) (90).

Table 6: Summary of Austrian ancillary services markets for participation of demand side assets

Market	Auction type	Minimum capacity of offer [kW]	Product time frames	Frequency of auction
FCR	Power	1 MW	4 h	Day-ahead
aFRR	Power	1 MW	4 h	Day-ahead
aFRR	Energy	1 MW	15 min	25 min ahead
mFRR	Power	1 MW	4 h	Day-ahead
mFRR	Energy	1 MW	4 h	60 min ahead
Grid Reserve	Energy+Power	1 MW	Annual/Seasonal	Annual

Wholesale market

In Austria, the main market places for short-term energy trading - day-ahead (DA) and intraday (ID) - are EPEX Spot and Energy Exchange Austria (EXAA). In general, it is possible to trade energy from demand side assets, but it is still not or rarely done, both on the intraday and day-ahead market (86). Significant volume of energy trading is also happening outside of organised markets (over the counter), but also here demand side flexibility does not seem to play a role.

In order to participate on the wholesale market, every market actor needs to be part of a balance group (represented by a balancing responsible party, BRP), registered at Austrian Power Clearing and Settlement (APCS) (91). APCS fulfils the role of the "Imbalance Settlement Responsible" (92) in Austria, hence it is settling the deviations between contracted and realized energy quantities and assigns imbalance costs for each balance group.

In Austria, dispatch schedules can be changed 15 minutes prior to delivery (93). Hence, up to this deadline, imbalances can be reduced by trading short term flexible resources (such as demand side flexibilities) on the ID market.

Table 7: Summary of Austrian wholesale markets for participation of demand side assets *(94)* & *(95)*

Market	Auction type	Minimum capacity of offer [kW]	Product time frames	Frequency of auction
DA	Energy	0,1 MW	1 hour/15 min*	Daily, day ahead
ID	Energy	0,1 MW	1 hour, 15 min	Continuous, 5 minutes ahead

* EPEX Spot: 1 hour products; EXAA: 1 hour and 15 min products

Retail market

In Austria, about 150 energy retailers are active on the market. Traditionally, the majority of suppliers focus their activities to a specific region in which they formerly also owned the distribution network (before unbundling rules have been applied) (96).

Although the EU directive requires large energy retailers to offer dynamic pricing schemes, the number of dynamic offerings on the market is very limited. In fact, it is mostly small private energy suppliers that focussed on the provision of dynamic offerings. Some examples are:

- Awattar: offering hourly real time prices based on the day-ahead price for Austria at EPEX Spot with an additional surcharge in per cent (97)
- Spotty: also offering hourly real time prices based on the day-ahead price for Austria at EPEX Spot with an additional fixed surcharge (98)
- Wüstersttrom: offered a ToU pricing scheme with predefined price levels per time period within a day. Due to recent market developments the offer is currently not available (99)

Large incumbent players only offer dedicated pricing offerings for application as heat pumps with a daytime price and a night-time price. However, this cannot be considered as dynamic with regards to the definition in the directive.

The usage of dynamic pricing offers requires customers to be equipped with a smart meter provided by the local DSO. However, on an national average the roll out rate is currently at about 50%, with some regions nearly reached 100% and some only about 6% (100).

Other markets

In November 2022, a novel market mechanism has been launched as a result of the rapidly increasing gas prices. In order **to reduce peak load** in the Austrian electricity system as a whole the procurement of a so called "**Demand Side Response Product**" has been started. In this way, consumption can be reduced during peak hours, when the share of electricity from gas fired power plants is high. The new product has been defined in the Electricity Consumption Reduction Act ("Stromverbrauchsreduktionsgesetz") and is procured by APG, the Austrian TSO (101). The peak hours are published by APG, with a focus on the winter season (December-March). There are weekly auctions for all days of the week, conducted at least seven days before the week of delivery. The product time slice is 2 hours, the minimum bid size is 2 MWh during a specific time slice. Aggregators are explicitly mentioned as eligible bidders on this market. It is planned as a temporary measure until end of 2023, but depending on the market situation it might be extended.

Table 8: Key facts of the novel DSR product for national load peak shaving in Austria

Market	Auction type	Minimum capacity of offer [kW]	Product time frames	Frequency of auction
DSR peak shaving	Energy	2 MWh per 2 hour time slice	2 hour	Weekly, at least 7 days in advance

Energy communities

Following the requirements of the EU Clean Energy Package, the concept of energy communities has been officially defined in Austrian Renewable Energy Act in summer 2021 (102). There are two types of energy communities: REC (renewable energy communities) and citizen energy communities (CEC). Their main characteristics are based on the EU directives and shown in the table below.

Table 9: Difference between REC and CEC in Austria *(103)*

	REC	CEC
Geographic proximity	Local (common low voltage grid), or regional (common medium voltage grid)	Unlimited
Grid tariff	Reduced tariff*	Full tariff
Technology	Renewable electricity only	All energy carriers

Participants	No large companies or energy suppliers	No restrictions, but medium and large companies and energy suppliers are not allowed to have decision authority in the community

*57% for local RECs

In Austria, there is also a specific support facility (103) that provides knowledge for implementing energy communities with branches of this facility located in each of the 9 federal states.

In practice this means that people in Austria can now collectively engage in a n energy community by founding a dedicated association or cooperative. All participants have to sign an agreement with their local DSO (=grid operator) and those with an energy generation assets share their surplus generation with the other participants. The "sharing" is done by the local DSO by assigning the energy quantities to each participants' electricity bills.

Flexibility is not a core topic in energy communities

Energy communities as defined by the Austrian Renewable Energy Act 2021 offer a basic scheme for energy sharing. However, offering demand side flexibility services is not a core topic tackled by this scheme. The law (i.e. Article 16b of the Austrian Energy Industry and Organisation Law (104)) specifies that energy communities are allowed to

- Engage in aggregation
- Offer energy services and energy efficiency services
- Offer EV charging services

However, the energy communities implemented so far do not cover these aspects due to numerous barriers. A future driver towards unleashing the flexibility potential of energy communities might be the currently emerging commercial service providers that offer specifically developed software tools for the management of energy communities. With increasing market uptake of battery storage and EVs, these tools will also address the management of flexible assets in energy communities.

Alternative community models

Some initiatives for community-like energy projects have emerged already before this legislation has been implemented in Austria. Such initiatives follow a similar vision, but they don't fall under the definition of energy communities. Communities that already have offered direct peer-to-peer energy trading or sharing usually are built upon dedicated balance groups. This means that all prosumers have supply contracts with one energy supplier that facilitates the bilateral contracts between peers and takes care of imbalance management etc. (105). In Austria, frontrunners who have implemented this model are the start-up “e-Friends” or the cooperative “Our Power”. Similar to energy communities their focus is on a basic principle of energy sharing, but enabling flexibility services using household appliances, heat pumps and EVs is a dedicated goal of some of these initiatives.

Barriers for energy-mobility sector coupling

No local flexibility markets: in Austria, there are no functioning local flexibility markets in place and hence no market-based instrument for prosumers offering their flexibility to the DSO. The launch of such markets is also not planned in the near future. According to the Austrian DSO, it is not planned to introduce dynamic grid tariffs as an implicit measure, but rather to further develop the concept of interruptible tariffs that are already existing. By doing so, a certain power capacity can be contracted as guaranteed for the user, and on top of that loads can be curtailed on demand by the DSO (106).

