Best practices and assessment of regulatory measures for cost-efficient integration of electric vehicles into the electricity grid

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Executive Summary

The main objective of this study is to identify the remaining technical and regulatory barriers to the development of smart charging, taking into account the needs of various stakeholders, and to propose and evaluate possible legislative and non-legislative policy measures addressing these barriers. The policy measures are grouped into proposed policy options that address a number of specific policy objectives, with the ultimate goal of enabling technically robust and cost-efficient integration of electric vehicles (EVs) into electricity grids.

The study builds on five main tasks, comprising the following:

1. Identification of best practices for the cost-efficient integration of EVs into the electricity grid through smart charging;
2. Identification of remaining barriers to the development of smart charging;
3. Identification of possible policy measures addressing these barriers, and grouping them into policy options achieve the ultimate objective of cost-efficient integration of EVs into electricity grids;
4. Cost-benefit analysis of the policy options; and
5. Comparison of policy options and recommendations.

Best-practices for the cost-efficient integration of EVs into the electricity grid through smart charging

Seven best practice themes were identified at the study's outset. Supported by literature research of ongoing and completed projects worldwide and stakeholder consultation, a number of pilot and early-stage commercial projects where smart charging was applied to help facilitate the integration of EVs into the electricity grid were selected. Some key lessons learned pertaining to the seven best practice themes were identified based on this research.

- Use of dynamic pricing and Time of Use (ToU) pricing in order to avoid congestion in the electricity grid: projects in the US and UK have demonstrated that dynamic electricity pricing or ToU pricing can help convince EV users to delay their vehicle's charging in order to take advantage of cheaper electricity prices, ultimately helping to avoid adding to electricity demand at peak load times;
- Ensure or incentivise smart charging at home: informing EV users of the environmental and social benefits of smart charging, combined with monetary reward schemes, is an important factor to recruiting EV users to participate in smart charging projects;
- Cooperation between smart charging initiatives and Distribution System Operator (DSO) planning: having DSOs play an active role in smart charging projects helps identify potential benefits smart charging can have for EV integration with the electricity grid;
- Ensure or incentivise that new and refurbished publicly accessible recharging points can be used for smart charging: smart charging of EVs requires smart charging infrastructure—a regulation in the UK requires that all new or refurbished chargers meet minimum smart charging requirements, including communications and metering capabilities;
- Vehicle to Grid (V2G) best practices: V2G and other bidirectional charging technologies may contribute to profitable business models in certain jurisdictions and depending on energy market conditions—the benefits generated by V2G are nevertheless highly location-specific, and it is important to understand the conditions under which V2G can be profitable prior to generalising its use;

- Ensure that the electricity used for the recharging of EVs come from renewable sources: financial incentives such as monetary rewards or lower electricity prices at times of high renewable electricity production can help shift EV charging times to capitalise on high renewable energy production—what's more, should there be an excess of renewable energy production relative to the base load, smart charging can help avoid curtailment, i.e. the shutting off of renewable energy sources.
- Seamless V2G public charging experience: car-sharing fleets are an ideal target for V2G applications, as they allow for a centralised approach through a single operator, often using a limited number of vehicle models with identical characteristics—V2G technologies can help offset the costs of vehicles while they are not in use, which is a commonly cited factor limiting the business case for car sharing fleets.

Identification of remaining barriers to the development of smart charging

The study identifies main technical and regulatory barriers to wider uptake of unidirectional and bidirectional smart charging. The analysis addresses both publicly accessible and private charging and Member State and EU level barriers. The presented barriers are a results of analysis of best practices, literature search and a stakeholder survey. The stakeholder survey included participants from 14 different stakeholder groups involved in smart charging ecosystem in Europe today, with slightly higher representation from charge point manufacturers and energy suppliers/aggregators/ElectroMobility Service Providers. Survey identified not only technical and regulatory barriers, but also other barriers, analysis of use cases and possible short and long-term policy measures to address identified barriers.

The analysis shows that unidirectional smart charging has fewer barriers to wider uptake than bidirectional smart charging. The relevance of presented barriers to unidirectional or bidirectional smart charging are clearly indicated.

When it comes to technical barriers to unidirectional smart charging lack of deployment of smart charging infrastructure and lack of communication standards are the barriers perceived to be of the highest importance. The most important technical barriers to bidirectional smart charging identified by the stakeholder are technical limitations of available EV models, lack of standard interoperability and lack of deployment of private smart charging infrastructure. Battery degradation is broadly discussed in literature and among stakeholders but is not perceived of equal importance. This is understandable taking into account mixed literature stance on battery degradation, with newer studies showing battery degradation is more complex and cannot be directly and solely related to unidirectional or bidirectional smart charging.

At the side of regulatory barriers, unidirectional and bidirectional smart charging face similar barriers, where barriers perceived as the most important are lack of dynamic pricing, electricity network tariff design and, in the case of bidirectional smart charging, double taxation. Regulatory barriers are related to multiple EU directives and regulations including the Electricity Market Directive, Electricity Regulation, Energy Taxation Directive, Alternative Fuels Infrastructure Directive, Energy Performance in Buildings Directive and others, where policy measures should be taken to improve these directives and regulations but also to assure their implementation in practice once of Directives are transposed on Member State level. The fourth most important regulatory barrier is lack of access to EV battery and charging data, where the main recommendation from survey respondents and literature has been to allow the data access and right to share to EV users.

Aside from technical and regulatory barriers, other social and infrastructure readiness barriers have been discussed in this report. Of those, awareness raising of the stakeholders, complexity of information communicated with the stakeholders and EV user hesitance to grant access to the battery are found to be most important for all stakeholders. While the first two barriers can be addressed with clear and simple communication and tailored awareness raising campaigns on EU and member state levels, the user hesitance is also mitigated with these measures.

When it comes to optimal use case for uptake of unidirectional and bidirectional smart charging, private charging (either of passenger cars or commercial fleets) has been identified to have a larger potential compared to public charging. Regardless of the use case, longer time periods are needed for steering the charging as a source of flexibility for the grid. Therefore, charging duration is the decisive factor to weigh in when assessing a use case potential for wider uptake of unidirectional and bidirectional smart charging.

When discussing barriers to unidirectional and bidirectional smart charging it is important to keep in mind that the following differences between Member States create a more or less supportive environment for further uptake:

- level of transposition and on the ground implementation of the EMD;
- electricity taxation policies based on the Energy Tax Directive;
- national political support for unidirectional and bidirectional smart charging (including incentives for infrastructure) affecting user acceptance and stakeholder awareness;
- users' mobility preference variations;
- vehicle taxation and climate policy;
- integration of national policies for transport (charging infrastructure), energy (grid state, digital meters, flexibility), climate (GHG) and buildings (building codes, planning, procedures);
- collaboration and coordination between local and national levels.

Identification of possible policy measures and potential policy options

Based on the best practices, literature search, survey and targeted interviews and discussions with stakeholders, the study defines policy measures to remove the remaining identified technical, regulatory and other barriers and support the development of unidirectional and bidirectional smart charging services in competitive markets. The identification of possible legislative or non-legislative measures makes a clear distinction between requirements for unidirectional or bidirectional smart charging, public or private charging and normal, high or ultra-high power charging, as well as whether measures should be implemented on Member State or EU level.

In addition, possible policy measures are scored based on their effectiveness to respond to seven identified policy objectives:

- Assuring all chargers are smart chargers (including needed measures for EVs);
- Clearly defining the functionalities of smart chargers;
- Development of smart charging is coupled with development of renewable energy sources, considering the EV electricity demand;
- Assuring open access to EV and charging data;
- Development of energy market, and interoperability, enabling the development of competitive smart charging market;
- Stakeholder awareness raising; and
- Integrated strategic planning of energy, transport and building sectors including smart charging infrastructure.

Policy options are defined taking into account defined possible policy measures focusing on publicly accessible unidirectional or bidirectional normal power smart charging.

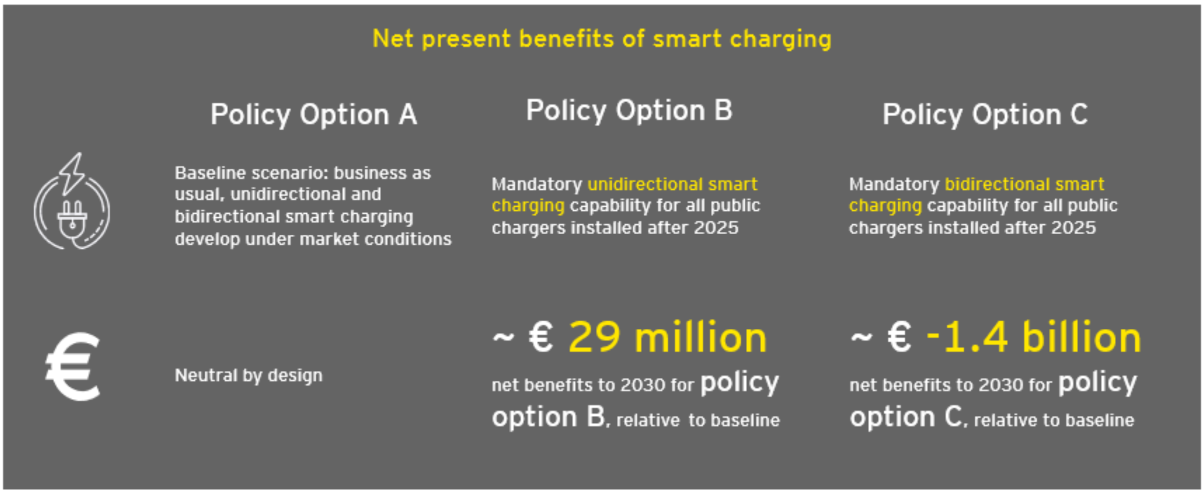
Policy option A, i.e. the baseline option, assumes no change in policy relative to what is currently in place or expected to be realised in the near future. It is assumed that, under the baseline scenario, an estimate of 80 % of all vehicle chargers in 2025 will be capable of smart charging, of which 90 % is unidirectional smart charging capable and 10 % will be capable of bidirectional smart charging[1]. In 2030 and under the baseline scenario, it is assumed that nearly of all vehicle chargers will be capable of smart charging, of which 70 % is unidirectional smart charging capable and 30 % will be capable of bidirectional smart charging.

Policy option B aims at removing remaining barriers to smart charging services and at fully enabling smart charging services in competitive markets. In comparison to policy option A, it aims at setting a legally binding framework for the roll-out of an infrastructure for unidirectional smart charging, and setting common definitions and standards on a legal basis for all EU Member States.

Policy option C aims to go beyond policy option B, in order to fully capture the potential benefits of smart charging through bidirectional smart charging. In comparison to policy option B, it aims at setting a legally binding framework for promoting the roll-out of bidirectional smart charging.

Policy option D builds on the requirement for unidirectional smart charging considered in policy option B, adding a policy measure calling for support to pilot projects assessing the feasibility of bidirectional smart charging, with the aim of determining the conditions under which bidirectional smart charging is feasible and cost-efficient.

Cost-benefit analysis of the policy options



A cost-benefit analysis of the proposed policy options reveals a significant contrast between unidirectional and bidirectional smart charging. According to our analysis, the net present value of total net benefits accruing from the deployment of additional unidirectional smart charging points under **policy option B** would amount to **over 29 million €** from 2021 to 2030. This supports the argument for generalising unidirectional smart charging across public chargers.

As regards bidirectional smart charging, the net present value of total net benefits accruing from the deployment of additional bidirectional smart charging points under **policy option C** would be **negative of 1.4 billion €** from 2021 to 2030. Policy option D sets the same requirements for public chargers installed as of 2025 to be capable of smart unidirectional charging, with additional non-legislative measures aiming to accelerate the deployment of smart bidirectional charging. The total net benefits of **policy option D**, as regards the mandate for public chargers to be capable of smart unidirectional charging, are identical to those for policy option B and amount to **over 2.9 million €**. The additional costs and benefits of non-

[1] https://www.utilitydive.com/news/2021-outlook-the-future-of-electric-vehicle-charging-is-bidirectional-bu/592957/

legislative measures to accelerate the deployment of smart bidirectional charging were not assessed quantitatively.

The net benefits of policy options B and C are presented relative to what is expected under the baseline scenario, and therefore represent the additional benefits expected as a result of the policy option. In the case of policy option B, the overwhelming opinion of stakeholders consulted for this study is that the majority of EV chargers, public and private, should and will be capable of unidirectional smart charging in the near future. The requirement, under policy option B, to make all new chargers capable of unidirectional smart charging as of 2025 will therefore only concern a small number of chargers.

In the case of policy option C, it appears that the high cost of bidirectional smart chargers, coupled with some uncertainty around the level of benefits that can be derived, results in a negative outlook for the net benefits of the policy option. This reflects the opinion of many stakeholders consulted in the course of this study, according to whom bidirectional smart charging technologies are still in an early stage of development, and are likely to be beneficial only in specific jurisdictions.

Comparison of policy options and recommendations

The comparison of policy options provides an assessment of the impacts of the policy options according to the following criteria:

- Effectiveness: to which extent does each policy option contribute to achieving the specific objectives pertaining to the cost-efficient integration of EVs into the electricity grid?
- Efficiency: do the benefits associated with these policy options outweigh their costs?
- Proportionality: are the measures foreseen under these policy options proportional to the objectives, or do they go beyond what is needed to achieve the objectives?
- Feasibility: is there a general consensus among business, civil society and other stakeholders on the desirability of implementing the policy options?

Based on these criteria, a net preference emerges for policy option B, combined with option D. The call for public chargers to be at least capable of unidirectional smart charging is supported by a wide range of stakeholders consulted through this study, including EV and EVSE manufacturers, TSOs, and aggregators. Nevertheless, this report acknowledges a number of limitations, particularly regarding the analysis of costs and benefits of policy options, that may impact the policy recommendations.

Limitations

This study aimed to be as comprehensive and accurate as possible in the analysis of best practices for, remaining barriers to and possible policy measures for the cost-efficient integration of EVs into the electricity grid. The following section will list some of the limitations to the study.

Smart charging technologies are highly innovative and are evolving quickly. In the case of bidirectional smart charging, many uncertainties remain around the technical characteristics of the systems that will be developed. Additionally, a number of regulations, certification processes and market mechanisms must still be adapted to accommodate smart charging to its full potential. Extensive consultation activities with stakeholders that are currently involved in the deployment of smart charging resulted in a very current and up-to-date picture of smart charging, as well as in informed predictions as to its future evolution.. Nevertheless, such forward-looking forecasts are inherently uncertain, particularly given the highly innovative nature of smart charging.

Introduction to the project

Background

The electrification of road transport plays a crucial role in reducing greenhouse gas emissions from transport and in meeting the EU's decarbonisation targets. The market for e-mobility has substantially grown in the past decade and, with the expected rise of the number of electric vehicles on the road worldwide, e-mobility will evidently transform the transport sector and, more broadly, will have a significant impact on our energy system.

The impact of growing levels of EVs on the energy sector and more particularly on the electricity grid is essentially twofold: while EVs represent an extra load in global electricity systems, their cost-effective integration to the electricity grid can also allow for more balancing of the grid, notably through smart charging and bidirectional technologies. Smart charging is referred to in this report as the charging of EVs in a more intelligent manner in order to reduce peak loads in the electricity distribution grid. Smart charging can contribute to avoiding congestion and can limit the amount of costly investments into grid capacity. Through unidirectional and bidirectional smart charging, EVs effectively become a flexible asset to better match demand and supply of electricity, also enabling greater integration of renewable energy.

Integration of EVs through smart charging is increasingly considered an enabler to the mass uptake of EVs and would benefit consumers, the energy sector and the environment. Yet, a number of regulatory and technical barriers are still hindering the large-scale deployment of the technology. The EU policy framework lays the basis on the electricity market side to encourage the development of smart charging technologies, notably with The Clean Energy for All Package, by taking a clear step in this direction. As a cross-cutting technology, the development and regulatory framework of smart charging must be looked at from a multi-disciplinary policy perspective ensuring clear alignment of energy, transport, technology and data privacy policies.

Objectives and scope

In order to ensure the successful deployment of unidirectional and bidirectional smart charging, there is a strong need for in-depth research on the subject, from a policy, regulatory and technical point of view, with the view to developing effective policy measures directly and specifically addressing the roll-out of unidirectional and bidirectional smart charging. This is where this study on "Best practices and assessment of regulatory measures for cost-efficient integration of electric vehicles into the electricity grid" stems from, aiming to draw lessons from current initiatives to drive future policy-making around smart charging, including the revision of the AFID (Alternative Fuels Infrastructure Directive).

