European Commission

ELECTRIC VEHICLES AND THE GRID
SOLUTION BOOKLET

Smart Cities Marketplace 2024

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WHAT IS THE SMART CITIES MARKETPLACE?

The Smart Cities Marketplace is an initiative supported by the European Commission bringing together **cities, industry, SMEs, investors, banks, research and other climate-neutral and smart city actors**. The Smart Cities Marketplace Investor Network is a growing group of investors and financial service providers who are actively looking for climate-neutral and smart city projects.

WHAT ARE THE AIMS OF THE SMART CITIES MARKETPLACE?

The Smart Cities Marketplace has thousands of followers from all over Europe and beyond, many of which have signed up as a member. Their common aims are to **improve citizens' quality of life, increase the competitiveness of European cities and industry** as well as to **reach European energy and climate targets.**

WHAT CAN THE SMART CITIES MARKETPLACE DO FOR YOU?

Explore the possibilities, **shape** your project ideas, and close a **deal** for launching your smart city solution! If you want to get directly in touch with us please use info@smartcitiesmarketplace.eu

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WHAT AND WHY

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WHAT AND WHY

Electric Vehicles (EVs) have been actively promoted on the European market for almost a decade. The first Tesla appeared on Norwegian roads in 2013. In 2023, there were around 4.7 million electric passenger cars on European roads, an increase of almost five-fold compared to 2019.

A distinction is made regarding their potential in the exchange with the grid: uni-directional (V1G) or bi-directional (V2G). The former can charge, the latter can both charge and discharge. V1G are already widely available on the market, whereas V2G are only offered by a small number of manufacturers on a limited selection of cars.[1]

Charging infrastructure for electric vehicles can be distinguished into two different categories: **public charging stations** (e.g., public parking, hotel parking, mall parking) and **private charging stations**. Currently, most EV owners make use of private charging stations, but due to the increase in EV uptake, also the public charging infrastructure will need to grow significantly. While 80% of the private EV buyers have access to private charging[2], public charging access is a different story. According to a survey conducted by OECD in six European countries, a third of the respondents reported that there were no public charging stations for electric cars within 3 km of their homes.

1 OECD (2023): How Green is Household Behaviour? Sustainable Choices in a Time of Interlocking Crises.
2 DNV (2023): Transport in Transition

Following the global growth of the EV market, the amount of charging infrastructure will have to rise substantially to support the projected demand. At the end of 2023, there were over 630 thousand charging points in the 27 European Union Member States (EU27), a 41% increase of the 2022 stock and 3.6 times the number of charging points available in 2020.[3]

EV's interaction with the electricity grid presents an opportunity that must be addressed. As cars are parked most of the time, there is considerable flexibility in the way they are charged or even discharged.

There are several benefits to EVs over conventional petrol/diesel cars. Several studies show that the overall lifecycle emissions of EVs, when compared to conventional vehicles, are substantially lower, representing decreases in greenhouse gas emissions from 19% to 69%.[4] By eliminating tailpipe emissions, EVs have the potential to **improve air quality**, resulting in health improvements. Moreover, **noise reduction** and **lower maintenance** are other benefits of EVs. By 2025, it is expected that 20% of global passenger vehicle sales will be EVs, growing to 30% in 2030.[5] In Norway, from 2014 to 2022, EV sales grew from 12.5% to 79%, leading to a decrease of 8.4% in emissions for the transport sector, with projections for 2019 to 2030 reaching decreases of nearly 30%.[6, 7]

3 International Environment Agency (2023): Global EV Outlook 2023 – Catching up with climate ambitions.
4 The International Council for Clean Transportation (2021): A Global Comparison of The Life-Cycle Greenhouse Gas Emissions Of Combustion Engine And Electric Passenger Cars by Georg Bieker.
5 International Environment Agency (2023): Global EV Outlook 2023 – Catching up with climate ambitions.
6 European Alternative Fuels Observatory.
7 OCDE (2022).

Further reading: E-BUS Solution Booklet and smart-cities-marketplace.ec.europa.eu/insights/solutions

Without exploiting EVs flexibility, their high volume poses a challenge to the electricity grid.

A significant share of drivers will likely charge their cars at home most of the time, hence, a significant share of vehicles will be charged in the early evening when the EV driver returns from work. However, **when a high number of EVs are charged around the same time, a high amount of power is required from the grid, which can lead to congestion problems.** This can be compared to a traffic jam: when all drivers return home from work at 6 pm, heavy traffic is likely to occur. When roads are congested, the driving time increases. Similarly, if too much energy is requested from the grid, the power lines may not have enough capacity to deliver this energy. Moreover, EV charging comes on top of the existing peak power demand in the evening, adding further to the grid constraints.
The integration of electric mobility will have a great impact on the energy market and the grid. Indeed, smart charging, defined here by the monitoring and optimising of charging patterns, helps the grid to be more efficient and reduces losses. EVs have the potential to significantly contribute to **cost-effective electricity generation support and storage due to the built-in energy storage capacity of their onboard batteries.**
Smart charging could also provide charging flexibility for EVs by adapting to the demands of EV users through, for example, charging plazas. A charging plaza is a set of charging stations connected to the grid by a single connection can reduce the required peak capacity by 80-90%, distributing the scarce local network capacity among the vehicles smartly.[8]

One way to solve this congestion problem is to "build a bigger road" and, therefore, upgrade the grid infrastructure. However, upgrading the grid infrastructure, is a costly operation. In Germany, such upgrade for EV unlimited charging is expected to cost between €20 billion and €25 billion.
Luckily, increasing the grid capacity is not the only solution, as there are innovative ways to benefit from the EVs' charging and discharging flexibility.

In 2020, 80% of EV buyers in Europe had access to private chargers. More than 50% of Europeans lack direct access to private chargers.

In Europe, in 2023:

96.000 fast chargers.

536.000 slow chargers.

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8 DNV (2023): Transport in Transition

V1G: smart charging

An average EV user will charge their car for about two hours per day. As most EV users charge their vehicles at home in the early evening (7 pm) and do not need to leave for work again until early morning (7 am), this leaves plenty of room to schedule charging smartly.

Simply delaying the moment of charging towards the night ensures that the charging peak does not coincide with the household peak (cooking, washing, heating,...). Alternatively, alignment of the charging period with the local demand would be beneficial at the neighbourhood level, too.

The potential of smart charging is not limited to its use at home. **When parked during the day, smart charging can be aligned with renewable energy production.** Like this, charging can be aligned with moments of excess resulting from solar or wind energy. Similarly, the charging could be interrupted temporarily when there is a risk of an imbalance between supply and demand. This excess or shortage can exist at the national level but can also be localised.

Ruben van Loon presenting Alliander's Smart Grid solution during City-zen Days in Amsterdam, 2019. ©City-zen

V2G

When the vehicle can allow bi-directional exchange with the grid, an entirely new range of possibilities for supporting the grid opens up.

Not only can the EV be used to relieve stress from the grid by smart charging (similar to a V1G), but it can also actively support the electricity grid (V2G in a discharging mode).

Moreover, the EV can operate as a power backup for buildings, contribute to local congestion management, optimise consumption on the building or neighbourhood level and maximise the use of renewable energy sources.

However, implementing V2G technology requires more complex hardware infrastructure than V1G: both the communication and energy flow need to be bi-directional to enable such advanced services. In addition, V2G may affect the EV battery lifespan. More importantly, V2G should be accompanied by clear incentives for the end user, who by facilitating its battery capacity and discharging should be able to obtain an economic return.

Bi-directional V2G charging station installed for the City-zen Project VPP pilot. ©Alliander

CITY CONTEXT

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CITY CONTEXT

Changing to sustainable urban mobility patterns that meet the 2050 carbon neutrality targets is a major challenge in any city. Infrastructures need to be designed or redeveloped in such a way that they promote the most sustainable transport modes, making sure that people will effectively change their mobility behaviour. This will often imply a reduction of the size and number of car lanes and parking spaces while increasing the size and number of footpaths, cycle roads, bicycle parking and public transport lanes, and deploying public charging infrastructure.

The co-benefits of shifting towards sustainable transport are manifold, including:

- decreased energy consumption and carbon emissions,
- reduced air pollution and noise levels,
- increased traffic safety,
- reduced traffic congestion with related economic costs,
- health gains from increased active transport with related savings in public health expenditure,
- more employment in the local green economy,
- increased scenic quality and sociability of urban public spaces,
- improved biodiversity, integrated water management and control of the urban heat island through the reallocation of public space to urban green areas.