Strict prequalification criteria on balancing markets: Although the minimum threshold of 1 MW for market participation can be considered DR-friendly, prequalification criteria are still tailored to large power plants. This means that for aggregated DSF pools, each asset needs to be prequalified individually. Also, each asset needs to guarantee 100% reliability. With APG joining the European Crowd-Balancing-Platform “Equigy”, prequalification processes are expected to become less prohibitive for decentralised and small-scale flexible assets (107) (88).

Lack of dynamic pricing offers: Dynamic pricing offers are scarce on the Austrian market. This also goes for contracts for EV charging. Typically, retailers either offer an EV charging electricity contract or a full charging service including provision of charging infrastructure (e.g. in multi-family houses). In both cases, the price structure is not dynamic. This is mainly due to the reason that smart charging is not applied in these standard solutions. The only load management functionality widely applied is to avoid congestions at a building’s grid connection (108) (109). Thus, only electrical components at the building are protected by this load management, but there is no charging optimisation in terms of energy price.

Energy communities are not yet ready to provide flexibility: Currently, the focus of national energy community policies is mostly on supporting investments in PV, but this is only one goal that can be achieved through energy communities. To enable aggregation and charging services within energy communities (as foreseen by the legal definition) there are still some barriers to be overcome and also incentive and support schemes to be provided by authorities. Some of the main practical barriers in this respect are listed as follows (110):

- The DSO is responsible for assigning the energy quantities shared within the energy community. This is done **not in real time**, but based on the smart meter readings (15 minutes interval) that are retrieved once a day by the DSO. This enables simple energy sharing, but it does not enable optimisation of energy self-consumption within the community. For flexible building management or smart and bidirectional charging of electric vehicles, real time meter data from all community members is a must

- There are still uncertainties about the suitable **legal form** of an energy community, especially regarding taxation. As energy communities are supposed to be non-profit initiatives, revenues (such as from grid services due to smart charging) might be a conflicting issue
- Renewable Energy Communities can be only implemented within the **grid area of a single DSO**, which can be a major barrier for the widespread emergence of energy communities. For example, the second largest city of Austria, Graz, is divided into 3 DSOs areas.
- There is a **lack of commercially available software** specially designed to manage and optimise assets within and energy community. Some options are emerging but have yet to be established and widespread.

No mechanism for independent aggregation: Access for demand response (DR) aggregators to various electricity markets is already ensured, but there are no mechanisms in place for compensating BRPs for any deviations caused by flexibility activation (86). This means on the one hand that no remuneration is required, but on the other hand that an aggregator requires BRP's agreement prior to load management. Also, all independent aggregators need to bilaterally negotiate with the respective BRP concerning consumer data, curtailed volumes and money exchange, which creates difficulties and conflicts of interest between parties (86).

D4 Switzerland

Flexibility markets

In 2009, the Swiss market was partially liberalised. Companies with an annual consumption of more than 100,000 kWh can now freely choose their supplier. However, households and smaller companies are so-called "captive customers", They are obliged to consume electricity from their local supplier, who is often also the local DSO (111).

In the following paragraphs, all organised markets in which demand side resources can participate in Switzerland are discussed.

Ancillary services

In general, the Swiss market for ancillary services is open to all participants from generation and demand assets, but they are still dominated by offers from hydro power plants. There are four balancing markets and also a market for procuring power loss compensation, all run by Swissgrid, the Swiss TSO (88) (111):

Primary control (Frequency Containment Reserve - FCR): This is the most accessible ancillary services market for DSF. There are daily tenders for four-hour blocks with a minimum bid size of 1MW. The bids need to be symmetric (upward and downward flexibility must be offered in the same bid). Contracted offers are remunerated only for their availability. Switzerland is part of the EU FCR Cooperation platform.

Secondary control (Automatic Frequency Restoration Reserve - aFRR): There are weekly tenders for aFRR, but the minimum bid size is 5MW, which is rather high for DSF assets. There is an availability and an energy auction. Bids can be asymmetric.

Tertiary control (Manual Frequency Restoration Reserve - mFRR): As for aFRR, there are separate power and energy auctions, but assets that have not been contracted in the availability auction can also bid in the energy auction on a voluntary basis. Also asymmetric bids can be submitted. The minimum bid size is also 5MW. The auctions are conducted weekly and daily. In the energy auctions, all bidders have to submit bids for three different products: national tertiary control (TRE), replacement reserve (RR) and RR_TRE (a mixed product) up to the awarded volume of tertiary control capacity. Swissgrid is part of the ENTSO-E TERRE platform for RR market coupling.

Active power losses: There is a specific product for procuring energy to compensate for active power. Minimum bid size is 1 MW. This product is procured on a yearly, quarterly or monthly basis.

Table 10: Summary of Swiss ancillary services markets for participation of demand side assets

Market	Auction type	Minimum capacity of offer [kW]	Product time frames	Frequency of auction
FCR	Power	1 MW	4 h	Day-ahead
aFRR	Power	5 MW	1 week	Weekly
aFRR	Energy	5 MW	On demand	On demand
mFRR	Power	5 MW	1 week/4 h	Weekly/daily
TRE, RR, TRE_RR	Energy	5 MW	1 h	Hourly
Active Power Losses	Power	1 MW	Yearly/ quarterly/ monthly	Yearly/ quarterly/ monthly

Wholesale market

The main marketplace in Switzerland for short-term energy trading is EPEX Spot. In order to participate on the wholesale market, every market actor needs to be part of a balance group.

Table 11: Summary of Swiss wholesale markets for participation of demand side assets *(94)*

Market	Auction type	Minimum capacity of offer [kW]	Product time frames	Frequency of auction
DA	Energy	0,1 MW	1 hour	Daily, day ahead
ID	Energy	0,1 MW	1 hour, 30 min, 15 min	Continuous, 30 minutes ahead

Retail market

There are about 650 electricity retailers in Switzerland. About 600 of them are small and local, integrated DSOs and suppliers, operating at the municipal level as a local monopoly (112).

Typically, the pricing schemes for households are flat prices throughout the day, sometimes with a differentiation between daytime and night-time price. So far, only large industrial consumers could benefit from wholesale energy prices. A first offer of a more dynamic pricing scheme has been launched by “Azienda Multiservizi Bellinzona”, a local integrated DSO and supplier in 2020. It’s an opt-in tariff scheme for households based on the smart price system developed by the start-up “Hive Power”. This pricing model is dynamic and varies the high and low tariff bands from day to day. The customer receives this information at noon every day. It is suitable for all households equipped with a smart meter and especially for those who have the possibility to shift consumption within the day (113).

Energy communities

In 2018, the Swiss legislation introduced the concept of self-consumption communities (“Zusammenschluss zum Eigenverbrauch – ZEV”). In this concept the end-users of one or also several buildings share their locally generated electricity amongst each other. This is a benefit for the end-users, as no grid tariff applies for the shared energy. For one building a typical case is a multi-family house with a common PV installation on the roof. If there are more than one building involved, this is only possible as long as all end-users share a common connection point to the distribution grid (no public grid between the users) (114). This is equivalent to the German “Mieterstrommodell” or the Austrian “gemeinschaftliche Erzeugungsanlage”, which are both based on EU legislation.

Barriers for energy-mobility sector coupling

Liberalisation not fully implemented: Household customers are “Captive customers” of the integrated DSOs and suppliers, that have a local monopoly. This means, they cannot freely choose a dynamic energy supply contract. However, this would be necessary in order to engage in implicit DR. For EV charging this means, that smart charging for minimising supply costs cannot be implemented, as the customer can only choose from the tariff offered by its local supplier.