In this context, the aim of the study is to assess and develop possible measures at EU level to remove any identified technical and regulatory bottlenecks to the cost-effective integration of electric vehicles in electricity grids.

This report presents the study results and includes the following sections:

- Introduction to smart charging and its potential benefits;
- Identification of best practices;
- Identification of technical and regulatory barriers;
- Proposed policy measures;
- Cost-benefit analysis of policy measures; and
- Concluding comparison of policy measures.

1. EVs' costs to the grid and the business case for smart charging

Smart charging, as discussed above, is a means of managing EV charging in order to reduce peak loads in the electricity distribution grid. It also allows to better match demand and supply of electricity, potentially enabling greater integration of renewable energy. This section will present the benefits of smart charging for EV users, for distribution system operators (DSOs), for transmission system operators (TSOs), for charging point operators (CPOs) and for the businesses, in particular aggregators, who may act as intermediaries between these different parties. References made to smart charging in this section include both unidirectional and bidirectional smart charging. The remainder of this report will distinguish between unidirectional and bidirectional smart charging specifically.

The development of smart charging requires that there be a favourable business case, allowing all parties involved in the smart charging process to recoup their investment. Stakeholders consulted in the course of this study agree that for the full benefits of smart charging to materialise, EV users and their intermediaries in the EV charging ecosystem must be able to "stack" revenues from a number of different value streams. An overview of the main revenue streams associated with smart charging is presented in Figure 1 below.

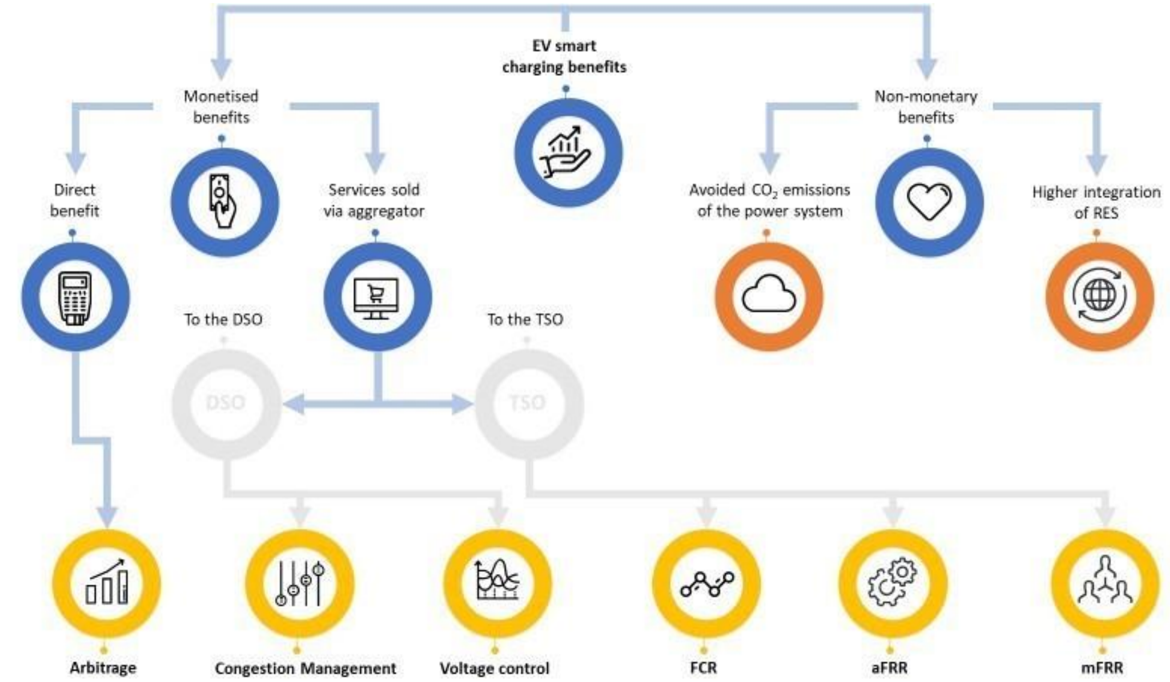


Figure 1: Main revenue streams for EV smart charging. Source: Transport and Environment

TSOs procure services from third parties in order to maintain the stability of their electricity transmission networks. These services include:

- Frequency containment reserves (FCR)
- Automatic frequency restoration reserves (aFRR)
- Manual frequency restoration reserves (mFRR)

The markets for these three distinct services differ as to the capacity that is contracted by TSOs and the response time required by service providers (and, correspondingly, how often the service is called upon). Table 1 below presents some important characteristics for these services, including the volumes contracted by the Belgian TSO Elia as an example.

Table 1: Types of TSO services contracted by Elia

	FCR	aFRR	mFRR
Activation	Automatic	Automatic	Manual
Activation time	0 to 30 seconds	30 seconds to 15 minutes	Within 15 minutes
Volume	87 MW	145 MW	895 MW

EV batteries can be activated on very short notice, and are therefore well suited to providing FCR, as these are usually only activated for short periods of time. FCR services, in comparison to other TSO services, also command a higher price per unit of energy. However, with the declining price of batteries and the rise of energy storage, experts predict an erosion in the prices of FCR services procured by TSOs[2].

DSOs can also procure services from EV owners through smart charging. These include grid congestion management and voltage control. Congestion issues in electricity distribution grids can arise from both sides of the production-consumption spectrum. Intuitively, grid congestion on the consumption side occurs when households, businesses and other electricity consumers within a distribution grid, consume large amounts of electricity concurrently. This may happen at peak electricity consumption times, e.g. when households tend to switch on many appliances in the evening.

On the production side, grid congestion may occur when renewable energy sources connected to distribution grids supply more electricity than the grid can absorb. With the rise in distributed energy resources characterised by variable production, local grids are increasingly experiencing such grid congestion events, leading to the curtailment of production.

On top of services to TSOs and DSOs, smart charging allows for a third type of monetary benefits in the form of arbitrage. EV users, or third parties acting on their behalf—including CPOs and aggregators—may participate in arbitrage by delaying EV charging to take full advantage of cheaper electricity prices. In the case of bidirectional smart charging, EV users or third parties acting on their behalf may charge their EVs in periods of low electricity prices, and discharge their batteries to the grid in periods of high electricity prices.

Smart charging of EVs has the potential to mitigate the grid congestion issues expected to result from the uptake of EVs. It also has the potential to mitigate renewable energy curtailment, by shifting demand to times of high renewable energy production. In Belgium and Germany alone, the volume of additional renewable energy that could be produced by mitigating curtailment through smart charging is in the range of 1.4 to 1.7 TWh (Elia, 2020). This represents enough energy to power 380,000 to 460,000 households. Similarly, smart charging can ensure more distributed renewable energy sources are used to charge EVs. While not directly monetised this will ensure the lifetime well-to-wheel CO_2 emissions of EVs are reduced because of the cleaner electricity mix used to charge the vehicle.

While some of the value streams presented above are linked to well-developed markets, as is the case for e.g. services provided to TSOs, these markets are not (yet) always well adapted to procuring services from small-scale distributed resources such as EV batteries. Additionally, markets for services provided to DSOs are generally undeveloped, and a high level of uncertainty is associated with the expected size and value of these future markets.

[2] Poplavskaya, K. “Impact of balancing market design on business case for storage”, 2018, Available online at http://horizon2020-story.eu/wp-content/uploads/Session-III-_-KseniaPoplavskayaK_final.pdf

The revenues discussed above ultimately stem from avoided costs. All else being equal, the introduction of a large number of EVs into electricity grids, as is expected given the EU targets for the decarbonisation of road transportation, could lead to significant costs for a number of parties. In the absence of smart charging, local electricity grids in areas where EVs are expected to be popular could face risks of grid congestion and the case for grids already suffering from congestion might worsen. This would lead to significant investments required from DSOs.

Similarly, in the absence of smart charging, there would be a need for additional electricity generation capacity to cater to peak demands, resulting in additional costs at system level. The peak installations used to accommodate peak demands on system level are expensive and often more polluting compared to base load plants. Peak shaving at system level can represent a monetary benefit at system level for TSOs, as well as significant non-monetary benefits including the reduction of CO_2 emissions.

Smart charging: who benefits?

The benefits of smart charging to DSOs and TSOs are valuable, and their value is discussed in section **6** of this report. As a result, EV users providing flexibility services could be compensated for agreeing to participate in smart charging. In a typical scenario, for publicly accessible charging points, CPOs would act as intermediaries for EV users, sharing in the benefits they earn.

Where is smart charging most relevant?

Smart charging is most relevant for destination charging, i.e. where EVs are parked for long periods of time, with normal power chargers, i.e. chargers with a capacity of under 22 kW. This includes charging at residential private chargers, charging at the workplace, as well as charging in public locations including long-term parking (e.g. at airports) and overnight on-street parking in dense residential neighbourhoods where EV users may not have access to a private charger.

For whom is smart charging most relevant?

Smart charging is often viewed as being most relevant for light duty vehicles, either private passenger cars or fleets. The main reason for this is that these vehicles are often used for short commutes and are often plugged in for extended periods of time. Their charge can therefore be relatively easily delayed. The large size of batteries in heavy duty vehicles generally means that longer charge times are required. Operators of truck and bus fleets also require low down times, therefore limiting the level of flexibility that can be procured for smart charging. Nevertheless, truck and bus depots do offer a certain level of flexibility potential via smart charging, as they represent a large single flexibility source, whereas light duty vehicles are individually too small to provide meaningful levels of flexibility to DSOs and TSOs.

2. Identification of Best Practices

2.1. Selection of Best Practices

The aim of this task is to identify and collect best practices for the cost-efficient integration of EVs into the electricity grid. The identification and selection of projects was achieved around some key use cases that were agreed upon with DG ENER (public charging, private charging, charging at the workplace and fleet management, for unidirectional and bidirectional smart charging) and key best practices themes provided in the project’s ToR. Based on a set of qualitative criteria (Relevance, Effectiveness, Participation, Replicability, Sustainability), literature and project databases review, a selection of eight key international projects was made to highlight key unidirectional and bidirectional smart charging best practices. These projects are presented in the below table.

Table 2 – Selection of best practice projects

Use case	Project Name	Project objectives	Project dates	Project partners
Public smart charging	SEEV4 city - Flexpower project, Netherlands	Large-scale public smart charging pilot aiming to reduce the impact of EV uptake on the grid through smart charging and integrating renewable energy production.	2016-2019	City of Amsterdam; Nuon/Vattenfall; Liander; ElaadNL
Public smart charging and at the workplace	Power Your Drive project, United States	Pilot aiming to integrate electric vehicles into the grid through a day-ahead hourly rate promoting charging during grid friendly hours and supporting charging from renewable energy. It aims at increasing the adoption of electric vehicles at the workplace and multi-unit dwelling properties.	2016 - ongoing	San Diego Gas & Electric (SDG&E); ChargePoint
Private smart charging	The Electric Nation project, United Kingdom	Large-scale smart charging trial aiming to analyse domestic EV charging patterns, their impact on the grid and the role of financial incentives on the technology's uptake.	2017-2018	WDP; EA Technology; DriveElectric; Alfen; eVolt; GreenFlux; Crowdchange
	Chargeforward project, United States	Pilot exploring the potential of smart charging to lower grid operations costs, support renewable energy integration and the role of consumer incentives to encourage the technology's uptake.	2015-2020	BMW; PG&E; UC Berkeley Transportation; Sustainability Research Center
Smart Fleet management	Mayor of London / Gnewt Cargo project, United Kingdom	Project aimed at examining the benefits of introducing larger EVs as part of Gnewt Cargo's delivery and urban logistics operations, managed through smart charging, and to assess the associated impacts on London roads and power networks.	From 2018	Mayor of London; Gnewt Cargo; UK Power Network; Innovate UK
	Smart Electric Urban Logistics project, United Kindgom	Project supporting the electric transition of UPS' commercial fleet in London based on a smart system integrating energy storage and grid capacity assessment tools in an operational environment.	2017-2019	UK Power Networks Services; UPS; Moixa; CRP
V2G Fleet management	The Smart Solar Charging Network project, Netherlands	Pilot aiming to develop a network of solar-powered smart V2G charging stations to encourage the uptake of EVs in the region and utilize them to support the local electricity grids.	From 2016	Renault; ElaadNL; LomboXnet; Jedlix
	The Parker Project, Denmark	Operational pilot aiming to test the role of a V2G vehicle fleet in supporting the power grid with a particular focus on frequency regulation services. It tested technical requirements and standards for V2G and assessed the commercial viability of the technology.	2016-2018	Nuvve; Nissan; Enel X; Mitsubishi Corporation ; PSA; Frederiksberg Forsyning; Insero; DTU

An additional set of 16 ongoing / upcoming projects were identified as relevant for the purpose of the study, but the limited data availability or too recent nature of the projects did not allow for in-depth case study analysis. However, these projects are considered as relevant and to be monitored. The list is presented in Annex **9.2**.

2.2. Lessons Learned

Seven best practice themes were identified in the ToR. Based on this, some key lessons learned, drawn from the selected projects, were categorised for each theme, as presented in this section. This analysis is supported by individual projects' case studies in Annex **9.1**, presenting key lessons learned and a three-level maturity and replicability assessment (technical, market, regulatory) for each project. A recap of key best practices identified in our analysis is presented in this section, structured around the themes provided in the ToR.

2.2.1. Use of dynamic pricing and ToU pricing in order to avoid congestion in the electricity grid (steering of EV-charging behaviour)

Project	Use case	Lessons learned
Power Your Drive, United States[2]	Public smart charging	Generated off-peak charging through the provision of a dynamic hourly pricing scheme that is shared with users a day-ahead through an app. Customers are able to set a maximum charging price and when the hourly price exceeds the set maximum price, charging stops (taking into consideration higher on-peak prices).
Electric Nation, United Kingdom[3]	Private smart charging	Evening peak load was almost entirely removed during the project due to Time-of-use (ToU) pricing, encouraging participants to charge on later and cheaper off-peak hours around 10pm.

2.2.2. Ensure or incentivise smart charging at home

Project	Use case	Lessons learned
Electric Nation, United Kingdom[3]	Private smart charging	The launch of an awareness raising campaign to educate participants on smart charging benefits, combined with appropriate financial incentives, proved efficient in recruiting trial participants, incentivise the uptake of smart charging at home and encourage EV users' active participation in the trial.
ChargeForward, United States[4]	Private smart charging	Testing the efficiency of using special messaging around the environmental benefits of smart charging to maximize users' participation in the trial, it demonstrated that financial rewards remained the most efficient incentive to encourage EV users participation in the trial and the uptake of smart charging at home.

2.2.3. Cooperation between smart charging initiatives and DSO planning

Project	Use case	Lessons learned

Flexpower, Netherlands[5]	Public smart charging	Leading role of the local DSO and utility in the project which did not rely on an aggregator, but on strong collaboration between the DSO and CPO through open standard protocols to ensure efficient and timely communication and data-sharing. Important benefits for the DSO were generated in terms of grid support and avoided investments.
Power Your Drive, United States[2]	Public smart charging	Leading role of the local DSO SDG&E in managing the project and coordinating the design, permitting, construction of the charging stations, but also managing pricing, providing customer support and maintaining the charging equipment.
ChargeForward, United States[4]	Private smart charging	Close cooperation of the local DSO and utility with the project's smart charging platform provider, sharing renewable energy and grid event signals with the latter. Car manufacturer BMW itself acted as the aggregator, providing and managing the smart charging network and communications with the DSO and vehicles.
Smart Electric Urban Logistics, United Kingdom[6]	Smart Fleet Management	Active cooperation and involvement of the DSO UK Power Networks Services in the project having developed, installed and commissioned the smart charging system and infrastructure used for the pilot. The system generated important benefits in terms of optimizing existing grid assets by increasing the project's site charging capacity through smart charging.
Mayor of London / Gnewt Cargo Electric Vehicle Trial, United Kingdom[7]	Smart Fleet Management	Active involvement of the local DSO UK Power Networks Services in managing the smart charging system. The trial generated important benefits to the DSO by increasing the site's charging capacity and avoiding infrastructure work and grid connection upgrades.
Smart Solar Charging Network project, Netherlands[8]	V2G fleet management	Close cooperation of the DSO with aggregator Jedlix, in charge of providing load forecasts and managing EV charging accordingly, in the most optimal way. This was achieved through efficient data-sharing from the DSO providing grid status updates and safety analysis.
Parker Project, Denmark[9]	V2G fleet management	Close cooperation between the DSO and aggregator, Nuuve. The project argues that the increased integration of distributed energy resources (DER) requires more active management of the grid by the DSO using the flexibility provided. It calls for close cooperation between the DSOs, EVs and/or aggregators to be supported by appropriate market-based measures and tariff schemes.