Electric bus charging ©Getty images


Electric truck charging ©Netze BW, Unsplash

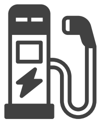
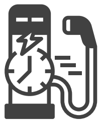
The way people use vehicles in cities is changing. Electric cars and carsharing are on the rise. **Public transportation is gaining importance in urban mobility as city centres become more and more focused on environmental topics, such as clean air, noise reduction and local reduction of CO_2 emissions.** The electrification of mobility is not limited to passenger cars. Public transportation, micromobility and industrial mobility are pivoting towards electric transportation as well. **Buses, taxis, electric trucks, on-site machinery, and mining equipment represent large battery-powered assets capable of impacting the electricity grid.**

EV carsharing in Madrid, Spain ©Javygo, Unsplash

In the interaction of electric cars with the grid, different approaches are available within the city. **Private and public charging is one distinction, where public chargers could be both normal and fast chargers.**

Private charging usually takes place on private property and is, therefore, not available to the public, such as a charger connected to a house, a charging point for employees or company cars on a company parking lot, or a single charger for clients of a bank.

Public charging, however, is available to a wider audience, benefiting from more users. With public charging, the charging infrastructure is provided by a charging operator (a company or a city service), for example, in public parking or along a highway.

	Normal charging	**Fast charging**
Power provided by the charging infrastructure	7 to 22 kW	> 50 kW
Charging time	2-6 hours	< 1 hour

Currently, there are systems able to charge vehicles at a power of over 100 kW, leading to a full charge in 20 to 40 minutes. However, this is limited to the vehicle's ability to receive such high powers.

Depending on the amount of time the EV stays connected to the charging infrastructure, charging patterns and grid interaction can be optimised. In public parking, the car usually stays connected for several hours, while on a fast-charging infrastructure along a highway, the connection lasts for some minutes. Thus, in fast charging events, the possibility of bi-directional charging is not an option.

The implementation of chargers in the city poses a challenge. Urban mobility needs to be aligned with city planning and the local grid infrastructure. Urban EV charging strategies should, therefore, be embedded in the Sustainable Urban Mobility Plans (SUMPs) of the cities[9].

Recent revisions of the trans-European transport network (TEN-T) Regulation include strong incentives to increase the use of more sustainable forms of transport and mandates that all 430 major cities along the TEN-T network will have to develop SUMPs to promote zero and low-emission mobility[10].

Increasing electricity demand in the city, partially due to densification, puts extra stress on the energy infrastructure, which in some locations might exceed the network capacity. As an example, around 3,000 neighbourhoods in the Netherlands with at least 100 EVs are expected to exceed the grid capacity by 2025, caused by the fast uptake of EVs[11].

Hence, city officers, policymakers and grid managers must ensure the power systems are ready to account for the increase in EV usage along with other challenges, such as the increased uptake of heat pumps.

9 European Platform on Sustainable Urban Mobility Plans (2019): Electrification, Planning for electric road transport in the SUMP context.
10 Provisional agreement on more sustainable and resilient trans-European transport network brings Europe closer together.
11 ElaadNL (2021): Elektrisch rijden in stroomversnelling – Outlook Q3 2021

Developing a strategic EV charging infrastructure implementation plan

Several cities have formulated strategic implementation plans for the rollout of EV charging infrastructure.

These plans often follow an approach structured around several steps:

- define the current context,
- identify future needs,
- formulate a common vision,
- develop a concrete action plan,
- revise the plan.

First, the context is described by using key indicators of the current situation concerning electric mobility (i.e., number of electric cars, number/locations of public infrastructure, energy demand, ...).
This information is important as a baseline and serves to forecast the expected evolutions and future needs of the city. **Both current and forecasted perspectives are the basis for the formulation of a long-term strategic vision.** This vision determines at a high level how a city should transition towards electric mobility, given a predetermined timeline. Designing this vision should be a collaborative effort including all important stakeholders in the transition, such as the transmission system operator (TSO), distribution system operator (DSO), regulator, charging point operators, public transport operators (PTO), and local authorities. **Consulting stakeholders is critical for adding their perspective on the existing gaps, barriers and opportunities.**

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Executing the vision requires an implementation plan consisting of concrete actions that explain how the vision can be achieved. These actions can take several forms, ranging from economic incentives to policy changes and partnerships with grid operators, energy suppliers and charging operators.

The implementation plan should describe each process, addressing key questions such as:

- **What are the different steps or procedures?**
- **Which stakeholders are involved and who is responsible?**
- **What is the timeframe?**
- **Which regulations are being followed?**
- **What financing can be used?**

All the steps mentioned above form the strategic implementation plan, which needs to be re-evaluated regularly to account for the real implementation progression and possible unplanned changes (i.e., once every one to two years).

An important topic in the strategic implementation plan for EV charging infrastructure is the electric grid and how to tackle grid-related challenges[12].

CASE STUDY

As examples, both plans in Amsterdam and Brussels[13] consider expected mobility changes in the vehicle fleet and the future energy demand in GWh/year.

Given these forecasts, the cities identified a concrete number of required charging points to meet the mobility demand and assess to what extent the energy demand will challenge the electric grid. Both Amsterdam and Brussels address how they plan to mitigate these impacts by suggesting concrete measures such as:

- capitalising on the existing grid to minimise additional costs (i.e., installing infrastructure at the location where the grid is already reinforced),
- reinforcing the electric grid where load congestion occurs,
- requiring charging infrastructure to provide electricity from renewable energy sources,
- developing a strategy to convert the existing electric grid into a smart grid,
- involving stakeholders that own a separate local electric grid in the rollout of charging infrastructure by negotiating access to it.

In the case of a PTO that does not use the full capacity of its grid during the whole day, fast charging hubs could be connected to their electric grid and grant extra capacity and power to alleviate additional load on the distribution grid.

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12 International Council on Clean Transportation (2020): Electric vehicle charging guide for cities - International Council on Clean Transportation (theicct.org).

13 More information on the Amsterdam case here and on the Belgium case here.

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TECHNICAL SPECIFICATIONS

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TECHNICAL SPECIFICATIONS

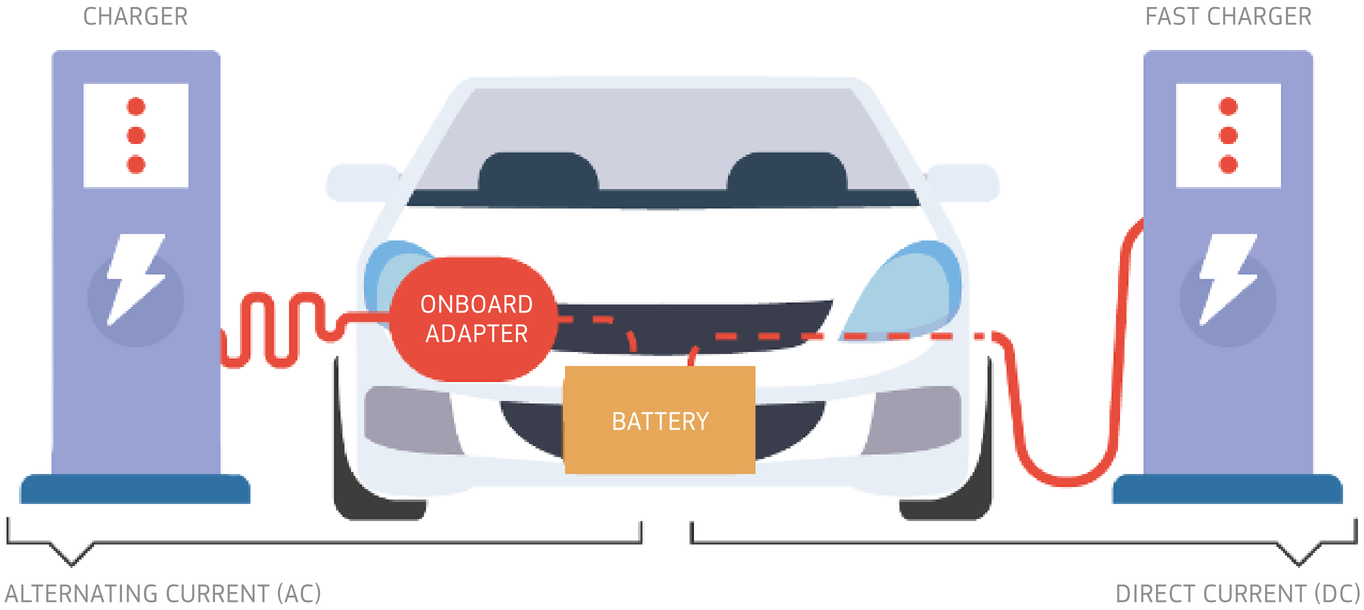
Components of the System

Hardware

The electricity grid operates on **alternating current (AC)**. A normal outlet in a European household delivers **220–240 Volt AC**. Common household appliances, however, do not function on AC, they make use of an adapter which transforms **AC into direct current (DC)**. The same situation occurs when charging an EV: the battery inside the electric car is usually a DC battery. Therefore, most EVs have an onboard adapter which can transform AC into DC to charge the battery.