BRP agreement for balancing service providers: Generally, prequalification processes at Swiss ancillary services markets are considered DSF-friendly, as the process can be done at pool level and not for each individual asset. However, all balancing service providers need to assign the role of a BRP for all their activities, which prevents independent aggregation. This makes also participation of EVs in ancillary services markets significantly more complex.

High minimum threshold for aFRR and mFRR markets: With a minimum bid size of 5 MW, this makes participation of aggregated load pools more difficult, posing an additional market entry barriers for EVs.

D5 Israel

Historically and until recent years the Israel Electric Corporation (IEC) (115) – a government-owned corporation – was a monopoly in the electricity market. The IEC was in charge of production, transmission, distribution, and supply, as well as operating the system. The Electricity Authority is the regulator of the electricity market.

In 2018 the electricity market reform was introduced, with the aim of liberalizing the market, increase competition, improve the market efficiency, and promote the integration of renewable energy. This reform limited the IEC's share in the production sector (to 40%), while maintaining its control over the transmission and distribution grids. The system operation functions were transferred from the IEC to a new Independent System Operator (ISO) company (NOGA) (116). In addition, in 2022 the electricity supply market (retail) was opened to new private suppliers (and virtual suppliers). In order to encourage new actors to participate in the charging sector, the IEC is not authorized to sell electricity through charging stations.

Flexibility markets

While the Israeli electricity market is becoming increasingly liberalized, the regulation to provide flexibility services is not yet in place. However, various governmental authorities are advancing the required regulatory framework for flexibility. The following is an up-to-date description of the various segments of the Israeli electricity market:

Production: This segment includes the IEC (ca. 40% of total production), privately-owned gas-fuelled power plants, utility-scale wind farms, thermos-solar and solar PV electricity generators. In addition to those, the share of small-scale electricity producers is growing, and includes mostly property owners who install roof top PV panels (aka prosumers). Prosumers may generate power for self-consumption while the excess is sold to the IEC in a tariff which is set by the Electricity Authority. Peer-to-Peer transactions are not allowed in Israel. The tariffs set for production facilities smaller than 100 kW:

- Up to 15 kW – 13 Euro cents/kWh
- 15-100 kW – 12 Euro cents/kWh

Distribution: This segment is run and managed by the IEC. Kibbutzim (small rural cooperatives) were historically considered independent energy units and were authorized wholesalers who purchase electricity from the IEC and distribute it to Kibbutz commercial and residential consumers. After the electricity market reform, Kibbutzim remained distributors in their area.

Conventional Suppliers: While the retail segment is now open for competition, the IEC is still the main supplier to households and most of the commercial consumers. Some power generation companies are allowed to sell electricity directly to large consumers.

Virtual suppliers (retailers): Various companies, organizations and corporations are now authorized to purchase energy from the system operator (NOGA) and sell it to consumers at a competitive price. To date, there are about 20 new virtual suppliers operating in the market. Virtual suppliers can only sell electricity to consumers who installed a smart meter. The rollout of smart meters is slow, and only a small fraction of households has installed smart meters. The share of medium and large consumers with a smart meter is higher.

Peak Shaving: This regulation is applied only to large consumers who have signed an agreement that gives the system operator a permission to cut their consumption on a short notice in times when the load on the grid becomes critical. For this flexibility service such consumers receive a base tariff of ca. 5.5 Euros/kWh depending on how long the notice is. Another model of peak shaving exists and does not involve and pre-signed agreement. In this model the system operator approaches large consumers and ask for their permission to "shave" their consumption in exchange for a tariff of ca. 2 Euros/kWh. In this model such consumers have no obligation to give their consent for such peak shaving.

Energy communities

The Israeli definition of energy communities is different to that in the European Union. In the Israeli context energy communities refer to distributed production of energy in the community using solar panels installed on the roof of residential buildings in the benefit of all property owners. A joint document issued by three ministries -The Ministry of Energy, Ministry of Welfare and Social Services and Ministry of Environmental Protection – provides policy recommendations to enable energy communities in Israel. The Ministry of Energy funded a couple of pilot projects mainly on rooftops of public housing buildings. The Israeli Energy Forum (117) promotes rooftop PV installations on residential buildings by working with the tenants to reach consent and sign agreements. In addition, several pilot projects run in the Innovation Zone of the City of Beer Sheba.

No specific regulation or legislation refer to energy communities as such. However, community energy initiatives are bound by a range of regulations that refer to solar energy generation for self-consumption by prosumers.

Barriers for energy-mobility sector coupling

Differential electricity rates: Currently, small consumers (<40,000 kWh per year) pay a flat rate, while larger consumers pay a ToU tariff. The new retailers, however, are not committed to a flat rate.

Tax losses: Electricity price for residential consumption is low compared with other EU countries (about €0,15per kWh), whereas the petrol/diesel prices are one of the highest in the OECD due to high tax rates (118). To reduce carbon emissions, Israel applies regulatory guidelines instead of a tax policy. Therefore, the transition to EVs implies loss of tax money to the State Treasury which will have to be substituted by another source of income (the Tax Authority considers a milage tax instead).

Lagging deployment of charging stations: Market share of EVs is expected to increase to an average of 0.6% in 2025 and to reach 6% on average in 2030. The expected number of EVs in 2025 is 188,000 on average requiring 149,184 private charging stations and 12,891 public ones across the country. Currently, there are about 400 slow (AC) public charging stations, 105 fast and ultra-fast public station and another 500 (AC+DC) in construction or planned.

Saturated grid capacity: The transmission system is not ready to accommodate the expected number of EVs. The development of the grid for 2023-2030 is being planned now and will take several years to accomplish.

Need for cooperation between relevant actors: To support the incorporation of hundreds of thousands of EVs to Israel, cooperation and information sharing in needed between various government offices, planning institutions, local authorities and the private sector.

Lagging deployment of smart meters: Consumers can choose their virtual electricity retailers for competitive rates, provided they install a smart meter in addition to the primary electricity meter installed by the IEC. However, the deployment of smart meters is lagging. Right now, consumers have to pay for the meters which may be a barrier as well.

Data sharing: The IEC and the Electricity Authority do not have clear rules for sharing consumption data – that are protected by a privacy protection law. Consumption data can potentially be used by consumer associations to get better electricity rates and have stronger purchase power in the changing electricity market. Therefore, the flow of information that is obtained from consumer meters should be managed in a way that benefits the market and in favour of developing advanced evidence-based services for consumers. A public participation event on the data management rules has taken place in June 2020. Any future data sharing will have to comply with privacy laws and regulations.

Aggregators: Currently there are no demand-side power aggregators in Israel. However, the system operator (NOGA), the Electricity Authority and the representatives of a company called Sympower (flexibility service provider) are now conducting a pilot simulation project in which Sympower is the BSP. Based on the results of this pilot project it is likely that in the near future the regulation will be formulated.

Lack of monetary incentive: In the current situation, there is no real monetary incentive for end-users to use their car as a battery storage. This is because the prices of EVs are relatively high, whereas the electricity tariffs are still comparably low in Israel.

ANNEX E - TECHNOLOGY FRAMEWORK: STATUS QUO AND BARRIERS

This annex provides an in-depth description of technological barriers that have been identified.

E1 Electric vehicle charging connector standards

For the integration of electric vehicles into a local or regional energy-management system, certain communicational abilities must be technically provided.

For simplification, only fully battery-powered electric vehicles are considered.