2.2.4. Ensure or incentivise that new and refurbished publicly accessible recharging points have smart charging potentials

Project	Use case	Lessons learned
All projects concerned	Public and private smart charging	One condition for the successful deployment of the selected projects and best practices is the deployment of smart-ready charging infrastructure. Defining a regulatory framework for smart charging infrastructure is a way to ensure that new and refurbished recharging points, both public and private, have smart charging potential. The UK government Automated and Electric Vehicles (AEV) Act of 2018 represents a best practices in this sense. Through the AEV, the government aimed at ensuring that all new charging points in the UK are smart-ready, by prohibiting the sale or

		installation of electric charging points that do not meet certain requirements of the smart functionality, notably in terms of electronic communications, recording of the energy usage and reaction to the charging information.[10] By making the technology mandatory, such legislations can have beneficial effects on bringing the cost of smart charging technology down through scaling effects.

2.2.5. V2G best practices, including identifying barriers for V2G

Project	Use case	Lessons learned
Parker Project, Denmark[9]	V2G fleet management	The project demonstrated that a fleet of EVs can successfully support the grid by providing frequency regulation services, through V2G. The focus was set on frequency regulation services as the most commercially attractive grid support service. It highlighted that a sustainable business case for V2G is crucial for its large-scale adoption. While the project presented a strong business case, it also demonstrated its variability across different countries and jurisdictions with estimated benefits ranging 2,304 Euro per car/year for the best case against -955 Euro per car/year for the worst case. The project identified some key regulatory, market and technical barriers to V2G deployment including: battery degradation, double taxation, lack of common market for aggregators and social barrier to V2G.
Smart Solar Charging Network project, Netherlands[8]	V2G fleet management	The project estimated important benefits that can be derived from public V2G charging, ranging between €120 and €750 annually per EV owner, depending on EV and user category. The project identified key regulatory barriers to the development of V2G including: double taxation, the lack of incentives to produce local renewable energy in combination with smart charging, the need to establish a level-playing field between public and private charging points and the VAT liability of the EV driver for receiving compensation from bi-directional charging.

2.2.6. Ensure that the electricity used for the recharging of EVs come from renewable sources

Project	Use case	Lessons learned
Power Your Drive, United States[2]	Public smart charging	Renewable energy integration through the provision of a dynamic hourly pricing scheme with lower charging prices at times of high renewable energy production, to incentivise greater match in renewable energy production and charging behaviours.
ChargeForward, United States[4]	Private smart charging	Integration of renewable energy with financial incentives in the form of rewards bonuses for participants charging at off-peak and high renewable times, to incentivise greater match in renewable energy production and charging behaviours.
Flexpower, Netherlands[5]	Public smart charging	Integration of renewable energy by intensifying charging speeds at times of high solar generation and setting current limits at peak times. Limited results due to the lack of consumer incentives to encourage shift In consumer charging behaviours.

Smart Solar Charging Network project, Netherlands[8]	V2G fleet management	Integration of renewable energy through the objective of installing 10,000 solar panels for V2G charging. While only preliminary results were published, the upcoming final assessment should provide valuable insights into combining smart charging with local renewable energy production.

2.2.7. Seamless V2G public charging experience

Project	Use case	Lessons learned
Smart Solar Charging Network project, Netherlands[8]	V2G Fleet Management (public car-sharing)	The project is a large-scale V2G pilot aiming to develop a total of 1,000 AC V2G chargers, 1,000 shared EVs and 10,000 new installed solar panels. Combined with a car-sharing service of Renault Zoe cars, the pilot is one of the first projects testing large-scale public V2G car-sharing. In its initial results, the pilot provides conclusions on consumer acceptance, benefits of V2G and regulatory barriers as outlined in the above best practices themes. The upcoming final results will provide further insights into V2G public charging and car-sharing experience applied at a large-scale in Europe.
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This task has provided some key conclusions on best practices for smart and bi-directional charging in different use cases, based on a selection of international pilot projects. The analysis was conducted simultaneously to Task 2, through a stakeholder survey that was used to validate and seek complementary information on our selected best practices. In addition, through each project's maturity and replicability assessment achieved in Annex **9.1**, Task 1 results fed into Task 2 by providing an initial identification of key technical, regulatory and market barriers which could prevent the replicability of the smart charging projects. These barriers are discussed in further detail in the following chapter of the report, aiming to analyse remaining technical and regulatory barriers to smart and bidirectional charging.

3. Identification of technical and regulatory barriers

The aim with this chapter is to present and discuss technical, regulatory and other potential barriers to the wider uptake of unidirectional and bidirectional smart charging. This chapter puts forward the results of the analysis of a literature inventory on barriers for unidirectional and bidirectional smart charging, including literature from the analysis of best practices, complemented by expert insights gathered from the survey and focused interviews. A common inventory of barriers based on the literature review was compiled. The reviewed material was no older than 2016 and the focus was on peer-reviewed publications, pilot project reports, and review articles (see Figure 2).

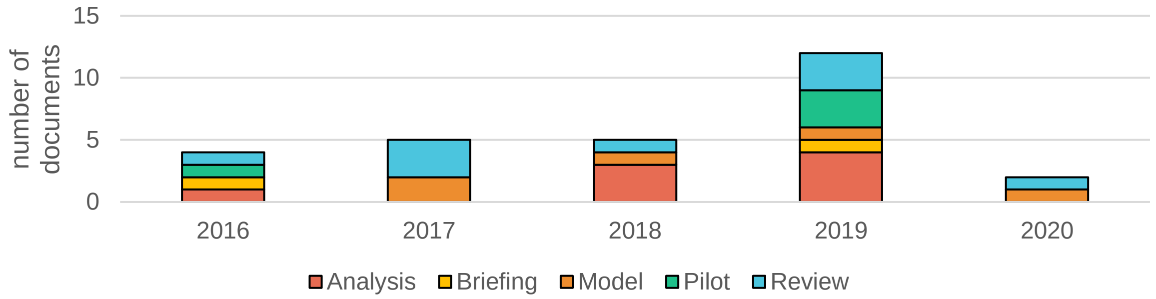


Figure 2: summary of reviewed literature per publication type and year.

The aim of the survey was to gather information on the following aspects: *(i) What are the main barriers to the expansion of smart and bidirectional charging? (ii) What is needed for alleviating these barriers and achieving a wide uptake of smart and bidirectional charging? and (iii) Which use cases for smart and bidirectional charging have the largest potential for wider uptake?*

The list of potential barriers, which the respondents to the survey were asked to rate, was sent out to key contact persons from various stakeholder groups. Figure 3 illustrates the distribution of respondents per stakeholder group. Before launching the survey, a test session with three selected stakeholders was run in order to ensure that the questions were easy to understand and relevant to the respondent pool. The survey was anonymous, unless the respondents indicated otherwise. Some of the respondents were also contacted for a short follow-up interview. The survey was initially sent to 94 persons, and 80 answers were received. It is not possible to conclude what the exact response rate was since the respondents notified that they had further shared the survey with colleagues or with members (applicable in the case of trade associations).

The majority of respondents (26% in total) belonged to either charging point manufacturers or multiple stakeholder groups, e.g. network operators that are also charging point operators, and charging point manufacturers. In general, the representation of stakeholder groups is diverse, yet with a slight majority coming from the electricity supply and charging point manufacturing side. Standard developers and standardization bodies were also represented, as well as representative organizations from the civil society. The barriers of main concern have been derived by summing up the number of responses per barrier and stakeholder marked as "Very important". In chapter 3.1 and **3.2**, the barriers are explained, and possible policy solutions are suggested. Nevertheless, regulatory and policy solutions are further analysed and discussed in Chapter **4** and 5. The technical and regulatory barriers are discussed in the following sections, where each individual barrier is described based on literature review, interviews and survey insights. In addition, each barrier discussed in the sections below includes a concluding summary of suggested measures that could assist in alleviating the barrier based on survey responses and the literature study. In this way survey insights are linked to the work presented in the next chapters of this report regarding possible policy measures.

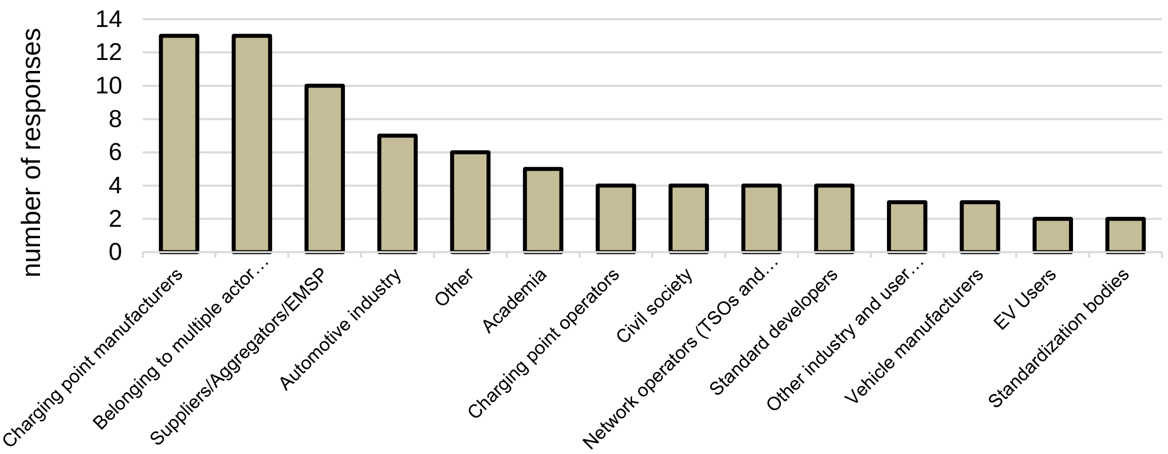
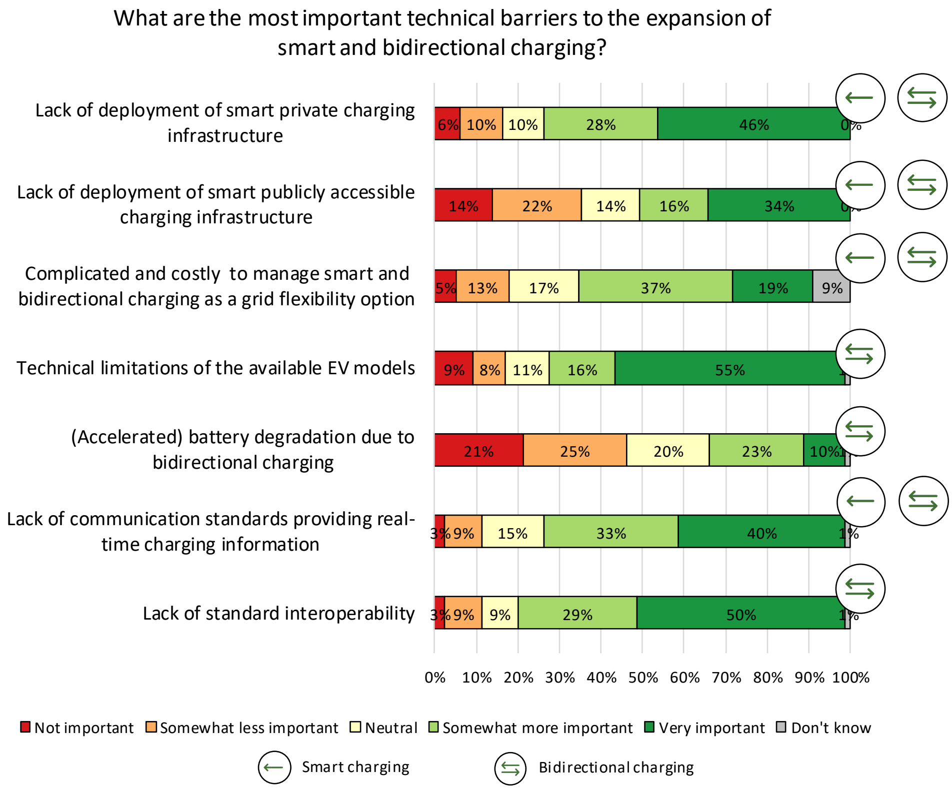


Figure 3: Survey respondents distributed per stakeholder group.

3.1. Technical barriers

Figure 4 presents the respondents' perception of the main technical barriers to the expansion of smart charging. The respondents had to choose between "not important", "somewhat less important", "neutral", "somewhat more important", "very important" and "don't know" for each specific barrier. In the figure below, a distinction is made between the barriers' relevance for unidirectional and bidirectional smart charging, respectively.



(Number of respondents, from top to bottom: 80, 79, 78, 76, 80, 80 and 80)

Figure 4: Technical barriers to the expansion of smart charging according to survey respondents. The relevance of each barrier for smart and/or bidirectional charging is also distinguished.

The survey results show that the decisive technical barrier was technical limitations of available EV models (for bidirectional charging), followed by lack of standard interoperability, lack of deployment of smart private recharging infrastructure and lack of communication standards.

Barriers such as battery degradation and lack of public smart charging infrastructure have a more evenly spread type of responses, thus it is more difficult to conclude on their perceived importance.

3.1.1. Technical limitations of available EV models

There is a very limited number of EV models that currently support bidirectional smart charging capabilities. With AC bidirectional charging, DC power from the EV battery needs to be converted to AC power and fed to the grid, which requires the integration of a bidirectional inverter. This inverter can be integrated on the vehicle or the charger side. Some manufacturers integrate the inverter in the vehicle, others in the charging equipment. Generally, the latter allows for a lower EV price, but it also reduces the flexibility. Future EV users will potentially be able to choose from a range of options in terms of price and level of technology capability [11]. Regardless of whether AC or DC charging is applied, such functionalities require additional development and production costs.

When it comes to smart charging, there is low risk of technical limitations compared to the case of bidirectional charging. However, it is worth noting that EVs that allow high-current charging (e.g. 32 A) can be more affected by smart charging schemes than EV models that are restricted to charging at 16 A, since they can operate at different charging speeds and therefore can influence to a larger extent smart charging volumes and grid power demand variations. As a result, the composition of the EV fleet in a country is a significant factor in the smart charging potential and its impact on the grid [12]. A large number of PHEVs are restricted to 16 A charging, for example.

The role of 5G technologies

The future intelligent transport system (ITS) will comprise complex networks where a fundamental requirement is interoperability among the different devices and infrastructures [13]. Also, when the commercialization of bidirectional charging services grows, the amount of transmitted data increases, which may cause communication barriers for utilities in smart grids due to bandwidth constrains. This requires several attributes that the 5G network can provide. The 5G technology comes with high capacity and ultra-low latency (i.e. it is able to process more information with lower delays), as well as a high reliability and low power consumption, which can meet the bandwidth as well as the reliability and security requirements of bidirectional charging services [14], [15]. A faster network with short response time that allows for more data to be transferred enhances the level of communication and can consequently enable the development and expansion of smart EV services as well as autonomous vehicles [13].

Unidirectional and bidirectional smart charging require secure data transmission and cyber security is thus also an important topic. It needs to be assured that the data transmitted is kept confidential and the security system can identify and manage denial-of-service attacks as well as dubious traffic patterns [16]. There is a need to develop standards addressing technical issues such as communication frequencies, security and access to in-vehicle data and resources to bring security and privacy requirements into a universal form. The BRIDGE initiative, collaboration Interconnect (DT ICT 10) and Open Dei (DT-ICT-13-2019 "Digital Platforms/pilots Horizontal Activities") are activities working towards a proposal of new standards focusing on multi-lateral security and privacy for smart homes and grids. ISO (IEC standards such as ISO/IEC 27030 ("Guidelines for security and privacy in IoT") and ISO/IEC NP 30149 ("IoT - trustworthiness framework") are currently under development.

In the survey, a total of 71% of the respondents considered technical limitations of available EVs to be important, out of which 55% emphasizes it as "very important". Several stakeholder groups highlighted this barrier as one of the main concerns. For charge point operators, this barrier stood out in comparison to other technical barriers, but also charge point manufacturers, EV users, network operators, standardization bodies, other industry and user associations and the energy industry considered this to be one of the most important barriers.