The physical size of adapters depends on the power they need to convert. For fast charging, the adapter is, therefore, already included in the charging infrastructure, i.e., outside of the car, and the electricity that flows into the car is already DC. For V1G, **the energy is flowing from the grid into the car** and not the other way around, so both AC and DC charging options can be used. In the case of V2G, operating in a mode of injecting electricity into the grid (at normal charging power), a special adapter is needed. The adapter must be able to **transform DC (the battery) into AC (the grid)**.

Today, only a few EVs include DC-AC adapters on board, which excludes the bulk of AC charging infrastructures offering V2G services. A V2G charging point includes an AC-DC adapter as well as a DC-AC adapter. This ensures that energy can flow in both directions.



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Software

Any charging or discharging is managed by a controlling algorithm. The amount of energy exchanged at any moment depends on the battery technology, the desired and effective state of charge, potentially the voltage on the connection point and user preferences. Even in the absence of smart or bi-directional charging, this controlling management is needed to ensure a safe energy exchange.

Smart and bi-directional charging requires an additional management layer that can calculate the ideal **charging/discharging times** and assess the amount of power that needs to be exchanged. For grid operators to effectively manage public EV charging and grid usage, real-time data and consumption forecasts from the energy market and other energy actors need to be available. EV users also need to share their state of charge, preferred and strict charging limits, location and estimated charge time, which is highly user-dependent.

Energy management by dcbel in Montreal, Quebec ©dcbel, Unsplash

Amsterdam's smart charging approach to reduce peak demands

CASE STUDY

Amsterdam's public charging infrastructure, which consisted of 10,000 charging points as of mid-2023, is an important facility for EV drivers in the city since most households do not have private parking. The daily average occupancy rate of the city's public charging stations is about 50% and increases to 70% at night.

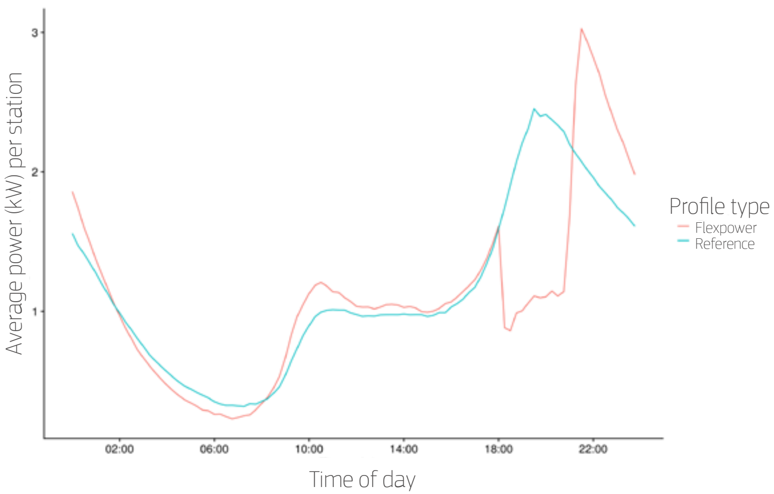
Typical charging infrastructures are built on three-phase connections with a current limit of 25 Ampere (A). The impact of a charging station using such a connection on the electricity grid is much larger than that of the average household. Peak loads of up to 17 kW are possible for EV charging, while a Dutch household needs an average of only around 1 kW.

In this pilot, 52 EV charging points were adapted to enable a higher charging current of 35 A overall, but with limitations during the morning (20 A) and evening peak hours (6 A). This 'best of both worlds' scenario allowed EV drivers to profit from higher charging speeds when the grid was underutilised while at the same time lowering grid load during peak periods. This benefited EV drivers and grid and charging point operators by lowering charging times and operation costs. Moreover, it may allow for better synergy with solar and wind production.

The impact of this optimised charging scheme was measured using three indicators: average charging power, amount of transferred energy and share of positively and negatively affected sessions. The average charging power increased as a result of the new scheme and a reduction in the amount of transferred energy was detected during the evening hours as charging times became more spread out during the day. In general, 14% of EV charging sessions were positively affected while only 5% were negatively affected.

Amsterdam's smart charging pilot shows that managing charging times can be a win-win solution for drivers, cities and grid operators.

More information here.



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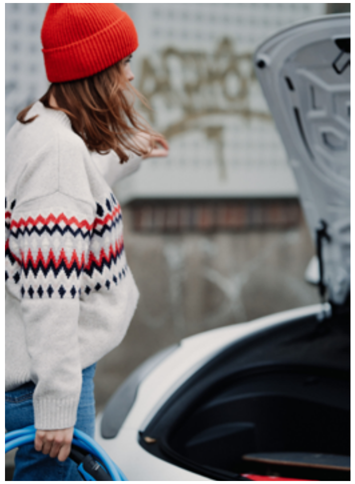

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OCTOPUS project (smart charging)

CASE STUDY

Since 2018, the Octopus project has been dedicated to promoting the uptake of EVs and facilitating complementary charging services in eight countries across the globe.

Their approach involves delivering a comprehensive EV package to users, encompassing a car, a smart charger, an EV energy tariff, complimentary miles, and tax savings via salary sacrifice facilitated by their employer, all conveniently bundled into one consolidated offering.

Octopus focuses on overcoming financial and technical barriers potential EV users face. Recognising that cost and lack of information impede transitioning to EVs, they offer experts to guide users on various EV-related aspects, including assistance in selecting a suitable vehicle and navigating optimal charging practices for cost reduction.

Octopus streamlines information on the purchase, operation, and maintenance of EVs, contributing to a more cost-effective transition to EVs than their petrol or diesel counterparts.

Further reading here.

©OCTOPUS project (smart charging)

Technical Barriers

Energy losses

The conversion from AC to DC upon charging EVs cannot be achieved with 100% efficiency. Current technological advances enable higher AC/DC conversion efficiencies and, hence, higher charging efficiencies, ranging from 90% to 95% for fast charging and 80% to 90% for slow charging. This means that from the power transferred from the charger, only 80% to 95% ultimately reaches the EV's battery.

Battery degradation

By allowing an external entity to control the charging and discharging of the battery, the number of charge cycles will increase.

For example, a battery pack for EVs degrades slightly with each charge and discharge cycle, where the charging power and the depth of discharge are important indicators for potential degradation.

This battery degradation proves a challenge as EV manufacturers are not keen on enabling V2G when this decreases the battery life of the vehicle. Developments in battery technology and improved battery management systems have substantially advanced and recent studies indicate that the effect of an extra cycle is negligible compared to the effect of driving the EV[14].

Standardisation of communication standards

As stated before, to make the most of the V2G technology, information needs to be available. Thanks to the latest standards such as ISO 15118-20, charging protocols (communication between charging point and EV) already allow for in-depth information transfers like location, current type and desired state of charge, or how long the vehicle will be connected. The challenge, however, lies in understanding the required data types needed for each operation. Moreover, grid information and forecasts are not uniformly available throughout Europe.

DSOs and TSOs will have to share this information more accurately in the coming years following the further implementation of the Clean Energy Package.

The European Commission is committed to streamlining and converging the standards and protocols for communication exchange in EV charging systems. The European Commission's Directorate-General for Mobility and Transport (DG MOVE) has been in conversations with industry stakeholders to understand current challenges and limitations regarding supported functionalities, applications and interoperability with other charging solutions, gathering valuable recommendations for upcoming delegated acts[15]. Conclusions and recommendations on concrete communication protocols for the main areas of the EV recharging ecosystem are available here.