Like the many available use-cases of electric mobility, several different charging standards have developed over time. The most important standards in the European union can be broken down into charging mode and type of charging station:

AC-Charging

- Mode 1 charging refers to charging an electric vehicle with internal rectification and charging management by directly connecting it to a domestic socket, without any protection against overloading. This mode is generally used as an emergency option and not recommended

- Mode 2 charging is also an AC charging method with internal rectifier, connecting to any domestic socket. Here additional mobile EV-supply equipment is used to reduce strain on the domestic electricity system. 1-phase and 3-phase charging is covered by this charging mode

- Mode 3 refers to charging at a fixed charging station with a dedicated robust grid connection and additional supply equipment. Again 1-phase and 3-phase charging is covered

DC-Charging

- Mode 4 describes DC-charging, where a rectifier is situated outside of the vehicle, in a fixed charging station
- These charging stations are generally used for high-power charging

For AC-charging, two connection standards are prevailing in Europe:

Type 1 connector

The Type 1 connector (SAE J1772) is a standard mainly used in Asian and north American car models. It only supports 1-phase charging with a charging power of up to 7.4kW. (119)

L1	AC Line 1
N	AC Neutral
PE	Protective Earth (Grounding)
PP	Proximity Pilot "Plug present"
CP	Control Pilot Communication

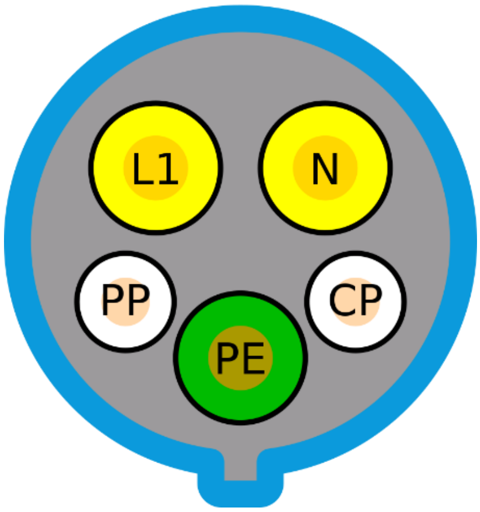

Figure 5: SAE J1772 connector (120).

Type 2 connector & CCS Type2

The Type 2 connector (IEC 62196-2/SAE J3068) is approved as the European Standard. It supports both 1- and 3-phase charging and charging power of up to 43kW. There are several interconnection options for the same connector, depending on the application. For high power DC-Charging, two additional contacts are added to the same connector type, to support high charging currents. This configuration is called combined charging system (CCS). In CCS plugs, which are exclusively used for DC-charging, the AC and Neutral pins are removed. The standard Type 2 connector can also be used for Low- or Mid-Power DC charging as represented in Figure 6. (120)

L1, L2, L3	AC Lines
N	AC Neutral
PE	Protective Earth (Grounding)
PP	Proximity-Pilot "Plug present"
CP	Control Pilot Communication

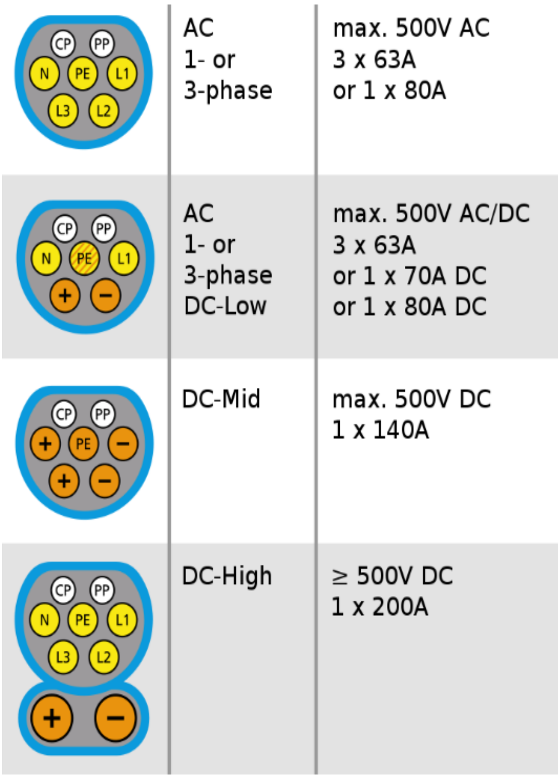

Figure 6: IEC 62196-2 (121).

CHAdeMO

This DC fast charging standard is mainly used by Japanese EV-manufacturers and still has a large market share in Europe. However, as the EU-parliament has decided, that each fast-charging station must at least offer a CCS 2 connector, this standard is gradually disappearing from the European market.

DC +/-	DC Lines
FG	Grounding
SS1/SS2	Charge sequence signal (Start/Stop charging)
DCP	Charging Enable (from vehicle to station)
PP	Proximity Pilot (connector detected by station, deactivates car drivetrain)
C-H/C-L	CAN-Bus/

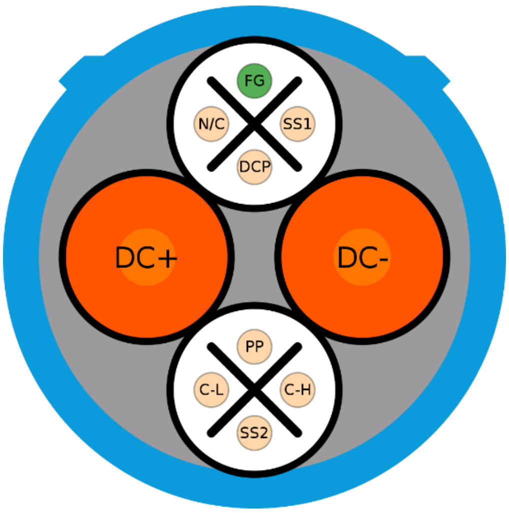

Figure 7: ChAdeMO (121).

Tesla

Tesla uses its proprietary charging standard in North America but has adopted the Type 2 CCS charging standard in Europe. For home charging, mainly the regular Type 2 is used with AC.

E2 Vehicle/Charging station communication standards

Control Pilot (CP), Standard IEC 61851-1 and SAE J1772

This communication standard is both applied by the Type 1 and the Type 2 connector and is used to communicate the charging status between station and vehicle, as well as the maximum allowed charging power from the charging station to the vehicle. This, relatively simple, pulse-width-modulation is mainly used to avoid overloading of the charging station, or its grid connection. There is also a resistance coding, which signals the connection of a compatible vehicle type back to the charging station.

CAN Bus (CHAdeMO)

CAN (controlled area networks) are used for high-level communication using a bus protocol in small areas. It was initially developed to reduce communication wiring in vehicles but is also used in industrial or building automation applications.

Sensors and actors must be connected to CAN-nodes, which consist of microcontrollers and power electronics.

The same system can also be used to communicate between an electric vehicle and charging station. A large range of information can be transferred, and many different applications can be implemented. As CHAdeMO is the only standard using this communication method, it is slowly becoming irrelevant for the European market.

ISO 15118-2 Vehicle smart charging

This standard is defining a communication system between the electric vehicle and electric vehicle supply equipment (charging stations). This allows for the communication of data, either via power-line communication or wireless via Wi-Fi.

This means, all existing charging connector types technically can be used for this standard. The standard defines how data is handled and routed between the devices, but also covers procedures up to the application layer.

The exchanged information is, like the conventional systems, necessary for the charging process but can also include information used for coordinated charging and vehicle to grid applications.