Suggested measures for addressing technical limitations of available EV models

- Introduce government and EU incentives and requirements for OEMs and EV manufacturers to include bidirectional charging functionalities.
- Conduct an impact assessment of the different alternatives to inverter integration for bidirectional AC charging (i.e. compare the options of the inverter being integrated as part of the EV or as part of the standalone charger).
- Provide clear national incentives to consumers to purchase smart or bidirectional charging ready EVs, such as decreased taxation. This would in its turn motivate EV manufacturers to include such capabilities.

3.1.2. Lack of common open standards and interoperability

Common standards and interoperability are particularly crucial for successful vehicle-grid integration [17]. EVs should be able to communicate with any charge point without restrictions. As a result, EVs and charging points should have a common "language", on contrary to diverse proprietary protocols and standards. At the minimum level, transfer of essential information in terms of power setpoint, battery size, EV ID and SoC (for bidirectional charging) should be supported [9]. Front-end communication protocols (between the vehicle and charging point) for unidirectional and bidirectional smart charging are either semi-open or at demonstration phase (e.g. ISO 15118-20). Back-end protocols (between the charging point and the DSO) are mostly proprietary and build further upon the non-proprietary OCPP protocol.

International standards on electric vehicle charging are largely defined by the International Electrotechnical Commission (IEC), the International Organization for Standardization (ISO), and the Society of Automotive Engineers (SAE, mostly for North America and Japan). The Technical Committee 69 of the IEC (IEC/TC 69) focuses on electrical power and energy transfer systems for electric vehicles. Table 3 presents an overview of standards relevant to unidirectional and bidirectional smart charging. All these standards are relevant for both public and private charging applications. Recommended actions for each standard are provided in the table.

Table 3: Overview of existing standards related to smart and bidirectional charging from ECOS, 2020 [18] *and recommended actions.*

Code	Title	Focus	Application	Status	Action
IEC 61850	Communication protocols for intelligent electronic devices at electrical substations	Smart grids	IEC TR 61850-90-8:2016 focuses on e-mobility showing how IEC 61850-7-420 can relate to IEC 62196, IEC 61851, IEC 15118 and IEC 61850-7-420 for high level of safety and interoperability.	Published, but IEC 61850-90-8 needs to be updated	Recommend the update of IEC 61850-90-8
IEC 61851	Electric Vehicle Conductive Charging System	Charging system	Safety requirements for charging with plugs	Published	-

			and cables (AC or DC) and the basic communication between the charging station and the EV. Does not cover bidirectional charging.		
ISO 15118-2	Road vehicles — Vehicle to grid communication interface	Bidirectional charging communication	Detailed communication between an EV (battery EV or a plug-in hybrid EV) and a charging station.	Under review	-
ISO 15118-20	Road vehicles — Vehicle to grid communication interface – Part 20: 2nd generation network and application protocol requirements	Bidirectional charging communication	High-level communication between a charging station and an EV for the control of charging services.	To be published in mid-2021	Follow-up on status
IEC 63110	Management of Electric Vehicles charging and discharging infrastructures	EV charging integration systems	Remote management of charging stations by charging station operators and their integration with energy management systems.	Early drafting stage	Follow-up on status and recommend accelerated implementation
IEC 63119	Charging Service Providers	EV charging services	Roaming and payment in the context of EV charging services.	To be published after 2022	Follow-up on status and recommend accelerated implementation
EN 50549	Requirements for generating plants to be connected in parallel with distribution networks	Smart grids	Definition of technical requirements for the protection functions and the operational capabilities for generating plants. Does not cover adjustable loads, which are expected to be covered by EN 50491-12 (see below).	Published	Should be revised or replaced
EN 50491-12-2	Smart Grid interface and framework for Customer Energy Management	Smart grids	Management of power flows inside buildings, including exchanges with EV charging.	To be published in 2021	Follow-up on status and recommend accelerated implementation

IEC 61851 is essential for operation of conductive charging, either AC or DC, as it covers the low-level communication between charger and EV. However, IEC 61851 does not include bidirectional charging. **ISO 15118** is thus used as a key complement to IEC 61851 in order to define high-level communication between charger and EV, giving the opportunity to controlled charging applications. Overcomplexity within the first edition of ISO 15118 led to launching procedures for revising the standard to a new version **ISO 15118-20** "*2nd generation network and application protocol requirements*" with the aim to enable more advanced smart charging scenarios, including bidirectional charging.

ISO 15118-20 is expected to support the following capabilities connected to unidirectional and bidirectional smart charging: (i) Precise time synchronization between charging station and EVs (essential for all types of smart charging including bidirectional); (ii) Advanced communication capabilities; (iii) Dynamic control; (iv) Bidirectional power flows; (v) Support for grid code-compliant operation (essential for all types of smart charging including bidirectional); (vi) Support for "grid forming generator behavior" (essential when the EV battery acts as emergency power supply) [18].

ISO 15118-20 is expected by mid-2021 according to interviews with key stakeholders and there will be additional time needed until testing specifications and increased numbers of ISO15118-20 compatible products exist in the market (at least 2 to 3 years since publication according to multiple literature sources). Projects where ISO 15118-20 is tested will show whether further updates and harmonization with other standards for smart grids, such as EN 50549, is needed.

EN 50549 defines power generation plant requirements for connection to electricity distribution networks. Previous analyses discuss that this standard applies to EVs that discharge energy to the grid, but it does not cover adjustable loads when e.g. an EV is not charging and therefore EV and charger inverters do not in their turn fulfill grid stability requirements. This can place large risks for grid stability especially when many EVs are connected in the future. This standard needs to either be revised or replaced. The standard **EN 50491-12** on "*Smart Grid interface and framework for Customer Energy Management*" is under development and necessary for defining principles for energy management for buildings, including charging of EVs.

ISO 15118-20 is a key component of the EV standardization ecosystem because it defines how charging station and EVs synchronize and communicate and provides the opportunity for dynamic steering and bidirectional power flows. ISO 15118-20 includes scenarios that describe grid-compliant operation and generator behavior that EVs could have when operating with bidirectional charging. Authentication is automatic with ISO 15118-20 and data security is ensured. Communication of the SoC will be optional but the vehicle will be able to communicate the energy needed for a full charge [17].

Another important component for smart charging processes is the standard **IEC 63110** "*Management of EVs charging and discharging infrastructures"* which defines remote management of charging stations by CPOs and integration with energy systems. This standard is also expected to be updated under 2021. **IEC 63119** "*Information exchange for electric vehicle charging roaming service*" standard is expected to become the international standard for roaming and payment for EV charging, but this standard will not be published earlier than 2022. **IEC 61850** *"Exchange of information with distributed energy resources"* is a crucial standard from a vehicle-grid integration. It is expected to cover/describe the technical specifications and data models required for the communication between DSOs with CPOs. However, alignment has to occur among all areas of the EV charging ecosystem. In addition, the standard shall ensure on a non-exclusive manner the communication channel for the exchange of information regarding demand response, price and load control, metering and capacity forecast, allowing grid management. **IEC 61850-90-8** includes EV charging but needs also to be aligned with, for example, IEC 63110 in order for advanced charging schemes to be incorporated, but it is unclear whether work on this standard update is currently ongoing since the alignment work was cancelled in 2019.

CHAdeMO is a proprietary protocol used for DC charging which allows the possibility for bidirectional charging and exchange of information on battery SoC. CHAdeMO lacks certain communication features that would be needed to provide the detail required for full implementation. CHAdeMO in collaboration with the China Electricity Council (CEC) is developing the new ChaoJi standard to offer new features [17].

As previously mentioned, there are also alternatives to the official or "de jure" standards from e.g. IEC, ISO and SAE. For example, OCPP is an open protocol which is the "de facto" standard for communication between charging point and charging point operator. Other open protocols include OpenEMS, OpenADR, IEEE 2030.5, and EEBUS and while they can generally be faster updated than de jure standards, additional work is needed for improving their capabilities [17]. Figure 5 illustrates how various protocols and standards link EV ecosystem components.

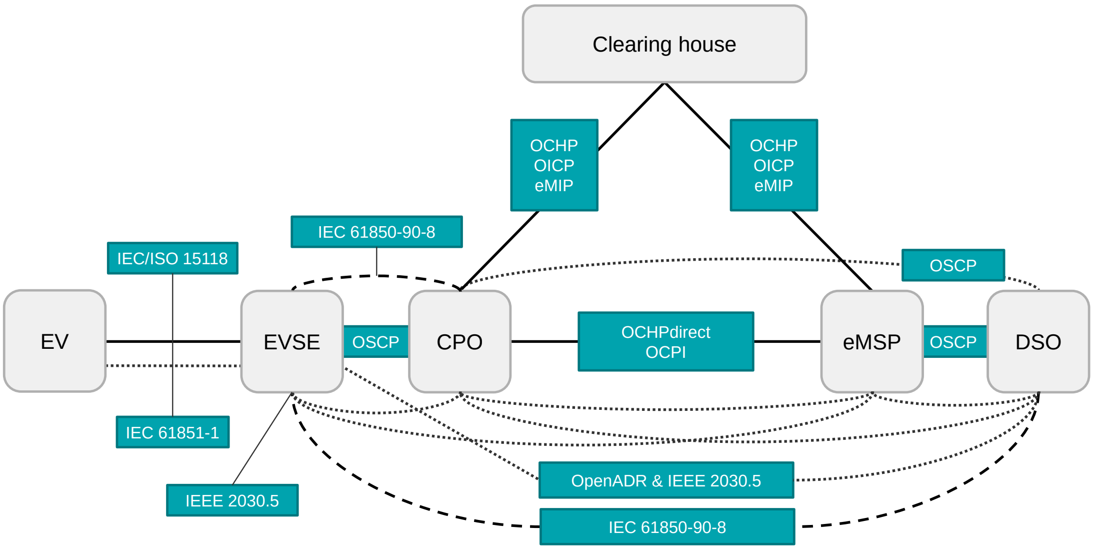


Figure 5: Communication protocols in the EV charging ecosystem.

Source: adapted from ElaadNL

CPO = Charge Point Operator; DSO = Distributed System Operator, eMIP= e-Mobility Interoperation Protocol, eMSP = e-Mobility Service Provider; EV = Electric Vehicle; EVSE = Electric Vehicle Supply Equipment; OCHP = Open Clearing House Protocol; OCPI = Open Charge Point Interface; OCPP = Open Charge Point Protocol; OICP = Open Intercharge Protocol, OSCP = Open Smart Charging Protocol

In summary, interviews with key stakeholders show that the update of ISO 15118 should be expected by mid-2021, but the analysis above as well as the interviews also showed that it is not solely ISO 15118-20 that is needed in order to address remaining barriers connected to the lack of standards and interoperability.

There are standard updates required at the wider energy system level, e.g. relevant to smart grids, transmission network security, and EV roaming and billing (the latter being particularly important for bidirectional smart charging according to interviews). It is necessary to adapt and harmonize standards such as IEC 63110 (remote operation of chargers), IEC 63119 (EV roaming and payment), EN 50549 (operational capabilities of generation plants), and EN 50491-12-2 (smart grids) as soon as possible. The expected finalization varies, with some standard updates being expected under 2021 and 2022 and others requiring time beyond 2022. Processes should be accelerated in order to ensure smooth integration of EVs in electricity grids. Although there is some indication in expected standard update timelines, it is quite common that delays occur. It is recommended that processes are accelerated though in order to ensure that the necessary standards are published in parallel with wider roll-out of EVs and consequently smart charging services. It should be noted that ensuring interoperability takes additional time even after the official publication of a standard.

Standardized open protocols should be adopted across the EV ecosystem in order to avoid the lack of interoperability as a barrier to further expansion of EVs and integration with the grid. Open protocols driven by European and international standardization bodies can benefit from incorporating and building upon existing open standards in order to accelerate the standard publication processes. For example, the OCPP 2.0 and IEC 63110 cover common areas regarding the management and interoperability of charging points and thus the experiences from OCPP can be useful in accelerating the development of IEC 63110. OCPP currently has no funding but will be bidirectional smart charging ready by end of 2021, and OCPI 2.2 already has some rudimentary support for bidirectional smart charging but needs to be improved and adapted to include CPO - DSO communication. This is an indication of a challenge with open industry-driven protocols regardless if proprietary or not, i.e. long-term continuity might not be secured, since interruptions can occur when the responsibility of undertaking the development is uncertain.

Some open protocols are at an early stage of development (e.g. IEC 63110), and other mature protocols include gaps preventing them from supporting innovative use cases. Furthermore, some gaps relate to how protocols link together. Examples of gaps followed by the recommendation are included below. OCPP, a back-end protocol, doesn’t yet define a use case for bidirectional power transfer and several companies are carrying out proprietary modification on OCPP to allow this innovative use case. Instead of developing their own proprietary language, these companies could provide input to the Open Charge Alliance, which develops and maintains the protocol, on what is required to enable bidirectional smart charging in a future version of the publicly available OCPP. Some additional work is required to align front-end and back-end protocols to facilitate implementing them together; for example, additional work is required to be able to combine ISO 15118 - OCPP and ISO 15118 - IEC 63110. In some instances, work is required to be able to combine two complementary back-end protocol such as OCPP, used between a charge point operator and chargers; and OpenADR used between a utility company (e.g. DSO or an energy supplier) and a charge point operator. Some alignment work required include adding or configuring message exchange between the protocols to ensure that neither protocol act as a bottleneck from the necessary information and control needed for dynamic charging. Moreover, there are no definitions for gateways between protocols and these should be defined to ensure reliable performance of the BEV ecosystem.

For example, EEBus or IEC 63110 can be implemented for the same communication link between an energy management system and a charging station. Similarly, ISO 15118 or IEEE 2030.5 can be implemented for communication between a BEV and a charging station. While there is an argument for the possibility of adopting different protocols in different regions, global manufacturers can save costs by implementing the same protocol in their products worldwide. Similarly, wasted investment and potentially stranded assets can be minimised while rolling out charging infrastructure if there is clarity on which protocol to adopt. As an example of early roll out of charging infrastructure, Norway provided funding to roll out public Type 1 chargers before the European Commission (EC) introduced legislation to ensure that charging stations are equipped with at least Type 2 plug for AC charging.

Impact of ultra-high power charging for Heavy-Duty Vehicles

The deterministic nature of charging of commercial heavy-duty fleets offers opportunities for application of smart charging strategies. In the recent years, buses have been the most prominent heavy-duty vehicle category with fast expansion of electrification but technological developments in battery and vehicle technology for trucks indicate an electrification trend for this vehicle category as well. Heavy-duty vehicles have larger batteries than passenger cars and therefore require higher charging power in order to reduce charging time. Charging 500 kWh into the battery of an electric truck in about 30 minutes would require, for example, a charging power of 1 MW. The fastest chargers currently available in the market operate at lower power levels. DC charging is nevertheless particularly popular for HDVs and has been facilitated by the introduction of liquid cooling for the cables (when plug-in charging is used) [19]. Alternative methods for ultra-high power charging include the use of Automated Connection Devices (ACDs), such as pantographs.

Organizations such as CharIn and CHAdeMO are supporting the further development of standard that can support ultra-high power charging for HDVs with DC plug-in charging of at least 1 MW being envisioned. CharIn for example, has established a task force for High Power Charging for Commercial Vehicles (HPCCV). The task force is aiming to define a an ultra-high power charging standard, considering charging power of 1 MW and beyond (up to 4.5 MW: 1 500 V and 3,000 A) with a time horizon for launching in late 2023/early 2024. The IEC has already started processes to update the CCS-related international standards (IEC 61851, ISO 15118, ISO 17409, ISO 21498-1) in order to include the high-power charging definitions. The HPCCV requirements include bidirectional charging [20].

The ChaoJi protocol of the CHAdeMO association technically allows charging above 1 MW, although not currently within the official scope of the protocol development. A harmonization of the CCS and ChaoJi for HDV ultra-high power charging could be probable, "[…] *although not likely […]"*, in the future [19]. The inclusion of ACDs to ISO 15118-20 would nevertheless allow automated bidirectional charging of electric trucks and buses using ACDs. The ongoing work from CENELEC and other stakeholders on updating this standard will give the opportunity of harmonization of infrastructure needed for electrification of larger commercial fleets of HDVs as well as bus public transport. This can be seen both as an opportunity and risk; opportunity in terms of the large flexibility potential introduced into the Member States' grids, but also a risk since the level of preparedness for increased power grid capacity can be low in some cases. The changes enforced by the future expansion of ultra-high power charging could be, for example, associated with the following impacts:

- Locating ultra-high power charging infrastructure should be made with regards to the available capacity of electricity grids, hence increasing the planning complexity for establishing such infrastructure. In situations where ultra-high charging clusters for HDVs are developed (e.g. along highways), costly investments for upgrading the local grid infrastructure or introducing energy storage solutions may be needed. High-level planning is required.
- From a technical perspective, the vehicles and batteries should be prepared to handle such high charging rates, i.e. by introducing more advanced thermal management techniques as well as strategies for mitigating battery degradation, especially if the batteries are used in bidirectional services.
- From a market perspective, demand charges for ultra-high power charging could be a concern from an economic feasibility perspective. Smart charging can reduce the costs associated with high power and ultra-high power charging. Site- and feeder-level controls could reduce energy costs and increase resiliency of energy systems [21]. Battery swapping and buffer storage at charging stations are among the possible solutions that could reduce demand charges and the stress on local grids [22].