The European Commission is further investing in the development of standards to enable and even oblige better communication between all involved actors.

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14 K. Uddin et al (2021): On the possibility of extending the lifetime of lithium-ion batteries through optimal V2G facilitated by an integrated vehicle and smart-grid system

15 Directorate-General for Mobility and Transport (European Commission) (2022): Mapping of the discussion concerning standards and protocols for communication exchange in the electromobility ecosystem.

Lessons Learned

- **Although V2G is maturing with multiple projects around the globe, it still requires solving a number of challenges for V2G services to become mainstream.** Only a few providers are currently on the market with effective commercially available bi-directional chargers and smart charging algorithms are not yet a mature business case, often demanding too much tailoring to make it economically viable. In addition, end users cannot enjoy economically attractive benefits from such bi-directional schemes with the risk of degrading their EV battery faster. Standardisation in communication, hence, needs to be combined with standardisation in offered business cases to enable a reduction of engineering costs.

- **Smart charging and V2G** can add value in case of local and recurrent excess in renewable energy production in grids with limited capacity.

- **Considering the different categories of users** will be key to achieve the desired impact on grid balancing or other energy services.

SOCIETAL AND USER ASPECTS

SOCIETAL AND USER ASPECTS

As V2G and smart charging are recent technologies, most implementations are pilot projects. These pilots generally focus on technical matters and the assessment of potential grid impact. Only a small number of test cases include societal and user aspects, though researchers agree that these are crucial in enabling the uptake of V2G technology.

Because EVs are, by definition, a distributed energy resource, more use cases will only be possible with a higher uptake of EVs. But the uptake depends on several societal and user aspects. The ownership of cars is an important aspect, and key in the transition of the existing car fleet to one, which has a substantial share of EVs. If car ownership is mainly with companies, providing cars as a part of the remuneration to employees, policy decisions can lead to a faster transition. However, openness to innovation will be a key element for the acceptance of the technology. Additionally, cultural aspects and habits influence how a car is used, including average driving distances and where it is parked.

Volvero connects vehicle owners and drivers to take advantage of underutilised vehicles. Through an app, individuals, corporations, and car rentals can significantly reduce their vehicles' costs and monetise their investment by renting to drivers.
More at volvero.com

Aside from these user-related aspects, societal aspects also influence the potential rollout of the necessary infrastructure as well as the public opinion towards EVs.

The **distribution system** plays a key role in supporting the implementation of chargers by a fast and self-evident procedure for the connection of such an infrastructure. Additionally, they might be keener on establishing a **market for services** when the grid suffers more from intermittent renewable energy sources or congestion due to increased demand. Finally, **environmental criteria** are highly relevant, and citizens might be susceptible to those depending on their **history, culture and educational level**.

Most societal barriers towards smart charging and V2G are a result of third-party access to the vehicle.

EV owners are giving away control of the **charging pattern** in exchange for financial and environmental benefits. This results in a perceived reduction in the vehicle's availability or flexibility as it restricts its availability due to limited range or charging status in case of an emergency. By informing citizens and EV users about the potential benefits and risks, many misconceptions and fears about these technologies fade away. **Social media campaigns, information events and school demonstration programmes** help to educate the general public.

Alternative ownership structures like carsharing, leasing companies or public transportation fleets are a way to reduce these societal barriers.
In B2B relationships, requirements and insurances are also more easily enforced.
The lack of a supporting infrastructure (maintenance and distribution networks) for EVs is stopping businesses from electrifying their fleet. Businesses need additional insurance or incentives in the form of subsidies or tax reductions to take a leap and transform their fleet into EVs.

V2G trial in the UK

CASE STUDY

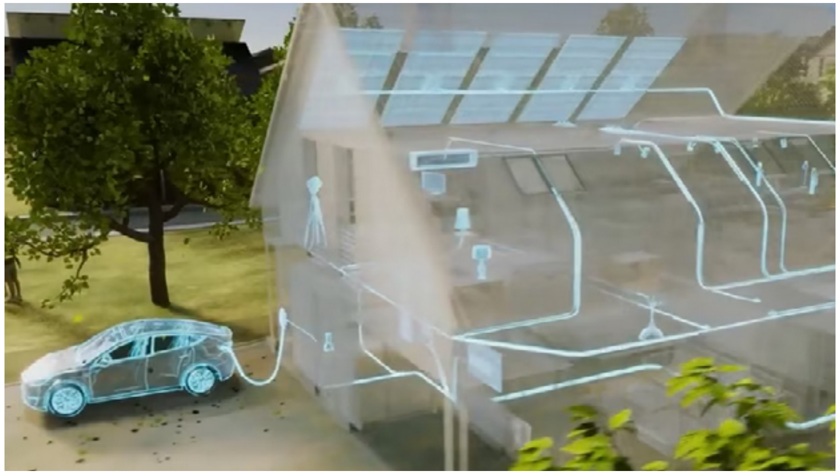
Over three years, OVO Energy conducted the world's largest domestic V2G trial. OVO Energy V2G was a part of the UK's Vehicle-to-Grid competition, funded by the Office for Low Emission Vehicles (OLEV, now OZEV) and the Department for Business Energy and Industrial Strategy (BEIS), in partnership with Innovate UK.

This trial stress-tested the impact of V2G technology in a real-life environment demonstrating that it can simultaneously alleviate the burden on the electrical grid and reduce costs for its consumers.

The project managed EV smart charging by considering real-time market signals like grid supply, weather, pricing, and charging vehicles when costs and carbon emissions were low. An integration with V2G charge points was set up, allowing customers to set preferred drive-ready times through an intuitive app while it optimised charging for affordability and sustainability. The partnership with OVO Energy and Nissan led to the deployment of 330 V2G devices across the UK, with around 3 million kilometres being made available to customers who exported energy during peak demand.

Within the context of the project, it was demonstrated that V2G technology can reduce the need for more than €3.5 billion in annual grid infrastructure upgrades. Furthermore, customers can passively earn an annual income ranging from €500 to as high as €930 simply by keeping their cars plugged in when they're not in use.

The trial results indicated high levels of customer satisfaction and a decrease in concerns associated with V2G technology. Throughout the trial, 93% of customers expressed satisfaction with their V2G hardware, while concerns about battery health decreased significantly from 61% at the trial's outset to 24% at the conclusion. Worries about cost savings while using V2G declined from 43% to 28%.



Read more about OVO Energy's trial here. ©Kaluza

Societal Barriers

Unavailability of information and distrust

The average EV user has limited knowledge about batteries, the electricity grid or the benefits of smart charging and V2G. This lack of knowledge, together with prevalent misinformation regarding the potential benefits of these technologies, easily leads to misconceptions about smart charging and V2G and increases consumer distrust. For example, battery degradation effects are often exaggerated, which stops EV owners from fully supporting V2G technology.

The FP7 project **City-zen tested a V2G charger** in Amsterdam. It dropped out every night around midnight. No technical issue could be found. Therefore, an employee of Alliander stayed in a car near the charger to observe the V2G charger and watched a person pressing the emergency button just before going to bed. It turned out that the person's bedroom window was just above the charger and the noise of the cooling fan in the charger prevented him from sleeping.

Third party access to vehicle

With smart charging or V2G, the charging of the EV is controlled by a third-party controlling algorithm. The EV user is allowing an external party to influence his vehicle and how and when it is charged and/or discharged. Not all EV users are comfortable allowing this kind of access and are worried about what will happen when the algorithm makes a mistake, and they are thus unable to use the car as intended or it negatively influences their energy bill. This kind of control also requires attention to privacy and data protection and the alignment of third parties with the applicable laws.

Range anxiety

Range anxiety is the fear that a vehicle provides an insufficient range to reach a certain destination. In contrast to traditional petrol/diesel vehicles, EVs require some time to connect to the grid before they are ready for departure. With smart charging and V2G, the EV might not immediately be charged to maximum capacity. This increases range anxiety because the car might not have the maximum amount of range in case of an emergency or an unexpected trip.

Marisca (Hoogschagen) Zweistra presenting Alliander's story during FuckUp Night in Amsterdam during City-zen Days 2019. ©City-zen

Insurance and guarantee

When allowing third-party access to an EV, the responsibilities in case of failure are not yet well defined.