Typical information is the battery charge status of the vehicle, its charging priority or the power limitation of the charging station. Due to privacy and safety concerns, this version of the standard has limited functionalities.

It´s main use at this point is "smart charging", also known as "coordinated charging" to reduce the peak loading on a charging point. One or more vehicles can communicate with a shared charging station, or controlling device, which regulates the charging power of each vehicle, according to a specified algorithm.

This allows for several functionalities. The most important is the "load balancing" function. If only a limited grid capacity is available for several charging vehicles, this available charging power needs to be distributed on the charging vehicles.

The specific algorithm managing the load balancing must consider different charging priorities of the vehicles, fluctuating grid capacities, schedules etc. and needs to be adapted for each specific application.

Controlling devices can also include a range of other information sources, to provide more high-level applications. By including production data from a local renewable energy power plant, charging schedules can be adapted to profit from cheap energy sources. The same principle applies if variable energy tariffs are contracted. Weather and other external data can be included to make predictions about energy availability and prices.

This standard (ISO 15118-2) also provides the communicational base for bidirectional charging. If the vehicle is equipped with the proper control procedures, most electric vehicles are technically capable of feeding energy back into the charging station.

ISO 15118-20

The successor of the ISO 15118-20 is including all the functionalities of the previous version, but is not compatible, as it solves the existing safety issues by implementing new communication messages on the network and application layer. (122)

It is designed to support many future applications, by providing secure high level communication possibilities.

This makes the communication of user-specific data possible, which is necessary for applications like "plug & charge". In this concept, all information for payment, charge (122) management, or vehicle to grid is exchanged between the vehicle and the charging station directly via authentication certificates, without any action from the user.

E3 Charging station/Network communication

OCPP 2.0

The open charge point protocol (OCPP) is a widely used industry-standard for communication between charging stations and control systems (123).

It is an application-layer protocol, which means it provides standardized communication interfaces between software modules.

The version 2.0 is compatible with ISO 15118 and therefore enables communication between a charging management system and an electric vehicle.

It is mainly used for controlling and monitoring commercial charging stations, independent from the manufacturer of the charging equipment. It can also be used by building-energy management systems or load balancing systems.

OCPP 1.6

Was introduced in 2016 and supports smart charging, demand response and load management. It is currently used in a large share of existing charging stations and not compatible with ISO 15118. Therefore, communication with the vehicle itself is not possible and functionalities are limited.

E4 Bidirectional charging

To discuss the topic of "vehicle-to-grid", a few terms must be defined.

Conventionally, electric vehicle batteries are exclusively used as energy storage for driving. As battery capacities are continuing to increase due to higher range requirements, typically only a fraction of the available battery capacity is used on a daily basis. "Bidirectional charging" refers to the possibility to not only transfer energy to a vehicle via the charging port, but also feed energy back out for other applications, essentially using the EV as a battery storage.

The different options mainly differ from each other due to electric capacity and communication requirements.

Vehicle to load

The easiest version of bidirectional charging is vehicle to load. An adapter is fixed to the electric vehicle port and the internal rectifier provides low voltage alternating current. Most manufacturers restrict the maximum power to 3,6kW. The current applications are mostly focused on providing a portable power supply, for remote construction sites, camping or emergencies.

Vehicle to home

If energy is fed back into the electric system of a residential home, this is called vehicle to home. The basic concept is to cover some portion of the electricity demand of a house. This can either be a constant power flow, a share of the momentary demand or reducing demand peaks. Either way, the main purpose is to cover the energy demand of the building and not feed energy into the electricity grid.

Vehicle to grid (V2G)

If the vehicle is used to put energy back into the overlying grid, the term vehicle to grid is used. The vehicle battery and power electronics can be used either for energy storage, gid stabilization or both. There is a range of different applications, depending on the optimization objectives, and subjected to several constraints.

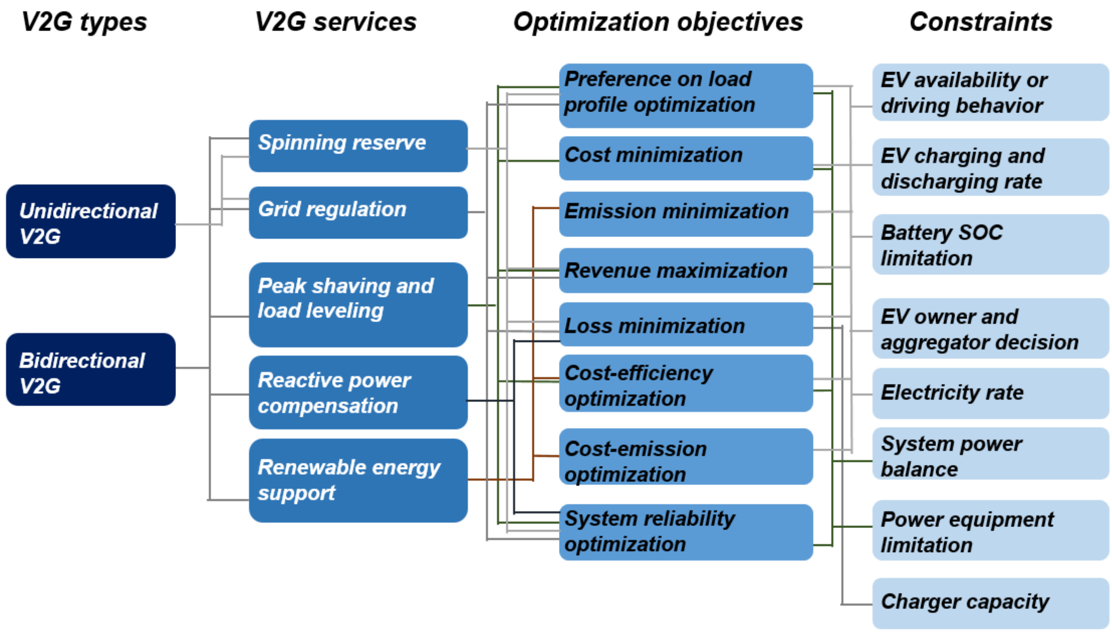

Figure 8: Vehicle to grid overview (Note: Here “Smart charging” is called “Unidirectional V2G”) (124).

The services V2G can provide, can be split into the two categories “power”, as in near instant energy flexibility, and “energy storage” which is a continuous flow of energy.

Power services

“Spinning reserve” and “grid regulation” refers to fast changes in energy demand, or feed-in according to the grid situation. Like in the spinning rotors of big power plants, flexibility is available almost immediately. “grid regulation”, also called “primary control” refers to very short timeframes (seconds to a few minutes), to stabilize grid frequency. It has a high power-requirement, but as it is only needed for a few minutes, not much energy is required. The spinning reserve on the other hand, is activated if a grid situation is not balanced after a few minutes and must provide a much higher energy quantity. Conventionally, this corresponds to large power plants, which are already producing energy changing their output. For electric vehicle charging stations, similar functionalities can be provided, if a large number of vehicles automatically fulfil these grid stabilization measures. As batteries can activate large amounts of energy very quickly and charging stations being equipped with the necessary power-electronic facilities, implementing these functionalities can be implemented relatively simply by vehicle manufacturers. Basically, the local grid frequency and voltage is measured and energy fed in according to a specified characteristic.