The potential of smart charging in combination with ultra-high power charging for HDVs is highly dependent on the use case; aggregating the power demand at specific times when the overall power demand is lower, such as with the case of overnight charging, would be beneficial in terms of system flexibility and could be possible to apply for private charging of commercial fleets, e.g. for bus or truck depots. The potential of public smart ultra-high power charging, e.g. along highways, could be lower but when public high power charging is complemented with normal power smart charging of other EV fleet segments peak demand stress to the electricity grid can be avoided. Higher voltage architectures and improved safety designs, and strategies for implementing automation and thermal management are necessary for implementing ultra-high power charging of HDVs [21]. High voltage architectures and increased needs for safety measures and automation are among the subjects addressed by the IEC/T 69. Automated EV charging is also a priority area of the ISO/TC 22/SC 37 roadmap [19].

The industry has to a large extent acknowledged that common standards, which would enable unidirectional and bidirectional smart charging, is the way forward. In the survey, 79% of the respondents considered the lack of standard interoperability to be an important technical barrier, out which 50% perceived this as “very important”. For respondents representing the academia, civil society, automotive industry, network operators, suppliers/aggregators/EMSP, the energy industry and other industry and user associations, the lack of interoperability was one the barriers of main concern. Lack of communication standards providing real-time charging information is also an important barrier according to the respondents, with 73% perceiving this to be “somewhat more important” (33%) or “very important” (40%). For the network operators and energy industry, this was also one of the barriers of main concern.

Suggested measures for promoting common standards and interoperability

- Promote the development of industry-supported open standards and protocols in the bidirectional charging domain.
- EU to request implementation targets for scalable technical framework conditions for communication, but also for security, taxation and billing standards.
- EU to support the launch of innovative pilot lines of bidirectional charging equipment in order to consolidate technical standards (notably ISO/IEC 15118-20).
- Accelerate through mandates the development processes for standards by international and European standardization bodies.
- Support, adopt and coordinate the advances stemming from the development of open standards and protocols, such as OCPP and OCPI 2.2 which foster quicker innovation and build the ground for the convergence of EU and international standards for the EV ecosystem.
- Standardize electric codes at both a national and EU level.

3.1.3. Lack of smart and bidirectional charging infrastructure deployment

The majority of the chargers being deployed today do not allow bidirectional smart charging due to the lack of standards and the associated additional equipment costs, which consequently precludes the possibility of utilizing EV batteries for grid stabilization. Today, it is still quite complicated to install a bidirectional smart charger, as the technology is more complex than for a common charger but also due to the lack of knowledge of stakeholders in the EV ecosystem. The rollout of infrastructure needs to be aligned with future requirements and take into account the automotive industry’s plans for EV model roll-out [11]. It is also important that the deployed chargers are bidirectional smart charging capable [23]. The gap between the planned rollout of infrastructure and future user needs is also highlighted in literature and it is concluded that more data is required to analyse the long-term cost-benefit ratio related to an infrastructure expansion [11].

In the survey, the lack of deployment of private smart recharging infrastructure was a barrier that concerned many of the respondents, where 74% considered this to be “somewhat more important” (28%) or “very important” (46%). For respondents representing the civil society, standard developers and energy industry, this was one of the barriers of main concern.

Compared to private smart charging infrastructure, respondents were overall less concerned about the lack of deployment of public smart charging infrastructure. However, the majority (50% in total) still perceived this as “somewhat more important” (16%) or “very important” (34%), as opposed to a total of 36% whom considered this to be “somewhat less important” (22%) or “not important” (14%). For civil society and network operators, this was one of the barriers of main concern. Some survey respondents also highlighted another related barrier of concern, namely that the currently available bidirectional smart charging points are DC only.

Bidirectional charging integration requires both technology improvements and additional costs for communication, control and coordination systems as well as electronic components [24]. The additional costs needed for electronic and power system components are connected both to the hardware and the software infrastructure. The costs also differ between AC and DC bidirectional smart charging, where the former requires a lower additional cost for the charge point compared to the latter, due to the addition of the inverter. In addition, the complexity of the required bidirectional battery chargers is also an issue that is raised in literature [25].

Suggested measures for addressing lack of smart charging infrastructure deployment

- Gradually deploy smart meters and charging infrastructure with digital metering capabilities in public and private locations in a centrally coordinated manner.
- Implement mandatory national deployment targets for smart charging at the EU level. In particular, require smart charging to be enabled in both new and renovated residential and commercial buildings.
- Enable deployment of charging infrastructure in multi-owner spaces and facilitate bidirectional charging as a service provider.
- Support pilots where unidirectional and bidirectional smart services and necessary market adjustments are tested at EU-level.

3.1.4. Complexity of managing charging as a flexibility source for DSOs

A deeper understanding of charging patterns is required to enable the use of EVs as a flexibility source and to stimulate such flexibility by developing more realistic price and incentive schemes [26]. Grid simulations are currently often based on assumptions regarding charging behaviour as well as power output of chargers and the actual potential to shift the charging sessions in time, leading to misleading results [27] [28].

Of the survey respondents, 56% perceived the complexity and high costs for DSOs to use smart and bidirectional charging as a grid flexibility to be “somewhat more important” (37%) or “very important” (19%). However, none of the respondents representing the stakeholder group “network operators” highlighted this as “very important”, pointing at the concern for this barrier mainly being held within other stakeholder groups. In this context, it is worth noting that the Clean Energy Package does not put forward the DSO as the stakeholder to directly manage flexible assets, hence also not chargers but provides for DSO to procure flexibility services in accordance with transparent, non-discriminatory and market-based procedure. The survey respondents and interviewees agree that unidirectional smart charging is more easily managed than bidirectional smart charging. An introduction of bidirectional smart charging as a flexibility service can provide additional stability to the power system, if integrated properly. In contrast to other technical barriers, the complexity of managing charging as a flexibility service is highly dependent on country-specific conditions, such as electricity and heating demand curves.

There is some scepticism regarding the purpose and function of bidirectional smart charging in the energy system. In countries such as Germany, for example, bidirectional smart charging as a flexibility option for the grid is not considered to be particularly relevant, while bidirectional smart charging for self-consumption is raised as a potentially valuable option [29]. In other countries, there may be a need for a societal shift in terms of mobility and energy perception in order for bidirectional smart charging to be a preferable solution for flexibility issues [23]. A previous study, in which experts in the Nordic region were interviewed, concluded that about 30% of the 257 interviewees perceived bidirectional smart charging as an unnecessary storage solution for the Nordic energy system [30]. As mentioned earlier, technical limitations of the EV fleet can also vary across countries depending on the share of Plug-in Hybrid Electrical Vehicles (PHEVs) and BEVs and this could in turn influence the potential of using the EVs as a versatile flexibility option.

Suggested measures for managing charging as a flexibility source

- Support research with real-time data for bidirectional smart charging systems with integrated renewable energy sources.
- Allow operators and aggregators to access in-vehicle-data free of charge by introducing necessary legislative measures.
- Support centralized control of EV charging loads (by aggregators) and decentralized demand side management mechanisms, where consumers can coordinate their charging based on the electricity prices or price signals reflecting the local available capacity.
- Analyse the potential for flexibility from unidirectional and bidirectional smart charging per Member State in order to design incentives and demonstration projects for roll-out.

3.1.5. Battery degradation

Unidirectional smart charging, in comparison to normal uncontrolled slow charging, tends to enhance the battery lifetime of EV Li-ion batteries as it mitigates the degradation due to optimization of e.g. the SoC and Depth-of-Discharge (DoD) [31]. As a consequence, unidirectional smart charging can provide benefits to both network operators as well as to EV users, where the latter may potentially receive advantages both in terms of lower battery degradation and economic benefits, if the charging is performed at a time of the day with cheaper electricity. However, there are indications that bidirectional smart charging may potentially cause higher battery degradation than unidirectional smart charging [4] [12] because of the frequent charging and discharging, in particular when deeper cycles are applied [8] [16]. Yet, the literature shows no consensus on the issue of battery degradation. It is a question of charging strategy; simplistic algorithms for bidirectional smart charging can be damaging to the battery and reduce its lifetime, yet bidirectional smart charging control algorithms can instead enhance its lifetime by only allowing access to the stored energy if it does not result in any negative impacts on the battery endurance [33].

A number of studies compare the grid benefits and ancillary services to the cost of battery degradation, where some point towards the degradation being a significant barrier and some are showing the opposite, that the battery degradation is in fact insignificant [34]. In order for a degradation of the battery to be acceptable, the economic benefits generated by the energy services provided must exceed the costs of degradation for the EV end-user [31]. This was also highlighted by both survey respondents as well as interviews. There are indications that a common shortcoming of several older studies has been that the Li-ion battery degradation has not been properly accounted for in the development of business models, where costs arising from potential battery degradation have not been considered [33].

In the survey, there was a discrepancy between the respondents' perception of battery degradation as a barrier to smart charging, where a slightly higher share considered this to be of less or insignificant importance. The stakeholder group mostly concerned by the risk of accelerated battery degradation was the automotive industry, because they are responsible for the battery guarantees. Also, one representative within each of the stakeholder groups of charge point manufacturers, operators, standard developers and civil society also highlighted this as "very important".

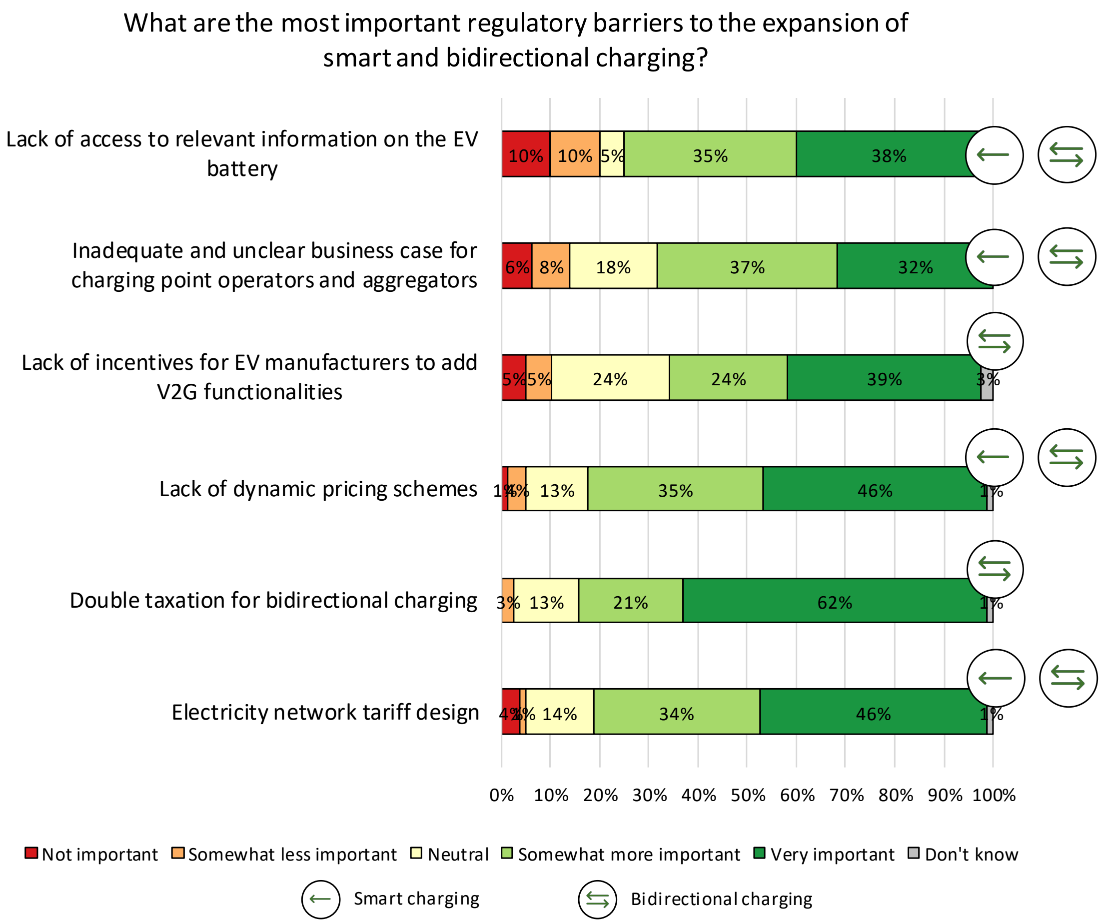
Suggested measures for addressing battery degradation

- Support technological improvements for advanced battery chemistry in order for EVs to handle bidirectional smart charging without significant degradation.
- Ensure that the requirements for service provisions, such as response time and duration, are not exceeding the necessary level to provide service to the grid [35].
- Quantify the economic impacts of battery degradation for the EVs in order to sufficiently compensate participation in bidirectional smart charging schemes.
- Support and encourage collection of data on battery degradation.
- Coordinate EV manufacturer dialog and knowledge exchange on battery degradation issues.

3.2. Regulatory barriers

In addition to the above defined technical barriers, large scale uptake of unidirectional and bidirectional smart charging faces several regulatory barriers. Some of these barriers are highly connected to technical barriers, while others are related to socio-economic effects of further EV uptake. Figure 6 presents the survey respondents perception of the importance of the main regulatory barriers to the expansion of unidirectional and bidirectional smart charging as identified by the literature review. In the figure, a distinction is made between the barriers' impact on unidirectional and bidirectional smart charging, respectively.

The survey results indicate double taxation in the case of bidirectional smart charging, lack of dynamic pricing schemes and electricity network tariff design as the most important barriers (based on the percentage of respondents indicating "very important"). They are followed by lack of incentives for EV manufacturers to add bidirectional smart charging capabilities, inadequate or unclear business case for market participants and lack of access to relevant information on the EV battery. The latter has the highest percentage of respondents indicating "somewhat less important" or "not important" which leads to the conclusion this is perceived as the least significant regulatory barrier. Overall, all listed barriers are perceived to be important with at least 63% of respondents indicating the barriers are somewhat more important or very important.



(Number of respondents, from top to bottom: 80, 76, 79, 79, 79 and 80)

Figure 6: Most important regulatory barriers to the expansion of smart charging. The relevance of each barrier for smart and/or bidirectional charging is also distinguished.

3.2.1. Double taxation for bidirectional smart charging

Double taxation is a problem for bidirectional smart charging and stationary electricity storage systems [36]. The Energy Taxation Directive provides that electricity is taxed when released for consumption but does not define whether electricity is released for consumption when supplied to storage facilities. This opens the possibility of double taxation of electricity that is stored and re-sold. [37]. The EU-financed Parker project also showed that double taxation is unfavourable for the uptake of bidirectional smart charging [9].

Double taxation in the case of bidirectional smart charging is recognized as the most important regulatory barrier by the survey respondents with 83% rating it as “important”. Moreover, 62% of the respondents consider the barrier to be “very important”. No respondents from charge point manufacturer, automotive industry and academia have categorized this barrier as “less important” or “not important”. Only 4% of the respondents say the barrier is somewhat “less important”, which is mostly due to the Suppliers/Aggregators/EMSP stakeholder group.

Article 15 of the Electricity Market Directive (EMD) has identified the need to assure no double charges for the electricity of active consumers that own an energy storage facility. As this has not yet been implemented in most EU countries [38], it does not yet apply to bidirectional smart charging for EVs. While the EMD has defined the difference for energy storage facilities, the Energy Tax Directive does not differentiate between electricity supplied to the end-consumer for immediate consumption or for storing the electricity in the energy storage device [36].

In addition, an analysis of the Nordic countries' electricity tariffs showed that taxes and network costs can take up to 87% of the electricity price (Denmark). In such cases, variations in the commodity price does not significantly impact the total electricity tariff to create price signals for the consumer [39].