When a problem occurs with the battery, the coverage of atypical use of the battery as with V2G might not be clear.

Also, today's guarantees are mainly based on an available range after a certain mileage. The lack of mature insurance standards and clarity on guarantees hinders a broad uptake of V2G.

Supporting infrastructure

V2G and smart charging are an emerging model. Although from a technical point of view, the technology is mature, there is a lack of supporting infrastructure.

Compared to traditional transportation the distribution and maintenance of EVs (e.g., repair shops, dealers) is limited.

The lack of support in case of failure with EVs is proving to be an obstacle for businesses wanting to electrify their fleet.

©Michael Jin, Unsplash

Smart, clean energy and electric vehicles in Amsterdam. ©Flexpower Amsterdam project | SEEV4-City

Lessons Learned

Several of the pilots since 2016 have looked into convincing end-consumers to join a smart car charging pilot or to take part in a V2G test. The general conclusions on societal and user aspects of innovative charging technologies include:

LESSONS LEARNED

- User acceptance of charging technologies is often higher when there is **added value or appropriate economic compensation.**
- It is important to **gain trust and take the time** to communicate broadly with the users and the wider community.
- **Enabling potential users to try out** innovative charging technologies (i.e., through pilot projects) allows them to develop knowledge with the technologies and fosters their acceptance.
- Pilot users are often willing to join but it is important to acknowledge their **participation and to value them** for that. Users gave up a perfectly working alternative to assist in the pilot's success, not the other way around.
- Immediately act when it is unveiled that something does not work according to plan, **ensure a committed team willing to resolve any issue**.
- Consider how citizens will use **transport in the future**. Possible modal shifts (soft and public transport) or decreasing ownership of private cars should be accounted for.
- **Mobility hubs, last-mile mobility solution services and carsharing** could all contribute to mobility-as-a-service. In such a format, car ownership is not with the end consumer, which facilitates the acceptance of innovative charging technologies.
- Providing good **communication, testimonials, and explanations on how the technology works and the related benefits and risks** help reduce the users' concerns or misunderstandings.
- The importance of **diversity in the consumer profile** to reduce the risks of obtaining biased results.
- An important enabler for acceptance is **to leave control to the user**. This can be achieved through apps where the charging process can be set up as desired.

GOVERNANCE AND REGULATION

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GOVERNANCE AND REGULATION

Technologies like V1G and V2G are challenged to compete in traditional energy markets that are not fully aligned with their capabilities. Energy regulation is complex and provides an obstacle for emerging technologies like smart car charging and V2G to make an immediate impact. Luckily, various projects throughout Europe are working on challenging and changing the legislation so it will be better aligned with the modern energy landscape.

The main EU legislation, the new Alternative Fuels Infrastructure Regulation, will ensure the necessary deployment of interoperable and user-friendly infrastructure for recharging cleaner vehicles across the EU. This legislation will set mandatory national targets for the deployment of light and heavy-duty vehicle recharging infrastructure and ensure interoperability, comprehensive user information and adequate payment options.

Even though national or European policies and standardisation processes cannot be directly influenced from a city level, local policymakers can make a difference with support for smart car charging and V2G initiatives.

The European Commission provides guidance and best practice examples to support local policymakers in rolling out smart charging and V2G initiatives through various platforms such as the Sustainable Transport Forum (STF)[16] and the EU Urban Mobility Observatory ELTIS[17]. The STF has developed various documents that identify the best practices by frontrunner cities that can be shared with other cities and regions initiating the rollout of charging infrastructure.

Report highlighting key findings and recommendations on the procedures of public authorities, and experiences of market participants with permitting and grid connection procedures for recharging infrastructure. Available here.

16 The Sustainable Transport Forum serves as a platform for structural dialogue, exchange of technical knowledge, cooperation and coordination between Union Member States and relevant public and private stakeholders. More information here.

17 The EU Urban Mobility Observatory facilitates the exchange of information, knowledge and experience in the field of sustainable urban mobility in Europe. Find relevant use cases here.

Governance and Regulatory Barriers

Roll-out of charging infrastructure

The integration of chargers in the public domain is a slow process as the interaction with the involved stakeholders (users, DSOs, TSOs, etc.) is often unclear. Two reasons for this can be easily identified:

- The role of the DSO is not clarified regarding the charging infrastructure. This creates tension as the DSO wants to control assets added to the network and being in charge eases the work. Being in charge could also mean a region-wide tender to indicate one or two providers of public charging[18] infrastructure.
- The lack of a city-wide charger location plan slows down any permitting procedure due to the fear of chargers appearing everywhere in the city. Integrated urban planning should have both an eye on the need and the location for chargers as well as a procedure to be followed by anyone willing to invest in such an infrastructure.

While the first aspect is to be tackled at a regional or national level, the second one is the responsibility of the city. This is where proactive city planning can play a decisive role in the transition of the fleet of its inhabitants.

©Ernest Ojeh, Unsplash

Partago is a citizens' cooperative for EV sharing in Leuven, Belgium. ©Partago

18 DNV (2023): Transport in Transition

Astypalea, a Greek island turning green

CASE STUDY

The "Smart & Sustainable Island" project, now in its third year of implementation, is a collaboration of Volkswagen Group and the Hellenic Republic to improve the lives of the residents of Astypalea, Greece, and turning this island into a model of green mobility and circular economy.

Conventional mobility services are being replaced with vehicle-sharing and ride-sharing (astyGO), and on-demand public transport services (astyBUS). Additionally, solar plants are being implemented to power electric cars, converting the island to all-electric mobility-wise. Moreover, all the mobility services are integrated within the astyMOVE app, allowing visitors and permanent residents of Astypalea to request such services through their smartphones.

This initiative was well received by the citizens: according to a survey, almost 50% of the 221 enquired stated they would consider giving up their vehicle to use the new electric mobility services. In the January - September 2023 period, 25% of the residents of Astypalea used the astyBUS on-demand public transport services, highlighting the acceptance and adaptation of smart mobility solutions by the local community. With a growing fleet of EVs, the available solar capacity by 2023 will cover 100% of the energy needed to charge the EVs and more than 50% of the island's total energy demand. Since the launch of the services, in June 2022, the users of the astyMOVE application have travelled more than 370,000 km in the vehicle-sharing EV.

The initiative will be monitored and evaluated over several years. Within five years, Astypalea will be largely converted to sustainable mobility and energy, with 100% EVs, smart mobility services and a green hybrid energy system.

Further reading about the Smart & Sustainable Island here. ©Kosmocar / astyMOVE

Lack of incentives

Smart car charging provides little added value today, aside from behind-the-meter optimisation with maximised self-consumption and peak shaving.

In some European Member States, chargers are already aggregated and can participate in the energy market, though this is not yet widely taken up. Energy price variations are limited and move users from peak to off-peak periods. However, no use is made of the full duration of the vehicle being connected to the charger to effectively flatten the energy demand profile and its spreading over the available timeframe.

There are only a limited number of European pilot projects experimenting with V2G. To facilitate the integration of V2G technology, additional government support is therefore required. Besides financial support for the purchase of bi-directional chargers or V2G-capable vehicles, regulatory support is also beneficial.

By allowing the pilot project to operate in regulatory sandboxes (for example experiment with a time-of-use tariff[19]) V2G pilots can steer the legislation of the future.

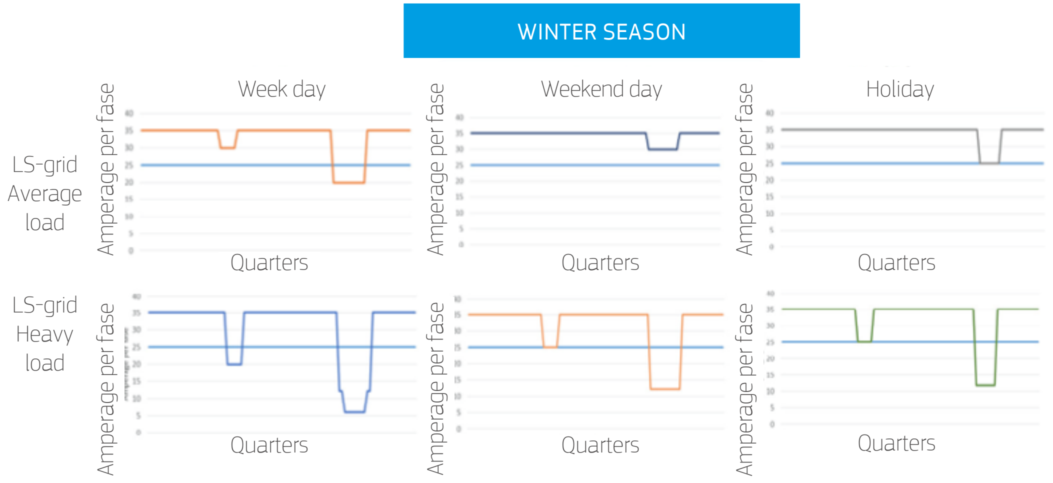
19 Check the upcoming section Business Models and Finance for examples applicable to regulatory sandboxes.