Technically, a bidirectional charger consists of an AC/DC converter, a DC bus and a DC/DC converter. Modern electric vehicle batteries are operating on typical voltages between 400V and 800V. In case of an internal rectifier, AC charging is possible with an AC/DC converter, which provides DC power to the DC/DC converter. Due to efficiency restrictions, internal rectifiers are usually used only for charging up to 3,6kW. For high-power DC-charging, the internal converters are bypassed and energy is directly fed into the battery. (Figure 9)

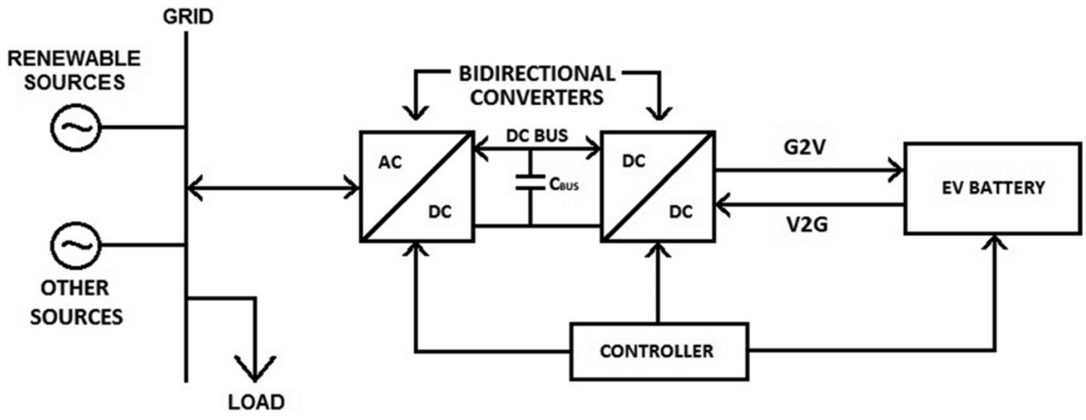

Figure 9: Basic Schematic of an Onboard Bidirectional Charger *(125).*

For V2G applications, this means that if higher power than 3,6kW is required, the DC charging-station must also support bidirectional charging. For a vehicle with onboard rectifier, the two converters and controller must be able to support bidirectional charging.

Another possible service is reactive power compensation. Reactive consumers within a power grid, like many electric motors or inverters, produce reactive power, which has to be compensated by power plants, for the transfer of energy being possible. If power plants or compensation stations are located far away from the reactive consumer, transmission capacity is lost. Power electronic devices like PV-inverters and EV-chargers are able to compensate reactive power both during charging and discharging, therefore providing a service for grid stability.

Energy storage services

In contrast to mainly "power services" energy services provide power over a longer timeframe. This can also mean a reduction of charging power, which is not considered here.

In combination with some form of renewable energy production, electric vehicles can be used to smooth out production fluctuations to either optimize own consumption, or feed in stored energy into the grid when feed-in prices are favourable. These functions can also be used without direct connection to a renewable power plant, simply by monitoring energy prices. This would provide a simple feedback-loop to balance daily power flows in a grid.

Peak shaving is also connected to this idea. Here local demand peaks between several minutes and hours, are smoothed, by providing energy for relatively short timeframes. These peaks can either be predicted, like the evening peak at a residential area, or on short notice, like the startup of a heavy electric machine at a construction site.

In case of an electricity outage or at remote locations, electric vehicles can be used to provide emergency power to a house or support a microgrid. Here it is important, that the connection with the overlying grid is physically separated.

E5 Battery degradation

The degradation of the vehicle battery due to V2G is a main concern. . By 2023 Lithium-ion-batterie (LIBs) are used in electric vehicles, with new technologies like solid-state batteries slowly appear. It is expected that Lithium-ion technology will continue to dominate the market in the foreseeable future. Therefore, this is the technology considered in this analysis.

Lithium batteries basically consist of a cathode consisting of lithium, generally embedded in a molecular structure like Lithium manganese oxide (LMO).

The anode of LIBs mainly consists of a graphite material. Graphite on a molecular level, consists of layers of material. The voids between these layers can absorb Lithium ions in a process called “intercalation”.

To electrically insulate the two electric contacts and transport lithium ions from one electrode to the other an electrolyte and separation layer is needed.

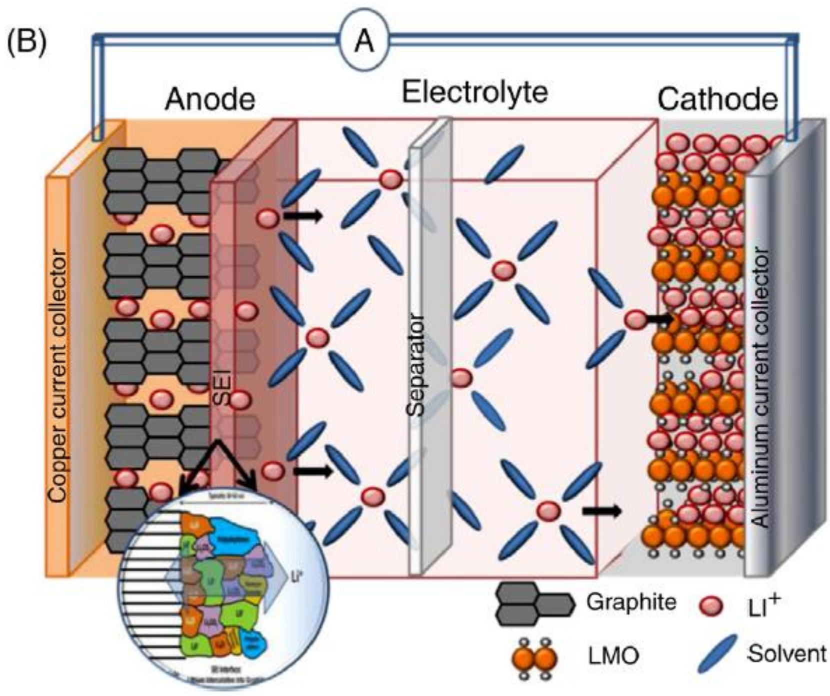

Figure 10: Discharging of a LIB, with solid electrolyte interphase (SEI) layer *(126)*.

There are several interconnected factors contributing to degradation as well as different processes within the battery, which reduce energy storage capacity and maximum power output. The three most important mechanisms are:

- Destabilization of a solid electrolyte interphase (SEI)
- Lithium plating of the graphite anode
- Particle fractures

Solid electrolyte interphase degradation

The SEI layer forms on the graphite layer of a LIB and is necessary for the normal operation. It acts as a passivation layer between the anode and electrolyte and is to a large degree permeable to lithium-ions, which travel in- and out of the graphite anode.

It forms during first charging of the battery, by partial breakdown of electrode and electrolyte material. Later decomposition of the electrolyte, due to high electric potentials can lead to build-up and subsequent excessive breakdown of this layer. These high potentials may be caused by slow reaction speeds, due to low temperatures and high charging and discharging speeds. Lithium itself is being immobilized in the degraded and ineffective SEI layer components and not available for energy transfer. The results are the degradation of the electrolyte material, increasing battery resistance and overall loss in capacity.

Lithium plating

The second effect is called "lithium plating" and occurs on the graphite anode surface. It happens under charging conditions, where lithium is being pushed out of the cathode, at a faster rate, that it can be absorbed by the anode. This happens during charging in cold conditions, fast charging and charging over maximum capacity. The lithium forms a metal surface instead of intercalating into the graphite material. This stops additional lithium ions to move into the graphite structure and increases the charging resistance. Due to the increased electric potential of this effect and the overall charging conditions, the SEI layer also builds up, and makes some of the lithium plating unavailable for discharging. The effect is slow loss of capacity and lower power output.