Suggested measures for double taxation

- Assure implementation of Article 15 of the EMD is extended to include bidirectional smart charging as a flexibility option for active consumer.
- Introduce changes to Energy Tax Directive to avoid double taxation for bidirectional smart charging.

3.2.2. Lack of dynamic electricity pricing

Lack of dynamic pricing schemes has been identified as the second most important regulatory barrier. This is shown by the survey results, where 81% of respondents stipulate this barrier as "important" (46% consider it "very important"). Standardization bodies and the automotive industry have identified this as the most important regulatory barrier.

Dynamic pricing schemes include both time-of-use price, as well as more advanced wholesale or spot prices. An obligation to allow dynamic pricing for consumers is defined in Article 11 of the EMD. This has been implemented, and was even already possible, in some EU member states but not all [38]. As discussed by survey respondents, without dynamic pricing, end users are not given price signals or an incentive to change their behaviour and use unidirectional or bidirectional smart charging. Dynamic pricing requires smart metering, which shows a slow roll-out in many member states [40]. Research reveals that implementation of intelligent technologies, i.e. real-time tariffs with smart metering, is less likely to encourage unidirectional or bidirectional smart charging if they are not coupled with dynamic pricing schemes [11]. Therefore, combination of dynamic pricing and smart metering is optimal to encourage unidirectional and bidirectional smart charging.

However, dynamic pricing should be followed with consumer education and awareness raising about the wider potential of unidirectional and bidirectional smart charging. The Parker project shows how it can be used for frequency regulation [9] while pilots in Amsterdam show how changes in the current during charging can help stabilize the grid [12].

Suggested measures for addressing dynamic pricing barriers

- Map the current dynamic pricing policy throughout the MSs.
- Assure dynamic pricing is widely implemented across MSs as it allows implicit demand side management mechanisms. [6] [24].
- Follow implementation of dynamic pricing with consumer education and awareness raising on the potential with unidirectional and bidirectional smart charging.

3.2.3. Electricity network tariff

Article 15 of the EMD 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. In addition, Article 18 of the Electricity Market

Regulation 2019/943 defines that member state regulatory authorities shall consider time-differentiated transmission and distribution network tariffs and where appropriate, time-differentiated network tariffs to reflect the use of the network, in a transparent, cost efficient and foreseeable way for the final customer.

Based on analysis of ten chosen member states, SmartEn report concludes that only two (France and Spain) have assured that double network charges are not possible for active consumers owning energy storage facilities, according to Article 15 EMD and two (France and Norway) have time-differentiated network tariffs that are cost-reflective according to Article 18 EMR [38]. On one hand, double network charges are a barrier for bidirectional smart charging only. On the other hand, lack of time-differentiated and cost-reflective network tariffs is a barrier for both unidirectional and bidirectional smart charging as it decreases incentives and consequently possibilities for viable business case development for this technology and other flexibility services.

Electricity network tariff design has been identified as the third most important barrier by survey respondents. All respondents belonging to the network operators' group, 91% of automotive industry and more than 80% of charge point operators and suppliers, aggregators and EMSP respondents find this barrier to be "important" or "very important". This is expected as these stakeholder groups are directly affected by the lack of optimal network tariff design. Interestingly, 29% of the respondents belonging to standardization bodies or standard developers indicate this barrier as "not important", while this opinion is shared by only 4% of all the survey respondents. In addition to double taxation and dynamic pricing, network tariff design should encourage use of flexibility services and technology.

Suggested measures for addressing network tariff design barriers

- Assure timely and clear implementation of Art 15 of the EMD at Member State level.
- Issue recommendation for requirements for setting up uniform distribution level flexibility markets based on EMD and Electricity Regulation 2019/943 that would help align and encourage implementation of time-differentiated network tariffs in different MSs.

3.2.4. Lack of access to relevant battery data

The ownership of the charging and EV data and access rights currently remain unclear [2] [10]. Currently, data are mostly proprietary to car or charging points manufacturers, which means that management possibilities by third-party companies are limited and the users have limited control of their data access and charging option choices [3] [6]. Allowing such practices increase the risk of EV car manufacturers becoming monopoly actors (controlling markets for EVs, charging points, aggregator and supply) on the energy and transport markets, creating the opposite effect to the empowerment of the end-consumers concept intended with the Clean Energy Package. Barrier of lack of access to data extends beyond the EV battery data to charging data and other data needed for battery and charging management.

Lack of access to EV battery data, relevant for both unidirectional and bidirectional smart charging, is seen as an important barrier by 73% of the respondents (with 38% of the respondents indicating this barrier as "very important"). Moreover, the barrier is defined as "important" by 80% of the network operators, charge point operators and suppliers/aggregators/EMSPs, who often depend on using these data for smart charging schemes. At the same time, 20% of the respondents perceive this barrier to be less relevant (10% of the survey respondents indicate it as "somewhat less important" and 10% as "not important"). Of survey respondents within the automotive industry and EV manufacturers 27% rate this barrier as "not important" (in comparison to 10% of overall survey respondents).

Suggested measures for addressing access to data

- Make access and sharing rights of EV users to their EV battery data and charging data mandatory.

3.2.5. Inadequate and unclear business case for charge point operators and aggregators

The EMD has defined the changes in the energy markets, including the role of aggregators, rights of active consumers and flexibility market. With the EMD transposition ongoing, even if member states have defined and allowed aggregation for demand response, there is no clear method adopted by the regulators for compensation for the offered services to the distribution system operators, in accordance with Article 17 of EMD [38]. Incomplete or vague regulations and immature flexibility markets at the distribution level are barriers to unidirectional and bidirectional smart charging [30].

The immaturity of distribution level flexibility markets is also reflected through lack of transparency and market priority rules among market participants. The lack of transparency of capacity management and availability between distribution network operators and aggregators has been defined as a barrier to optimal system functioning [9]. In addition, lack of clarity on priority between energy market and system participants (e.g. grid management by DSO and aggregator priorities based on wholesale market) is a barrier to implementation of unidirectional and bidirectional smart charging [23]. When paired with electricity tariff design barriers and difficulties in accessing necessary EV charging data [11], the independent aggregators' and charge point operators' business cases become in principle non-existent.

Inadequate and unclear business case for charge point operators and aggregators, due to above mentioned issues, is a barrier for both unidirectional and bidirectional smart charging. Of the respondents to the survey, 69% indicated this barrier as important (37% as "somewhat more important" and 32% as "very important"). In addition, 85% of CPOs find this barrier to be important (14% see it as "very important" and 71% as "important"). Stakeholder groups that perceived this barrier as less significant are the Suppliers/Aggregators/EMSPs as well as network operators. For these stakeholder groups, 19% and 14% respectively assessed an unclear business case not to be an important barrier. This might be connected to increased awareness of the benefits by some of these stakeholders.

Suggested measures for addressing electricity market barriers and business case for aggregators

- Mandate an expert team from MSs to work on clarifying the requirements needed for developing uniform distribution level flexibility markets across EU, specifically regarding demand response services based on the EMD.
- Provide long-term price signals in order to reveal a suitable revenue stream, thus minimizing investors' decisions.
- Assure transparency of information and clear priorities between different system participants: DSOs, suppliers, aggregators and charge point operators.
- Standardize access to TSO markets in terms of connection and prequalification.

3.2.6. Lack of incentives for EV manufacturers

Lack of incentives for EV manufacturers is the barrier to bidirectional smart charging. Improvements needed in hardware and software of EVs in order to be capable of bidirectional smart charging require additional costs from the EV manufacturer. Aside from additional implementation costs, EV manufactures are concerned about the influence of advanced charging schemes on the battery performance and lifetime [34]. Enabling bidirectional smart charging allows aggregators, EMSPs, CPOs and users to benefit from using the EV to provide energy services. Therefore, the benefits of these services do not directly affect the EV manufacturers, although they are making the investments. The combination of additional investments and lack of clear benefits results in little incentives for EV manufacturers to unlock external use of bidirectional smart charging capabilities. Some EV manufacturers have taken a role of EMSPs, CPOs or aggregators offering users unidirectional and bidirectional smart charging capabilities without allowing users right to share EV battery data and other stakeholders third-party access to the vehicle. The vertical integration of both mobility and energy services, and infrastructure is understandable from the point of view of the EV manufacturers but poses a major barrier to an open European energy market where cross-brand aggregation should be authorized.

The results of the survey show that 63% of respondents rate this barrier as "important (24% of respondents as "somewhat more important" and 39% as "very important"). On the other hand, only 10% assess this barrier to of lesser importance (5% indicating "somewhat less important" and 5% as "not important"). Stakeholder analysis reveals that in comparison to overall results, 20% of automotive industry and vehicle manufacturers respondents consider this barrier to be not important and 10% indicate it as somewhat less important. At the same time, none of the respondents belonging to the stakeholder group of network operators indicate this barrier to be "somewhat less important" or "not important".

Suggested measures for addressing lack of incentives for EV manufacturers

- Incentivize consumers to purchase unidirectional or bidirectional smart charging ready EV on member state level (e.g. lower taxes).
- Mandate unidirectional or bidirectional smart charging capability to EV manufacturers.

3.3. Other barriers

Non-technical and non-regulatory barriers were also included in the survey (see Figure 7). Social barriers and deficiencies of smart grid systems are nevertheless considered crucial for the uptake of unidirectional and bidirectional smart charging [42]. The survey respondents rate lack of stakeholder awareness regarding the purpose and functionality of smart and bidirectional charging as most important (important by 73% of survey respondents), followed by hesitation of EV owners to grant external control of their battery SoC level (70%), complexity of communication surrounding smart charging and bidirectional charging (65%), lack of deployment of smart electric meters (52%), and data privacy concerns by EV owners (38%).

Stakeholder groups differ on how they rated importance of other barriers. Lack of stakeholder awareness is considered as the most important barrier for the suppliers/aggregators/EMSPs stakeholder group, while it is the second most important for respondents from academia (100% consider this barrier to be important), charging point manufacturers (88%) and charge point operators (71%). These stakeholder groups have direct contact with the consumer and therefore may have more insight regarding their lack of awareness.

Hesitation of users to grant external control of the battery state of charge level is perceived as a "very important" barrier by the largest share of survey respondents (37%). Automotive industry (90%), network operators (86%), standardization bodies and developers (85%) and charge point operators (72%) find this barrier to be the most important "other" barrier. This barrier is directly connected to the awareness raising and clear communication of information with users/EV drivers.

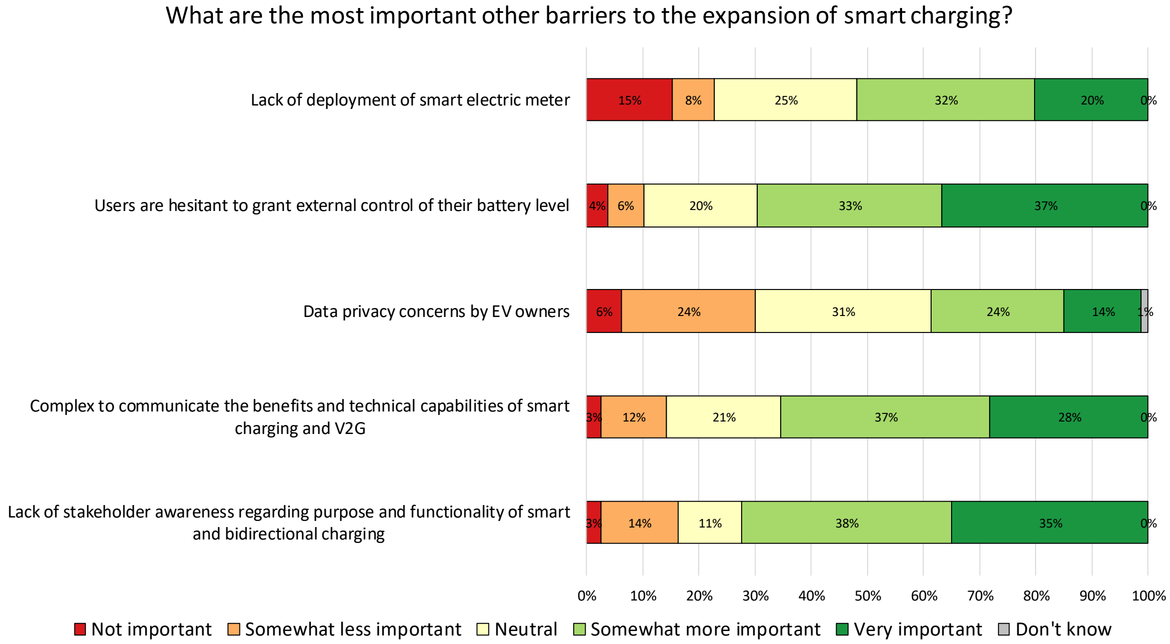


Figure 7: Most important other barriers to the expansion of smart charging

Overall, the complexity of communication regarding benefits and technical capabilities of unidirectional and bidirectional smart charging towards (potential) EV drivers is perceived as an important barrier with 37% of respondents indicating it as "somewhat important" and 28% as "very important". Specifically, this is the most important barrier for academia (100% with 80% as very important) and the second most important by standard bodies and developers (84%), network operators (72%) and suppliers/aggregators/EMSPs (56%). The interviews confirm the importance of presenting information regarding smart and bidirectional charging capabilities in a clear and comprehensible way.

The lack of deployment of "smart" electric meters is considered not important, somewhat less important or neutral by nearly half (48%) of stakeholders. Specifically, respondents from standardization bodies and developers (76%), charge point operators (71%), academia (60%), and suppliers/aggregators/EMSP (55%) rate this barrier as neutral, somewhat less important or not important. Additionally, further to interviews held with stakeholders, the lack of harmonisation of data from smart meters has been indicated as a barrier, leading to a sub-optimal utilisation of smart grid potential [43].

When it comes to data privacy concerns by EV owners, 30% of the respondents indicate this barrier as "somewhat less important" or "not important". Respondents from automotive industry (70%) and civil sector and EV users (80%) found this barrier to be important. All other stakeholder groups have only 14% or less respondents rating data privacy as a "very important" barrier. Respondents from charge point operators (57%) and supplier/aggregator/EMSPs (56%) stakeholder groups have the most neutral ratings for this barrier. This indicates that there is a need for communication between different stakeholder groups to deal with the data privacy, which seems to be an important barrier for EV users.

User acceptance of smart and bidirectional EV charging varies between countries and regions [8] [28]. While user awareness and acceptance can be considered to be a social barrier, well-defined regulatory frameworks, policy support [44], well-communicated pilot initiatives [44] and clear understanding of costs and benefits [18] [26] [28] would help mitigate this barrier. The main benefits from switching to unidirectional or bidirectional smart charging for users are the cost reductions, while from the grid perspective benefits include integration of renewable energy and stability of the electricity grid [34].

Suggested measures for addressing other barriers:

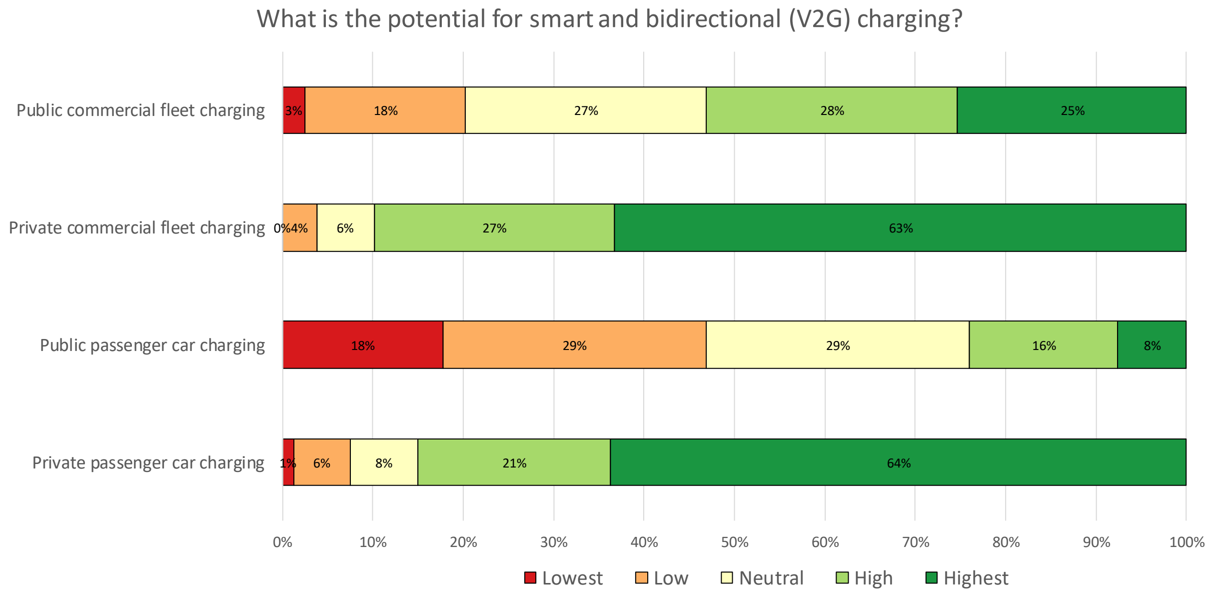
- Increase awareness of stakeholder with clear and simple communication of mechanisms of unidirectional and bidirectional smart charging on EU and member state level.
- Harmonize data accessible from smart electric meters within the EU.
- Increase discussion on data privacy among all involved stakeholders.