Time-of-use tariff

In most European countries, the moment when you use electricity does not substantially affect your electricity bill.

A more dynamic, so-called time-of-use tariff is another way to affect the energy consumption profile. If electricity prices are high when **local or global congestion occurs** (for example, in the early evening) and low if local renewable production is high and consumption is low, V1G or V2G can align consumption with the lower prices.

To enable this, a granular electricity tariff is needed with a different price setpoint, e.g., every 15 minutes. The tariff could also be adapted to the location on the grid to consider local congestion management. This requires the **collaboration of regulatory bodies, TSOs, DSOs and energy suppliers.** Throughout Europe, several pilot projects are experimenting with time-of-use tariffs. This **dynamic tariff will be implemented** in the near future, but the **complicated regulatory framework** is causing delays in many Member States. **Also, the rollout of digital meters is not finalised, hindering the potential uptake.**



FlexPower profiles applied in Amsterdam ©FlexPower

Standardisation

The technical barriers linked to interoperability are currently being assessed by European policymakers to arrive at a consensus with all stakeholders regarding the data exchanged, the interconnection standards and the protocols to be used.

Standardisation and interoperability, which enable charging points to cater to customers using any service provider, are essential for maximising charger utilisation, enhancing the customer experience, and optimising investments[20].

©inbalancegrid.com

Further reading about E-Bus Solutions here. ©Siemens Mobility

20 Further information on how governance can increase the uptake of EVs here.

Lessons Learned

LESSONS LEARNED

- The national/European **regulatory framework for V2G is yet immature**. It is expected that soon the legislation will accommodate the integration of V2G technology in the energy market. From a city context, the national legislation is not easily influenced. However, on the local level, incentives can be issued by funding and replicating innovative V2G pilot projects.
- A city can be a key enabler of the **transition to a smart electrical car fleet.** Having the urban planning and permitting departments aligned to ensure a smooth process will improve customer experience, attract investors, and ensure high visibility of the transition goals in the public domain.

  While an EV can benefit from participating in multiple energy services, the same applies to the charger. In the design of the charger planning, the city should **engage with diverse market actors to ensure a successful and replicable approach.**

- Cooperation with the distribution system operator is a key element for successful implementation in the more flexible energy market with service levels at low and medium voltage levels.
- National authorities and energy regulators are decisive in the design and implementation of the principles for flexibility markets, aggregation services, capacity mechanisms and dynamic tariffing. They should consider the lessons learned from the various pilots in this design. Regulatory sandboxes for trials could help to understand the specifics of the regional or national context, but only if the knowledge is not yet available.
  By no means regulatory sandboxes should be used as an implementation delaying manoeuvre.
- National and regional authorities should engage with the car and car charging manufacturers, aggregators and fleet operators to **emphasise the importance of interoperability standards and express clear expectations on the cooperation to the development and uptake of agreed standards and protocols.**

BUSINESS MODELS AND FINANCE

©Rawpixel, Unsplash

BUSINESS MODELS AND FINANCE

Possible Business Models

To enable business models that facilitate flexibility from EVs, **cost savings must be enabled for single end-consumers**. This will motivate EV users, DSOs, and TSOs to increase their efforts in activating grid-interactive charging, providing peak shaving or shifting and energy trading.

From designing tariffs to market bidding, several mechanisms can be deployed to turn cost savings into remuneration.

However, for countries with unbundled power markets, especially if the power market is only accessible to large suppliers and retailers, opening the energy and balancing markets might not be possible. Therefore, the **initial crucial step is to enable demand response and the involvement of entities like EVs, charging stations, and stationary batteries in the market**[21].

Moreover, market specifications, like minimum size and asset similarity, can create hurdles by setting minimum EV aggregation requirements. **Reducing this implicit entry barrier where feasible should be encouraged.**

Smart EV charging solution by Inbalance grid

CASE STUDY

Inbalance grid is a Lithuania-based EV charging company that's overcoming the grid limitation barrier through a cloud-based dynamic load management technology for grid balancing. Inbalance grid develops smart EV charging hardware and software and operates a charging network in Central and Eastern Europe. The grid balancing technology allows to build more charging points with less dedicated power, with benefits such as:

- reducing CAPEX needed for EV charging infrastructure,
- avoiding unsustainable and expensive grid upgrades,
- extending grid capacity by eliminating grid overloads due to unadjusted EV charging,
- creating charging availability for EV drivers.

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21 IEA (2022): Grid Integration of Electric Vehicles

Designing dynamic tariffs

Enhancing EV flexibility while preserving static tariffs for other users.

Tariff design, a technology-neutral approach, can align charging decisions with grid costs based on both periods and locations to help reduce system costs. Designing specific EV tariffs and separating metering can enhance EV charging flexibility while preserving static tariffs for other uses[14].

As an example, a study from the European Union shows that using real-time pricing can save up to 27% of power generation costs[22].

Some examples of dynamic tariffs are:

- **Time-of-use:** rates to be set at a higher price during peak periods to discourage consumption.
- **Real-time pricing:** change of tariffs in real-time conditions. This requires, however, complex, advanced, and expensive metering and communication resources.
- **Critical-peak pricing:** fixed tariff rates with the introduction of notably high prices when a reduction in consumption is needed.

For end consumers, however, the gain margins for this business model are not substantial. A pilot in the UK concluded that yearly savings for consumers would average a little under € 500[23].

22 European Commission (2019): Effect of electromobility on the power system and the integration of RES
23 Further reading about Project Sciurus here.

Providing grid services

As an alternative to designing tariffs, market-based procurement, through local flexibility markets, allows bidding based on capacity and energy, prioritising the use of the lowest-cost flexibility resources.

Because of the low margins on energy trading, these business cases are more interesting for aggregators, fleet managers or public transport electric mobility operators that have access to a larger capacity of energy.

EV aggregation

EV aggregation is a valuable method for distributed resources to actively contribute to energy markets, as EV aggregators can access the electricity market and connect with smaller entities that offer grid services or flexibility.

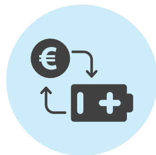
Vehicle-to-grid

V2G can help with local congestion management by aligning production and consumption on low voltage levels. However, there is still uncertainty with regard to the business models for low voltage services until details and values are defined at a local level and there is clarity on the balance between the demand for services and offerings. However, the expected values are to be seen compared to the best flexibility service (V2G, smart charging, etc.). Substantial remuneration for the contribution of a single EV is hence not to be expected.

Storage of locally produced energy

Balance the high-voltage grid

Production and consumption



Energy reused later

Energy reserves

Intermittent distributed renewable production makes the balancing between energy demand and supply a more dynamic challenge. To maintain power quality, "energy reserves" are engaged where capacity is reserved if the supply is unable to meet the demand or the other way around. Frequency variations further need to be limited, which demands fast actions on the supply or demand side.

EV fleets or public transportation fleets can engage as an energy reserve while they are connected to the grid.

Because EVs can react instantly to frequency variations (between 0 and 30s), they are very well suited for frequency regulation. Current strict regulations pose a challenge in many Member States regarding the integration of V2G-capable fleets into the energy reserves.

Entering this market requires a capacity of 1 MW at 100% availability which corresponds to 100 EVs connected to the grid.

Additionally, to ensure this 100% availability, the fleet must be substantially bigger to guarantee at least 1 MW.

Parker project: providing frequency regulation with EVs

A first pilot project connecting V2G and frequency regulation has been set up in Denmark (the Parker project). It was shown that bi-directional frequency regulation can earn, typically, €500/car/year. These margins provide sufficient incentives for aggregators to develop and maintain a V2G algorithm. However, some barriers to entry remain.