Particle fracture

The last effect described here is called "particle fracture". Both electrodes physically change during charging and discharging. The graphite anode expands slightly while lithium-ions are being intercalated during charging. During discharging, lithium crystals form within and on the surface of the cathode.

The electrode materials are brittle and have a limited electric conductivity, which is the reason to implement them as thin layers on conductive collectors like copper and aluminium (

Figure). Inhomogeneous reactions on the layer surfaces cause high local electric gradients. These in turn lead to effects like uneven expansion during charging. This mechanical stress causes particles to break away from the conductive collector, making the particle ineffective for further use.
Particle fracture on the anode can also lead to large sections of material loosing electric conductivity at the same time. It is therefore one of the most significant effects.
A similar effect occurs on the cathode, when during discharging, large crystals, so called "dendrites" are formed due to uneven electric gradients. During charging, lithium crystals which are in electric contact with the cathode are dissolved. Long dendrites are prone to break away from the cathode during this process. Once the

electric contact with the cathode is lost, this lithium particles are no longer available for energy storage.

Modelling of effects

The same external factors, cause different internal processes within a LIB, which lead to similar results: Loss of reactive lithium and rise of internal resistance (127). O´Kane et al., (2022) created a mathematical model estimating the interactions between the different effects and plots the effects as follows.

Cycling protocol	Discharge rate (C)	Charge rate (C)	Temperature (°C)
(i)	1	0.3	25
(ii)	1	1.2	25
(iii)	0.5	0.3	25
(iv)	2	0.3	25
(v)	1	0.3	5
(vi)	1	0.3	45

Figure 11: Six different cycling protocols, with differences in charge and discharge rate and temperature *(126)*.

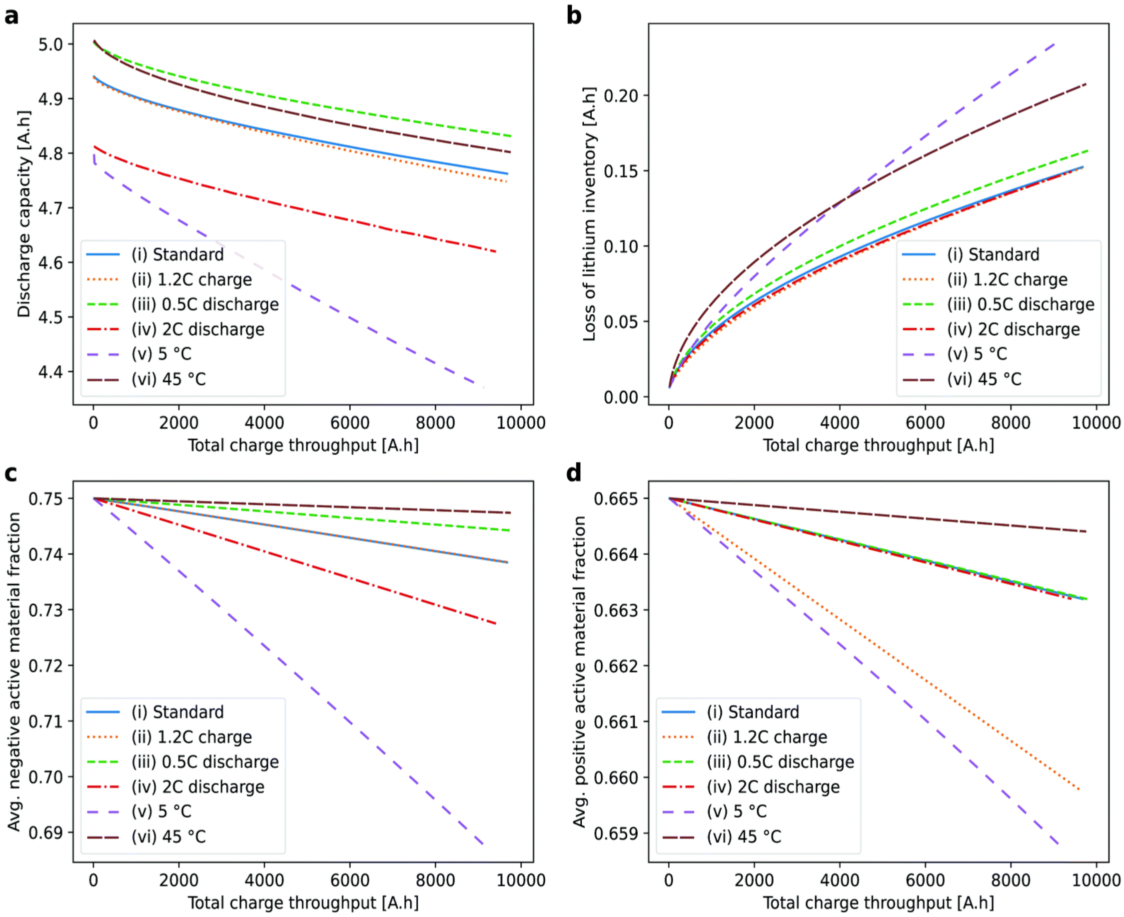

Figure 12: Effects of different cycling protocols on: (a) discharge capacity, (b) loss of active lithium, (c) graphite anode particle fracture, (d) lithium cathode particle fracture *(127)*.

Conclusions on optimal battery operation

It is clearly visible, that low temperatures, which inhibit chemical reactions within the battery, are especially detrimental for battery health. This effect is partially countered by resistance losses during charging and discharging, which warm up the battery. However fast charging or discharging before the battery is warmed up, has the strongest negative effect on battery life.

Fast charging also has a significant effect, especially the loss of lithium dendrites due to cathode particle fracture.

Fast discharging at a rate of 2C on the other hand causes particle fractures within the graphite anode which have a strong effect on the overall discharge capacity of the battery.

The best state of health is maintained by charging and discharging at low power levels and at relatively warm temperatures. Sources claim the optimal charging and discharging temperature to avoid lithium plating to lie between 20° and 30° Celsius. (128)

Conclusion for vehicle to grid

Electric vehicle battery use for grid purposes must be closely monitored to avoid negative effects on battery lifetime. This can be achieved by proper communication between the vehicle and charging station, to consider information about the battery, as overall capacity, battery technology and live data like the current battery state of charge and temperature.

Using this information and a control system with an underlying energy strategy, batteries can be utilized within their optimal operation range.

Fast charging and discharging should be avoided whenever possible and slow charging normalized. This would therefore lead to vehicles being plugged for longer timeframes, which in turn makes them available for flexibilities and grid services.

It seems reasonable to utilize bidirectional charging as low-power, long timeframe energy shifting method. This way the baseload of a building, a heat-pump or a community can be covered by stored renewable energy, while peaks are covered by the electric grid.

Another interesting synergy effect of the communication path and the continuous connection to the grid is the possibility of pre-conditioning the vehicle interior and battery before a trip. The vehicle is heated up or cooled down using grid power and internal heat pumps. This will on the one hand provide a comfortable driving experience from the start of the drive and will melt any mist or ice on the vehicle. In cold conditions, electric heating elements in the battery heat it to optimal temperature without loss of range and battery health. This preconditioning can be done either directly by the user via a mobile application or according to a daily schedule.