3.4. Differences between barriers to private and public charging

A part of the survey focused on the evaluation of the potential of various use cases. The following four use cases were evaluated: private and public passenger car charging, as well as public and private commercial fleet charging. The survey responses are visualized in Figure 8. The results show that the respondents in general identify the potential for uptake with private charging (either for passenger cars (84%) or commercial fleets (90%)) as higher compared to other use cases. Public passenger car charging is rated as the least promising case for smart and bidirectional charging (24% rated as high or highest potential). The respondents are rather split for the case of public commercial fleet charging. In the survey, the respondents were additionally asked to reflect on the differences of barriers between public and private charging. The main themes gathered from the 48 responses to this question are the following:

- Public charging not as relevant for bidirectional smart charging;
- Long connection duration needed for bidirectional smart charging;
- Clear user profitability picture when charging privately;
- Interoperability with other flexible assets when privately smart charging, e.g. at building level;
- Costs for home chargers need to be low, public chargers may use more expensive DC technology;
- Challenges exist related to aggregation and coordination with home charging;
- Public charging more cost-sensitive, private charging implies taxation issues;
- Easier introduction to unidirectional and bidirectional smart charging for private parking fleets;
- New infrastructure without bidirectional smart charging functionalities is being deployed;
- Less technical and regulatory barriers for private charging;
- Public charging more complicated when it comes to identification, authentication and billing;
- Unclear liability for public charging.

A preference for B2B options compared to B2C can be gathered from the interviews and survey, as it can be less complicated for OEMs (charge point manufacturers and EV manufacturers) and CPOs to work with aggregators or EMSPs than directly with users. The three most common themes (“Public charging not as relevant for bidirectional smart charging”, “Long connection duration needed for bidirectional smart charging” and “Clear user profitability picture when charging privately”) signify the advantages of deploying unidirectional and bidirectional smart charging for private infrastructure instead of the public one. However, private unidirectional and bidirectional smart charging has to be well-integrated ensuring interoperability at the household and building level for private unidirectional and bidirectional smart charging to work, as the fourth theme of the list shows (“Interoperability with other flexible assets when privately charging, e.g. at building level”). Annex 6.3 includes selected survey responses that are representative of the themes discussed above along with recommended actions for alleviating the barriers discussed.



(Number of respondents, from top to bottom: 79, 79, 79,80)

Figure 8: Perceived potential with various charging use cases from lowest to highest

At this point, it is necessary to return to the definition of public charging in order to understand the use cases for it; public charging refers to charging at publicly accessible charging points. As a result, the rest of use cases are private charging, including charging at home (only building tenants have access), charging at the workplace (only employees have access), charging at a bus depot etc. Public cases therefore include high power charging (e.g. along highways), curbside charging for EV users that do not have access to private charging, charging at shopping malls and parking spaces etc.

The definitions above gives insight on why the potential of public vs private use cases was perceived as in Figure 8. The survey nevertheless indicates that unidirectional and especially bidirectional smart charging require long connection duration, i.e. long sessions which provide the opportunity to steer the charging. The public charging use cases mentioned above imply in their majority short and usually time-restricted connections. As a result, the potential for these use cases to provide increased flexibility to the grid via unidirectional and bidirectional smart charging is limited. The above are a generalisation though, and the use cases differ a lot among Member States. For example, in cities where private parking space are limited (e.g. Amsterdam among other cities), curbside charging sessions can last longer and therefore provide the opportunity to apply smart charging schemes. It is thus recommended that attractiveness of a use case for unidirectional and bidirectional smart charging is assessed based on the following criteria, and not based on whether public or private charging is considered:

- The typical total connection time (the longer, the better)

- The typical charging duration (the shorter, the better)
- The aggregated volume of charging power that can be steered (the more vehicles at the same place, the larger the flexible power volume, and the higher the attractiveness of the use case)

It should be noted that public charging might offer limited potential for unidirectional and bidirectional smart charging compared to private, but potential still exist and could be increased if combined with the necessary on-site energy storage. The profitability of such a use case is very much dependent on local grid tariffs and popularity of the charger.

3.5. What are the main barriers to unidirectional and bidirectional smart charging and how to address them?

The literature review, survey responses, and interviews with key actors have shown that barriers to unidirectional smart charging are in general less complicated and can be solved through provision of, e.g. incentives to the users to shift their charging and further integration of aggregators and grid planning tools in the EV ecosystem. However, bidirectional smart charging seems to have more complicated remaining barriers that should be addressed in order to ensure further expansion.

When it comes to technical barriers, lack of deployment of smart private recharging infrastructure, technical limitations of available EV models with regards to bidirectional smart charging, lack of standard interoperability and lack of communication standards are the barriers perceived to be of highest importance. Battery degradation is broadly discussed in literature and among stakeholders but is not perceived of equal importance. This is understandable taking into account mixed literature stance on battery degradation, with newer studies showing battery degradation is more complex and cannot be directly and solely related to unidirectional or bidirectional smart charging.

At the side of regulatory barriers, double taxation in the case of bidirectional smart charging, lack of dynamic pricing schemes and electricity network tariff design are the most important barriers. These barriers are related to multiple EU directives, including the Electricity Market Directive, Electricity Regulation, Energy Taxation Directive, Energy Performance in Buildings Directive and Clean Vehicles Directive where policy measures should be taken to improve these directives but also to assure their implementation in practice once transposed on member state level. The fourth most important regulatory barrier is lack of access to EV battery and charging data, where the main recommendation from survey respondents and literature has been to allow the data access and right to share to EV users.

Aside from technical and regulatory barriers, other social and infrastructure readiness barriers have been discussed in this report. Of those, awareness raising of the stakeholders, complexity of information communicated with the stakeholders and EV user hesitance to grant access to the battery are found to be most important for all stakeholders. While the first two barriers can be addressed with clear and simple communication and tailored awareness raising campaigns on EU and member state levels, the user hesitance is also mitigated with these measures.

When it comes to optimal use case for uptake of unidirectional and bidirectional smart charging, private charging (either of passenger cars or commercial fleets) has been identified to have a larger potential compared to public charging. Regardless of the use case, longer time periods are needed for steering the charging as a source of flexibility for the grid. Therefore, charging duration is the decisive factor to weigh in when assessing a use case potential for expansion. When discussing barriers to unidirectional and bidirectional smart charging it is important to keep in mind that the following differences between member states create a more or less supportive environment for further uptake:

- level of transposition and on the ground implementation of the EMD;

- electricity taxation policies based on the Energy Tax Directive;
- national political support for unidirectional and bidirectional smart charging (including incentives for infrastructure) affecting user acceptance and stakeholder awareness;
- users' mobility preference variations;
- vehicle taxation and climate policy;
- integration of national policies for transport (charging infrastructure), energy (grid state, digital meters, flexibility), climate (GHG) and buildings (building codes, planning, procedures);
- collaboration and coordination between local and national levels.

Implementation of unidirectional and bidirectional smart charging can initially be demand driven. However, the uptake of EVs increases the need for a systematic approach to e-mobility planning and integration with energy and urban planning [6] [29]. The increased electricity demand and load changes caused by increasing number of EVs impacts the power systems at local, national and European level. These effects need to be included in long-term strategic planning [2] [6] [24] [29] [38] as follows:

- By promoting systematic solutions for integrating unidirectional and bidirectional smart charging with RES and assuring value stacking through synergies (such as photovoltaic generation and EV charging).
- By integrated planning for transport, energy, and buildings at different levels – the local, national and EU. Unidirectional and bidirectional smart charging should be part of overall energy transition, taking into account its ability to offer electricity storage and flexibility and not only provide environmentally preferable transport business case.
- By assuring adequate and timely planning for the necessary recharging infrastructure – actions to avoid lock-ins for the development of unidirectional and bidirectional smart charging networks should be taken already now, since a lot of this infrastructure is planned to be established in the near future.

The analysis of barriers to unidirectional and bidirectional smart charging in this chapter shows that barriers still exist at various levels, from behind-the-meter to local and system levels (see Figure 9). However, depending on the use case, the level and importance of the barrier might change. For example, bidirectional smart chargers installed behind the meter may be limited, as regards the ability to feed electricity back to the grid, by the grid connection capacity. In this use case, the grid connection capacity could therefore be a barrier. Nevertheless, especially in presence of local congestion issues, sizeable bidirectional smart chargers' installations with adequate connection capacity could represent interesting solutions for balancing local demand peaks.

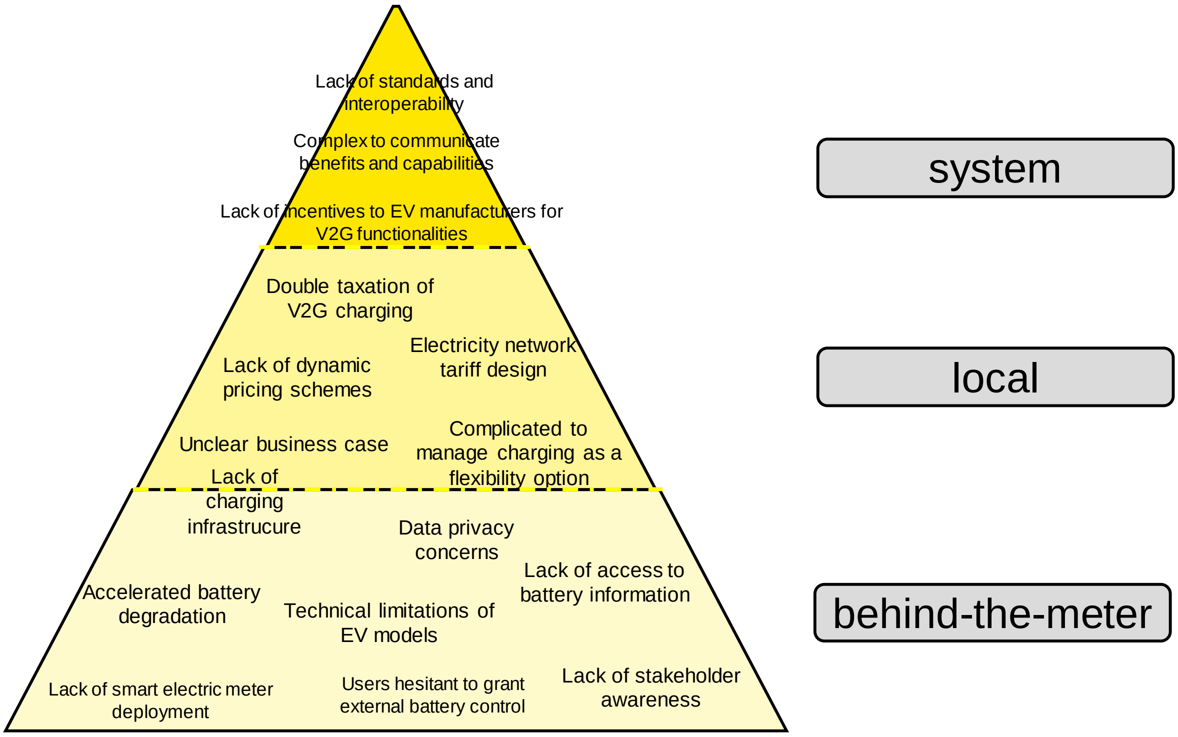


Figure 9: Illustration of technical, regulatory and other barriers at various levels; behind-the-meter, at the local, and at the system level.

4. Proposed legislative and non-legislative policy measures

Chapters 2 and 3 have provided an overview of the best practice examples and technical, regulatory and other barriers to development of unidirectional and bidirectional smart charging. This aim of this chapter is to propose legislative and non-legislative policy measures that can be taken to alleviate identified barriers and assure successful development of unidirectional and bidirectional smart charging in the competitive market.

To identify optimal policy measures, the following four step approach was used:

- Target vision for development of unidirectional and bidirectional smart charging outlined;
- List of policy measures based on best practices and identified barriers drafted;
- Workshop with stakeholders to discuss the proposed policy measures organized; and
- Detailed list of proposed legislative and non-legislative policy measures finalized.

To understand the overall policy aim, a possible vision for unidirectional and bidirectional smart charging is presented in 4.1. The vision identifies the current status and a strategy for further development of unidirectional and bidirectional smart charging for optimal integration with the grid. Based on this vision, draft goals and policy measures have been discussed with the stakeholders from various sectors. The workshops was organized with 50 participants active in the smart charging and electric mobility market, and representing charge point manufacturers, operators, distribution system operators, EV manufacturers, consumers, standard developers, consumers, and academia. The results of the workshop are presented in 4.2. The resulting list of proposed legislative and non-legislative policy measures is presented in 4.3, where they are grouped based on the specific objective they aims to achieve.

4.1. Vision for unidirectional and bidirectional smart charging

All charging infrastructure should be smart.

With increased shares of e-mobility, all charging should be smart in order to contribute to grid stability and quality of electricity supply. Smart charging includes everything from simple unidirectional chargers with capability of remote monitoring and management of charging time to bidirectional chargers with capability of remote monitoring and management of charging time, power and current. Different levels of smart charging have varying technical and regulatory complexity. The minimum requirement for smart charging needs to be defined.

Policies promoting smart charging should take into account both public and private charging infrastructure.

Currently there are nearly eight times more private chargers (1,5 million[3]) than public chargers (200 000[1]) installed in the EU. This is a worldwide trend that is expected to continue. Both public and private chargers are connected to the electricity grid and might affect its functioning. Even though, both public and private charging are important to assess, different policy objectives and measures will apply.

Smart charging should be coupled with renewable energy generation and other energy storage systems.

With electrification of mobility, mobility becomes an integrated part of energy system. Smart charging infrastructure helps electric mobility integrate better into the electricity system. In order for electric mobility to maximally contribute to a decarbonized and flexible energy system, the transport sector strategy and planning should aim for maximal use of renewable energy.

EV users should have full access, control and right to share their EV battery and charging data.

To assure development of smart charging in competitive markets, and if so allowed by EV owners, all interested parties should be able to gain access to battery and charging data. For competitiveness of different energy services, regulatory measures should address access to EV battery data (i.e. state of charge data), charging data (i.e. power, current), including any other data needed for management of charging and the battery (e.g. requirements set by the user, potential dynamic grid status data).

Smart charging markets should be transparent, clear and open to newcomers.

For a competitive and open market, smart charging market policy should support use of open and non-proprietary standards.

Flexibility markets should be clear and open to newcomers.

For competitive and open smart charging markets, policy should assure implementation of clear and simple electricity flexibility markets.

Smart charging should be simple and user-friendly.

The charging infrastructure should allow for user-friendly means to participate in smart charging across the EU, while ensuring that users' data are protected through adequate cybersecurity and data privacy control. For large scale use of smart charging of EVs, significant efforts need to be made to bring the concepts of smart charging, its use and benefits, closer to all involved stakeholders.

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[3] IEA EV Outlook 2020

Planning for charging points should be based on technical factors, mobility needs and geography.

Technical factors include the number and technical capacity of EVs on the road, existing charging infrastructure, smartness of existing electricity network, and availability and development of technical standards. Mobility needs depend on the socio-economic condition of a country, reflected in local and regional planning, dominance of private or public transport means, and mobility poverty. A further aspect is geography.

Planning for private and public charging infrastructure should be integrated on local, regional and national level and involve all needed stakeholders from the beginning, especially relevant DSOs.

4.2. Short- and long-term policy measures

While the survey presented in Chapter 3 mainly focused on unidirectional and bidirectional smart charging barriers, potential short and long-term policy measures were also discussed. The survey respondents were asked to propose three short and three long term (beyond 5 years' horizon) policy measures that address the identified barriers. The policy measures were then aggregated and organized depending on whether they are related to EU or national level policy.