Pre-qualification of aggregated EVs to provide frequency regulation can be challenging as technical regulations are not yet fully defined for this type of resource. The main economic barriers identified are the tariffs and taxation costs associated with two-way energy flow when providing V2G services and the current requirement on costly utility-grade settlement meters needed to record charger consumption.

More information here.

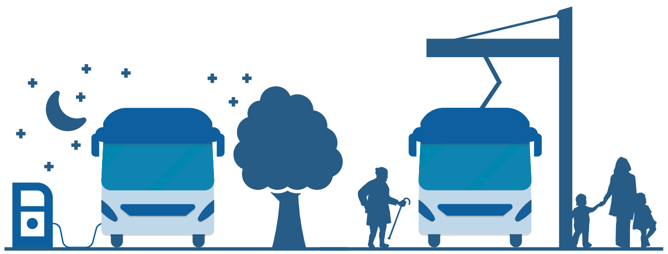
©Parker Project

Interesting opportunities

When combining grid services with additional mobility services, interesting business cases emerge. The additional revenue from EVs can make up for the added cost of electric mobility as compared to traditional ways of transportation. At the same time, the environmental benefits of an electric mobility fleet are not to be neglected. Examples of how different mobility services can interact with grid services to add value to EV users, energy suppliers, and other stakeholders are presented below.

V2G and public transport

Electrifying public transport can be a costly operation. If the mobility fleet is battery-powered, the EVs or buses will need to be charged. With **careful planning of the charging slots**, the electric fleet can generate added revenue by offering grid services. Because **predicted driving times are accurate and public transport typically represents a high capacity**, it is a natural fit to provide grid services.



Destination charging

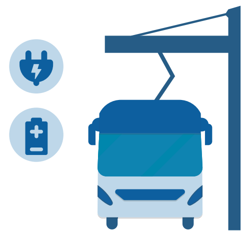
Opportunity charging

V2G and carsharing

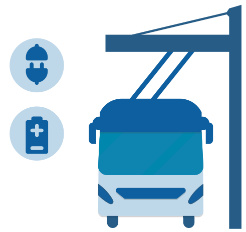
In a city context, carsharing programmes are on the rise. Because of the scarcity of parking spots and car ownership costs, more and more families make use of a carsharing provider instead of buying a car. **These programs can be combined with V2G.** The planning of driving times is more challenging because of the unpredictable user behaviour as compared to public transport. In the end, the carsharing provider controls the availability of the electric fleet, ensuring that the needed EVs are accessible to provide grid services if required by the TSO (or DSO in the future). This allows for entering the energy trading market which generates additional revenue.

Both public transport and passenger carsharing have the added benefit of the ownership structure: the driver is not the EV owner and, therefore, the societal barriers fade away. Information availability, range anxiety, insurance and third-party access to the vehicle are minor issues in a business-to-business relationship between a public transport manager and a V2G algorithm provider. On top of the grid services revenue, the traditional mobility services generate revenue as well. This combination of mobility services and V2G is, therefore, a promising business case in a city context.

Karos Mobility is an innovative carpooling solution integrated with public transport that aims to reduce the environmental impact of commuting trips by increasing the occupancy rates of vehicles. ©Karos Mobility

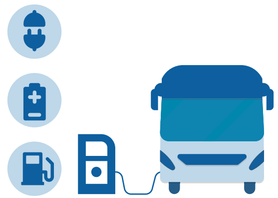


Battery Electric Vehicles (BEV)



Trolleybus with batteries

Fuel cell bus



Plug-in Hybrid Vehicles (PHEV)

Lessons Learned

LESSONS LEARNED

- Several business models can be deployed to foster smart charging and enhance EVs' flexibility. **Dynamic tariffs** are technology-neutral and discourage consumption during peak times, but a fair design can be costly. A **market-based procurement**, opening the energy market for energy bidding, allows remuneration based on the actual costs of the system, but might not always be possible due to high entering requirements of fleet size.
- In the current market, energy is cheap and the margins for valid business models are small. Ensure the business model is **based on value stacking.** A market as volatile as the energy market is too risky when targeting one revenue stream. Additionally, when aggregating flexibility, it is **best to combine smart charging with other technologies such as batteries, electric boilers, or similar ones.**
- Stick to facts, **verify assumptions with regulators and policymakers.** Too many pilots have emerged building on an assumption that will never turn into reality.
- The transposition of the flexibility or service market at low and medium voltage level included in the Electricity Market Directive, part of the Clean Energy Package, is **a key element in enabling transparency on the relevance and value of services.**
- The opening of the energy market for aggregated small-scale assets is lagging in several Member States. The **aggregation of EVs and the inclusion of smart charging and V2G enable the instantaneous activation of a large, distributed storage asset.**

GENERAL LESSONS LEARNED

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GENERAL LESSONS LEARNED

LESSONS LEARNED

The exploitation of EV charging flexibility is key to mitigating their impact on the grid. Smart charging can decrease peak consumption and contribute towards a high renewable energy systems uptake which will significantly reduce associated emissions. On top of this, V2G technology can help balance the electricity grid that might come under pressure with a high uptake of, among others, EVs and heat pumps.

From a technical and commercial point of view, smart charging is a mature technology. While various pilot projects throughout Europe have proven the technical feasibility of supporting the grid with EVs, V2G needs consolidation from a business and regulatory perspective.

To achieve a **large-scale rollout of smart charging and V2G**, attention must be paid to user **acceptance and societal aspects**. By understanding user needs and fears, industry and government can work together to educate the public.

For V2G solutions to be successful, they **need to address users' concerns regarding the control process of the vehicles**. This V2G process should be communicated adequately to the users and allow them to control some of the processes.

The current regulatory framework is not aimed at small, distributed energy sources entering the energy trading market.

To increase the uptake of grid-interactive charging, changes and support from national or local policymakers are required.

The decarbonisation of public transport systems will be crucial as European countries and cities move towards a net zero economy, and as such, the e-bus market will continue to expand. © Semitan

16 key actors signing Belgian's Leuven 2050 City Roadmap in 2019. © Leuven2030

LESSONS LEARNED

What Can You Do?

Support pilot smart charging and V2G initiatives with funding or tax reduction.

Assign regulatory sandboxes where energy experiments can be conducted with energy tariffs.

Make a joint assessment with the distribution grid operator to find opportunities where smart charging can help to balance the grid in the future.

Inform users and citizens about the benefits of smart charging and V2G through social media campaigns, informational events or educational activities.

Design compelling economic incentives for EV users to adhere to V2G, as they are the actors who ultimately decide whether to participate or not.

Create products or solutions that address the fears and concerns of users, such as allowing them to control the charge/discharge through customisable apps.