ANNEX F – POLICY AGENDAS

As a conclusion of this study, this chapter describes the most relevant recommendations the authors have identified for unleashing the flexibility of EVs through smart and bidirectional charging in large scale. As an addressee the authors want to target policy makers, authorities, energy market regulators, and industry interest groups at all levels (European, national or regional).

Policy agenda setting and decision making

Electromobility is on the rise. All over the world, the accelerated expansion of electromobility has an overarching goal, the limitation of global warming. EVs, along with their batteries, can support these efforts by enabling the flexible use of green but fluctuating renewable energy. Furthermore, EVs can provide important flexibility services for the power grid. Smart- and bidirectional charging need to be seen in a broader context, both have the potential to contribute solutions to central challenges.

The many players involved in electromobility not only need a legal framework, but also a political framework for orientation. The economy requires **clear and long-term political objectives to be able to plan and invest**. In the context of electromobility, smart- and bidirectional charging, specific goals should be formulated, which should then be clearly communicated. If certain goals have been set and decisions made, these should be pursued with vigour.

Although technology openness is vital in technological development processes, policy makers and authorities need to acknowledge, that **for passenger cars the expansion of electromobility has already been decided**. This relies on findings of the scientific community underlining the systemic efficiency of battery electric vehicles (BEV), but also the automotive industry has decided to foster predominately BEV development in the near future. As a result, policy makers should acknowledge the opportunities opened up by this technology, hence **introducing mechanisms to leverage the flexibility potential of EV fleets**.

Overcoming legal barriers and market design issues

As the implementation of smart- and bidirectional charging requires the collaboration of different actors, clearly defined legal framework conditions are required. Also, markets and regulations must reward flexibility. They must reflect the value of flexibility options for the system. A functioning market model must therefore be ensured where flexibility can be traded with the prospect of profit.

Standardisation activities

The implementation of smart- and bidirectional charging requires the cooperation of many different actors (e.g., charging station operators, network operators or automobile producers). For all applications it is crucial, that communication between the players is possible. Communication and cooperation take place via various interfaces, which must be standardized accordingly. Fortunately, there are **existing communication standards** which need to be made mandatory for all manufacturers of vehicles and charging systems. The extent to which smart- and bidirectional charging is made available to the user will be **specified by the vehicle manufacturer**. It is expected that market pressure will motivate producers to offer increasing bidirectional charging abilities over time. Using communication standards, different coordination and optimization applications can then be implemented by charging station manufacturers and operators.

User Incentives and awareness

Financial incentives are key for all actors, especially for users. The focus of attention should be on the customer, who is motivated by financial incentives to operate smart- or bidirectional charging. It is necessary to **inform the public** about the meaningful possibilities of smart- and bidirectional charging and to motivate people to participate.

Fostering applied research and stakeholder communication

Smart- and bidirectional charging are complex and multidimensional applications. A base of knowledge has already been gathered as part of numerous projects and studies. Nevertheless, there are still open questions and in the end the potential of these applications must be examined in each country individually. **Stakeholder conferences** can help to quickly identify opportunities and barriers. Sometimes, however, the concrete stakeholders have to be identified as a first step. In addition, **pilot projects** and/or studies should be promoted in municipalities, cities, or countries to clarify the potential that smart- and bidirectional charging enable.

ANNEX G - INNOVATIVE BUSINESS MODELS

As described in the brief summary, a business model making use of EV flexibility can be characterised by the following four determinants: fleet, charging mode, business and flexibility service.

In the following paragraphs each of these characteristics is discussed more in detail and conclusions for the further business modelling tasks of project are derived.

Fleets

The GAMES approach is to address so-called electric shared vehicle fleets (ESVF) offering their flexibility for various system services. Initially, two specific types of fleets have been targeted, which is also aligned with the planned case studies of the project:

- **Carsharing fleets:** this can be station-based (case study of Mobility in Switzerland) or free floating (Autotel in Israel)
- **Corporate shared fleets:** a pool of EVs is used by the staff of a certain company for business or also private trips (Windkraft Simonsfeld in Austria)

We expect that fleets with a **central fleet manager** would be the best starting point for business models targeting the flexibility of EVs. The fleet manager might have a central digital logbook and is managing the charging bills through a common backend. Hence, the manager is in a good position to also enforce a charging strategy for the whole fleet. Also, a commercial fleet manager is interested to find an **optimal trade-off** between generating revenues from flexibility services and reducing battery degradation. In the case of private EV owners this trade-off might be biased due to their limited knowledge.

Furthermore, the "shared" aspect of a fleet is not necessarily a precondition to use it as a flexible resource. This means that also fleets of individual car users could serve as target segments in such business models, but only if there is a central fleet manager that can control the charging process. However, we acknowledge shared fleets as an important concept for the future in order to reduce privately owned cars and achieve the energy and mobility transition.

The main question when focussing on centrally organised fleets is the **minimum viable size of a fleet** that can offer a meaningful flexibility potential for market players or higher-level aggregators. This should also take into account redundancies as EVs are not always plugged in. This is one of the questions that should be further investigated in the quantitative modelling tasks of GAMES.

Charging mode

Although there are many technical specifications, we generally distinguish between two relevant modes of charging:

- **Smart charging:** unidirectional charging, but controlled by a price or dispatch signal communicated in real time

- **Vehicle to grid:** smart charging but additionally featuring bidirectional charging functionalities

We expect that the main proportion of flexibility can be unleashed through the implementation of smart charging. It still remains unclear what is the **additional flexibility potential that can be reached through V2G**. Hence, this is also a question that should investigated in the quantitative modelling tasks of GAMES.

Business

There are a broad range of business actors that have a potential interest in entering the market with novel business models featuring smart charging and V2G. Some of the most promising ones are listed below:

- **Car manufacturers:** they can decide if they enable bidirectional communication for their models, hence they are in a powerful situation. They also need to guarantee the customers a certain lifespan of their batteries and therefore are cautious when enabling this functionality or even want to make use of it for their own charging services
- **Charging service providers:** they are operating the private or public charging stations. Their existing backend system for charging infrastructure is an important asset when starting this novel business model
- **Energy suppliers:** they are experienced in managing a portfolio of flexible assets on the electricity markets. They also are strong players in offering charging services, which puts them in a good position
- **Aggregators:** flexibility is their business purpose and therefore they have the technical capabilities to bundle large pools of EVs as flexible assets. However, there are currently only a few profitable businesses on the market
- **Energy communities:** they are an emerging concept and can use the flexibility for their own self-consumption optimisation. However, they might need support to implement such a complex business model in terms of technical and business know how

Flexibility services

Concluding from the analysis of electricity markets in the different countries and the trends on the European market design, it becomes evident that out of the whole range of services only a few can be considered reasonable for the deployment of EV fleets. According to this analysis, the most promising flexibility services are the following:

- **Balancing services for the TSO:** although strict prequalification criteria apply, an advantage of this services is that already well-established organised markets exist for trading balancing products. Also, the settlement prices per kWh are on average the highest of all markets in this analysis

- **Peak shaving for the DSO:** DSOs have strong incentives to reduce peak power costs. The main advantage is that DSOs can procure a uniform flexibility product among all grid users within their area
- **Portfolio optimisation for BRPs:** already nowadays, BRPs try to optimise their portfolio in order to reduce imbalance costs. Using EVs as a flexible resource is very promising, as energy suppliers often act as CPOs or e-mobility service providers (eMSPS)
- **Collective self-consumption optimisation for energy communities:** energy communities are currently adopted all over Europe. Communities with a high share of PV generation are also likely to couple their surplus with (shared) EV fleets in the near future

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