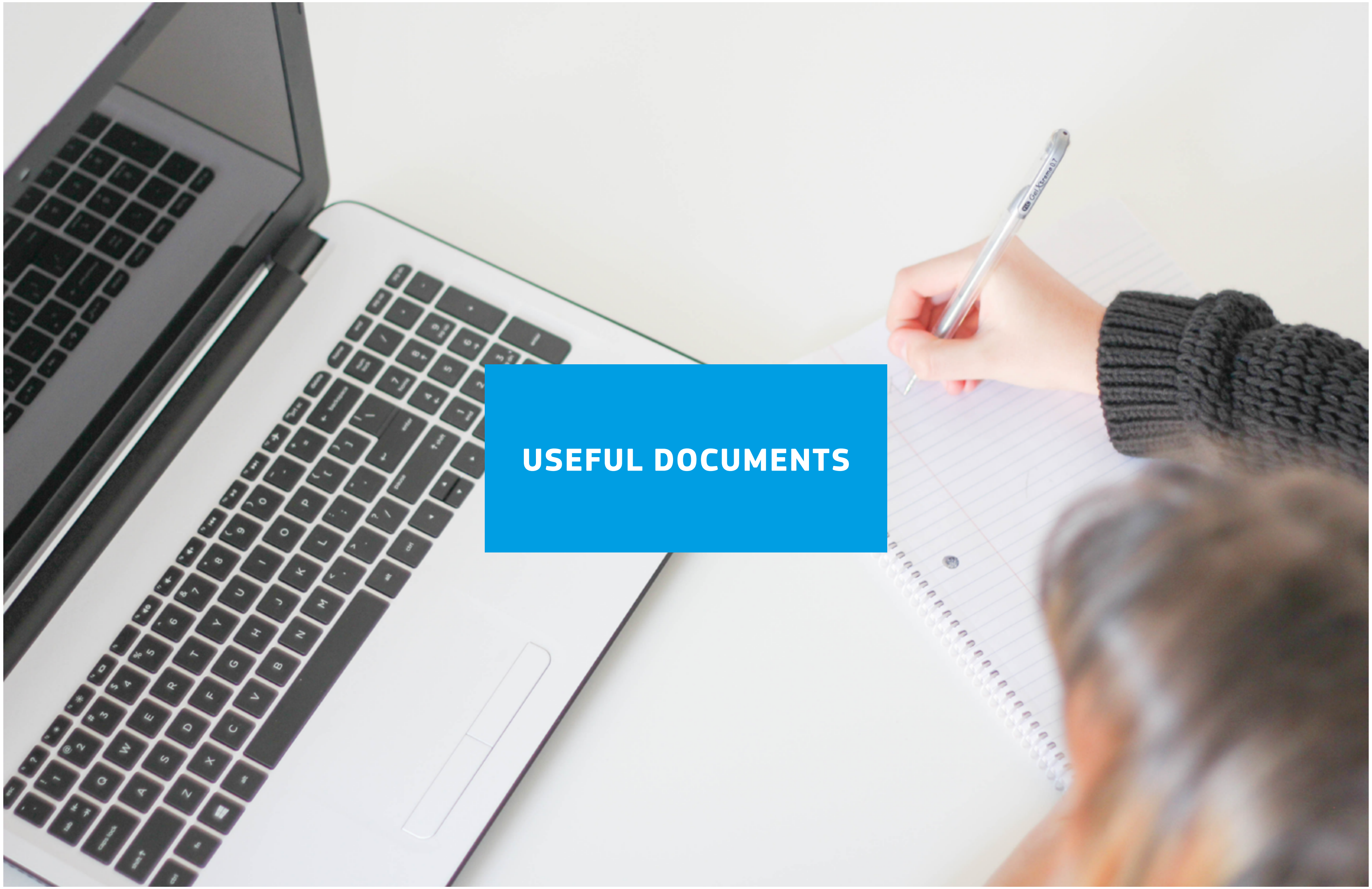
For V2G solutions to be successful, they need to **address users' concerns** regarding the control of the charging process of the vehicles. The V2G process should be communicated adequately to the users and allow them to control to some extent the process.

Connect different stakeholders to participate in innovative pilot projects (car manufacturers, DSO, TSO, aggregator, ...).

Incentivise EV stakeholders (dealerships, maintenance shops) to provide a support network for businesses that want to electrify their fleet through economic incentives or rewarding schemes.

Promote alternative business models where traditional mobility services are combined with energy services through smart charging or V2G technology.

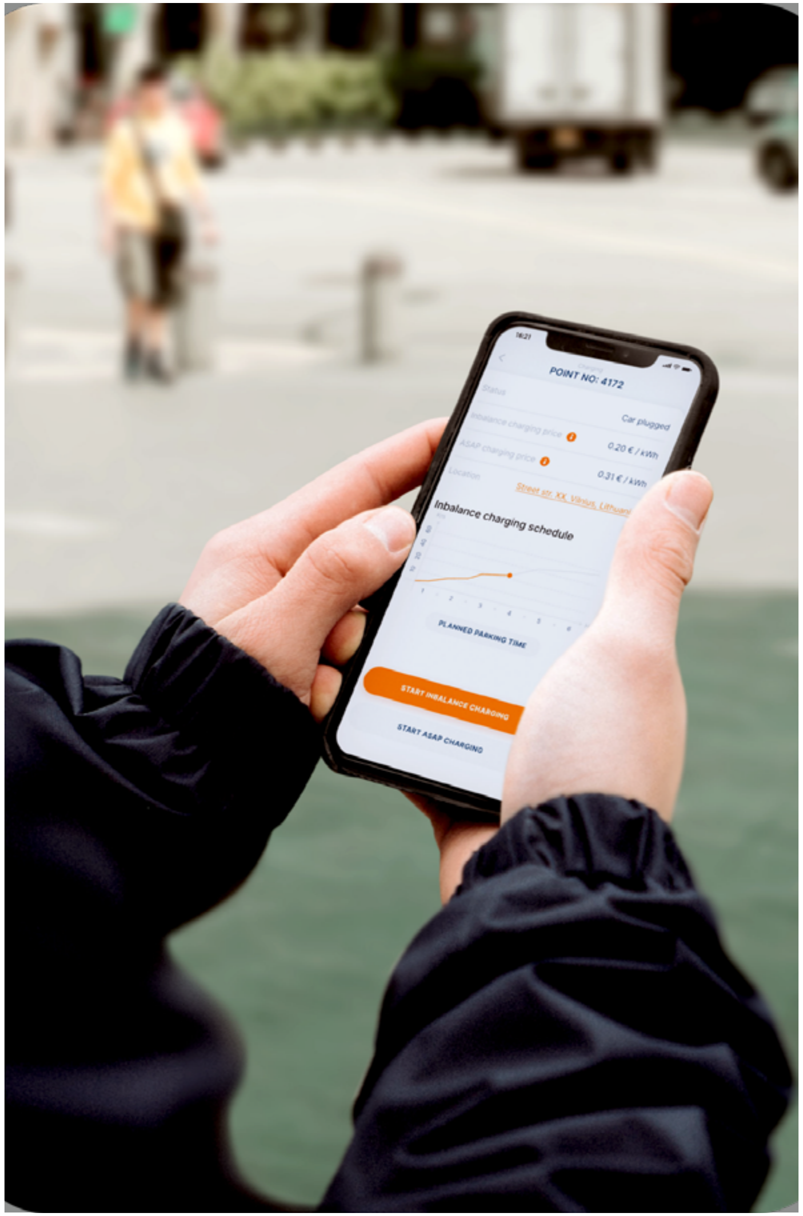
USEFUL DOCUMENTS



©Kelly Brito, Unsplash

USEFUL DOCUMENTS

- Mapping of the discussion concerning standards and protocols for communication exchange in the electromobility ecosystem (Report)
- Read more about Parker Project
- Redefining mobility in an entire island: The Astypalea projet
- Interconnect Project: Interoperable solutions connecting smart homes, buildings and grids.
- Electric Vehicles Are a Multibillion-Dollar Opportunity for Utilities (Article)
- How vehicle-to-everything (V2X) can turbocharge the energy transition (Article)
- Europe Electric Car Sales Report (Article)
- Impact of EV and charging infrastructure on European T&D grids – Innovation needs (Article)
- Shaping the future of fast-charging EV infrastructure (Article)
- Why is good power quality necessary (Article)
- Capacity and Ancillary Services Markets: Frequency Regulation (Lesson)
- Impact of Smart Charging for Consumers in a Real World Pilot (Article)



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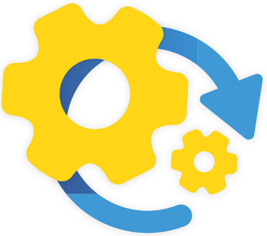
Smart Cities Marketplace

The Smart Cities Marketplace is a major market-changing initiative supported by the European Commission bringing together cities, industries, SMEs, investors, researchers and other smart city actors.

The Marketplace offers insight into European smart city good practice, allowing you to explore which approach might fit your smart city project. Discover our digital brochure here.



Matchmaking

The Smart Cities Marketplace offers services and events for both cities and investors on creating and finding bankable smart city proposals by using our Investor Network and publishing calls for projects.

Investor network

Call for Applications – Matchmaking Services

Project finance masterclass

Focus and Discussion groups

Focus groups are collaborations actively working on a commonly identified challenge related to the transition to smart cities.
Discussion groups are fora where the participants can exchange experiences, co-operate, support, and discuss a specific theme.

Focus and Discussion groups

Community

Scalable Cities

A city-led initiative providing large-scale, long-term support for the cities and projects involved in the Horizon 2020 Smart Cities and Communities project.

Scalable Cities

Smart Cities Marketplace is managed by the Directorate-General for Energy. ©Smart Cities Marketplace

ELECTRIC VEHICLES AND THE GRID

SOLUTION BOOKLET

Smart Cities Marketplace 2024

The Smart Cities Marketplace is managed by the European Commission Directorate-General for Energy