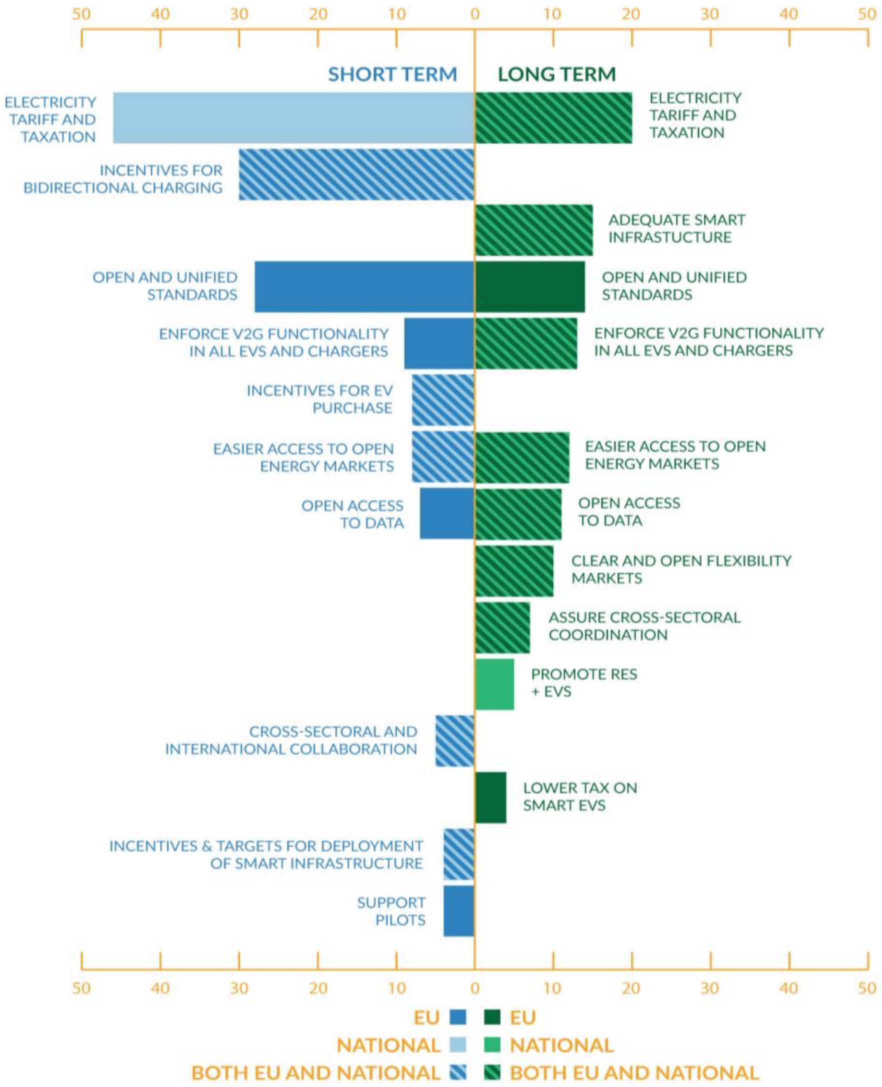

Figure 10: Short- and long-term policy recommendations from the survey respondents.

Figure 10 visualizes ten short and long term policy actions recommended by survey respondents and separates them at three levels: measures that should be taken at the EU-level, national level, and measures that are relevant both at the EU and national level. The majority of recommended policy actions are in fact relevant at both EU and national policy level meaning that actions needs to be initiated at the EU level, ensuring also adequate implementation at the EU level. The size of the box identifies the number of times the measure was recommended by the survey respondents. Colour identifies the level at which the policy is to be taken; at EU, national or both levels.

The survey-recommended policy measures, as well as the proposed vision, indicate that development of unidirectional and bidirectional smart charging will require implementation across multiple sectors. To address the identified barriers, policy measures related to charging infrastructure, electricity market, electricity taxation, smart and secure electricity network, smart buildings, renewable energy, user data access and protection, cyber security, and clean vehicles should be implemented.

The above discussed draft policy measures focusing on unidirectional and bidirectional smart charging infrastructure were presented in a workshop organized on the 13th January 2021 to more than 50 participants representing actors from the EV charging ecosystem, including industry, regulated entities, and stakeholder associations. Feedback from the workshop participants has been used for the measures presented and discussed in Section 4.3. More information on the workshop can be found in annex **9.8**.The main **discussion points** from the workshop are summarized as follows:

Unified EU strategy

There is a need for unified vision for electricity network and electric mobility, including charging infrastructure development.

Development of unidirectional and bidirectional smart charging infrastructure and electric mobility can be coupled with increased share of renewable energy sources with the policy defined target.

Definition of unidirectional and bidirectional smart charging

- There is a need for a clear definition of unidirectional and bidirectional smart charging on EU level.

Users and unidirectional or bidirectional smart charging

- Access to unidirectional and bidirectional smart charging should be clear and easy across Europe.
- Users could have a unique user identification to allow for easy billing and roaming across EU.

EV technical capabilities

- EVs should be obliged to go through type approval not only for their safety on the road but also their power quality (safety for the grid), interoperability, charging possibility.

EV smart charging market

- Interoperability of devices used during unidirectional or bidirectional smart charging is extremely important for the market expansion.
- Charge point operators find the policy burden related to electricity market, aggregation of assets, taxation of electricity, connection of the charger to the grid, lack of local flexibility markets and metering requirements to be the biggest business barriers.
- Taxation schemes should be tailored to the business case and not hinder the market development.

- Responsibilities and priorities of different actors on the market should be clear to all stakeholders.
- Enforcing smart charging should not financially overburden the charge point manufacturers, charge point operators and OEMs.
- Industrial actors are concerned that too many policy obligations on charging infrastructure could make its implementation not only complex but also costly and hamper the market development.

Unidirectional and bidirectional smart charging use cases

- The first focus to unlock potential of unidirectional and bidirectional smart charging infrastructure will be in private fleet charging.
- Due to differences between MSs and their urban area organization, it is expected that priorities on public and private charging are regionally dependent. Mapping of differences among MSs regarding planned development of public or private charging is needed for a clear picture on market development.
- Due to complexity of different use case options, including public and private charging, unidirectional and bidirectional charging, behind-the-meter or front-of-meter, policy should focus on enabling the operational use of smart charging. Optimal use case should be left to the market to develop.

Unidirectional and bidirectional smart charging incentives

- Where incentives for chargers do not apply to behind-the-meter chargers, they should be adapted to apply to behind-the-meter chargers as well.
- Policy measures should support the plans of Member states to invest in a EV smart charging infrastructure under the Recovery fund

Functionality of unidirectional and bidirectional smart charging

- Due to lifetime of charging equipment and the risk of deployed infrastructure being outdated in the few years, all EV charging infrastructure should be bidirectional ready.
- For bidirectional smart charging both EV and charger have to allow it, regardless of the inverter being on-board (AC) or off-board (DC). You cannot prescribe requirements on only one of those 2 elements. AFID should foster bidirectionality but remain technology neutral with regards to the way it is achieved.
- DC side of bidirectional smart charging is operational through OCPP (IEC63110) and CHAdeMO (IEC61851-24).

Integration of unidirectional or bidirectional smart charging and electricity network

- For integration of unidirectional or bidirectional smart charging with the grid, storage systems, including EV batteries need to be defined and allowed to modulate their capacity.
- Three-Phase requirements for unidirectional or bidirectional smart charging should not be prescribed, as it is more expensive for consumers.
- Can smart charger be used for metering purposes or do smart chargers require the installation of an additional (smart) meter?

Access to data

- To ensure the non-discriminatory access to in-vehicle data, third parties should have an easy access to EV data (e.g. state of charge, usage pattern , etc.) by 2025, subject to prior consent of the data owner. Access should be local or remote. ISO 15118 covers bidirectional data transfer.

- Other data except for battery and charging data is also needed for aggregation services, such as grid connection data, on actual and forecasted capacity availability.
- Data privacy laws have to be respected.

4.3. Legislative and non-legislative measures

Based on the best practices (Task 1), identified technical and regulatory barriers (Task 2), targeted vision and input from stakeholders, list of legislative and non-legislative policy measures is developed. It is presented here, grouped based on the overall achieved objectives. As a result, the following are the main objectives of the policy measures presented:

1. Assuring all chargers are smart chargers (including needed measures for EVs);
2. Clearly defining the functionalities of smart chargers;
3. Development of smart charging is coupled with development of renewable energy sources, considering the EV electricity demand;
4. Assuring open access to EV and charging data;
5. Development of energy market, and interoperability, enabling the development of competitive smart charging market;
6. Stakeholder awareness raising; and
7. Integrated strategic planning of energy, transport and building sectors including smart charging infrastructure.

4.3.1. Assuring all chargers are smart chargers

All charging infrastructure should be at least unidirectional smart charging for three reasons:

- Enforcing smart functionalities for charging infrastructure is consistent with the Clean Energy Package and policy of digitization of energy sector and transformation to smart grids.
- Article 19 of the EMD mandates the deployment of smart meters for all network users, subject to cost benefit assessment. A household user connected to the grid represents a user with an average power of 3 kW. One normal EV charger has a power range varying between 3.7 and 22 kW. It is therefore not logical to install smart meters for all users/households to detailed metering, remote monitoring and give access to dynamically varying price, while not having at least the same functionalities for unidirectional smart chargers.
- A charger has a lifetime of at least 10 years. Installing charging infrastructure today that is not smart capable introduces higher additional costs in the next 5 years due to the risk for lock-in or the need to upgrade existing infrastructure or even replace it.

The policy measure for all chargers to be unidirectional smart chargers focuses on hardware of the charging infrastructure. It is to assure that the infrastructure that is implemented today is capable of being smart (remotely monitored and controlled). The added software solutions installed by the stakeholders will enable the use of the smart capabilities of the charger. Smart chargers can have multiple use cases depending on the electricity market, network codes and duration of expected charging. To assure that the installed infrastructure is optimally integrated with the electricity network and that helps to develop a competitive market for smart charging the policy should specify minimal requirements for smart charging infrastructure.

The following overview presents proposed legislative and non-legislative policy measures:

Legislative

- L1- Definition of smart charging
- L2 - Mandate charging infrastructure to be smart
- L3 - Incentivize smart chargers
- L4 - Mandate smart chargers in public procurement
- L5 - Assessing functionalities of EVs for planning smart charging rollout
- L6 - Use of high and ultrahigh-power charging

Non-legislative

- N1 - Support large-scale smart charging infrastructure roll-out
- N2 - Register EVs and infrastructure
- N3 - Test high and ultra-high power charging
- N4 - Give recommendations based on best practices

Proposed legislative policy measures have multiple variations that are further analysed depending on the scenario in the cost-benefit analysis in the Chapter 5 of this study. Above listed policy measures are specified in tables below along with the level at which the measure is implemented, applicable use case (public/private, unidirectional/bidirectional and normal/high/ultrahigh power) and the addressed barriers. The measures are scored based on how effective they are in achieving the policy objective of all charging infrastructure being smart capable.

L1	Definition of smart charging point		Score:	2.5-5.0
Option 1	A smart recharging point is a recharging point that can, at the minimum, be remotely monitored (charging data (electricity exchange with the grid, charging power, time, current)), remotely controlled to start or stop the charging (charging time control only, not power or current) and allows electricity flow in one direction only, used for recharging for the electric vehicle's battery. This definition relates to the infrastructure (recharging point) and not the action (charging).			2.5
EU AFID	**Private & Public**	⟵[4]	**Normal & High power**	
Option 2	A smart recharging point is a recharging point that can, at the minimum, be remotely monitored (charging data (electricity exchange with the grid, charging power, time, current), remotely controlled to start or stop the charging (charging time, **power or current**) and allows electricity flow in one direction only, used for recharging the electric vehicle's battery. This definition relates to the infrastructure (recharging point) and not the action (charging).			3.0
EU AFID	**Private & Public**	⟵	**Normal & High power**	

[4] Symbol for (unidirectional) smart charging, the double arrows are for bidirectional smart charging.

Option 3	A smart recharging point is a recharging point that can, at the minimum, be remotely monitored (charging data (electricity exchange with the grid, charging power, time, current), remotely controlled to start or stop the charging (charging time, power or current) **used at least for recharging the electric vehicle's battery**. This definition relates to the infrastructure (recharging point) and not the action (charging and potentially injecting).			4.5
EU AFID	**Private & Public**	⟵⇆	**Private & Public**	
Option 4	Additional to Option 2 have clear definitions for bidirectional capable charging points: **Bidirectional** smart recharging point means a smart recharging point that allows electricity flow in two directions, used for recharging and discharging the electric vehicle's battery with functionalities defined in Annex II.			5.0
EU AFID	**Private & Public**	⇆	**Private & Public**	
Barrier(s):	Lack of clear terminology Complex communication on topic of smart charging			

L2	**Mandating charging infrastructure to be smart (as per the definitions in L1 above)**		**Score:**	**2.5-4.0**
Option 1	Require all **new** public recharging points to be at least smart recharging points (Option 3 from L1) from 2025.			2.5
EU	**Public**	⟵⇆	**Normal & High power**	
Option 2	Require all public recharging points to be at least unidirectional smart recharging points (Option 3 from L1) from 2025..			3.0
EU	**Public**	⟵⇆	**Normal & High power**	
Option 3	Require all new public recharging points under 22 kW to be at least unidirectional smart recharging points (Option 3 from L1) and bidirectional smart recharging points (Option 4 from L1) where cost-effective, from 2025.			3.0
EU	**Public**	⟵⇆	**Normal**	
Option 4	Require all new recharging points, whether public or private, to be at least unidirectional smart recharging points (Option 3 from L1) from 2025.			3.5
EU	**Private & Public**	⟵⇆	**Normal & High power**	
Option 5	Require all new recharging points, whether public or private, to be smart recharging points. From 2025 all **new** recharging points shall be bidirectional smart recharging points according to technical specifications in Annex II.			4.0
EU	**Private & Public**	⟵⇆	**Normal & High power**	

Barrier(s):	Lack of smart charging infrastructure

L3	**Incentivize smart chargers**		**Score:**	**4.5-5.0**
Option 1	Require MS to provide incentives (return on the price, decrease in price) to private users for the purchase and installation of a smart recharging point.			4.5
EU	**Private**	⟵⇆	**Normal power**	
Option 2	Require MS to provide incentives to private users for the purchase and installation of a bidirectional smart recharging point			5.0
EU	**Private**	⇆	**Normal & High power**	
Barrier(s):	Lack of smart charging infrastructure			

L4	**Mandate smart chargers in public procurement**		**Score:**	**4.0-5.0**
Option 1	Require MS to assure that recharging infrastructure purchased through public procurement consists of at least unidirectional smart recharging points.			4.0
EU	**Public**	⟵	**Normal & High power**	
Option 2	Require MS to assure that recharging infrastructure purchased through public procurement consists of at least bidirectional smart recharging points, where cost-effective.			4.0
EU	**Public**	⟵⇆	**Normal power**	
Option 3	Require MS to assure that recharging infrastructure purchased through public procurement consists of at least unidirectional smart recharging points. Starting from 2025 at least 50 % of all normal power public smart recharging points purchased through public procurement shall be bidirectional smart recharging points.			4.5
EU	**Public**	⟵⇆	**Normal & High power**	
Option 4	Require MS to assure that recharging infrastructure purchased through public procurement consists of at least unidirectional smart recharging points. Starting from 2025 all normal power public smart recharging points purchased through public procurement shall be bidirectional smart recharging points.			5.0
EU	**Public**	⟵⇆	**Normal & High power**	
Barrier(s):	Lack of smart charging infrastructure			

L5	Assessing functionalities of EVs for planning smart charging rollout		Score:	4.0-5.0
Option 1	If targets for the roll-out of smart recharging points are set, assure that they are based on the number of type approved[5] (taking into account grid operation safety, not only transport safety) EVs on the road			4.0
EU AFID	**Private & Public**	←	**Normal & High power**	
Option 2	If targets for the roll-out of bidirectional ready smart recharging points are set, assure that they are based on the number of type approved (taking into account grid safety, technical capability of EVs for bidirectional charging) EVs on the road			5.0
EU AFID	**Private & Public**	←⇆	**Normal & High power**	
Barrier(s):	Technical limitations of the available EV models			

N1	Support large-scale smart charging infrastructure roll-out		Score:	5.0
Require that recharging points financed through EU programs (e.g. CEF, InnovFin) be smart.				
EU	**Private & Public**	←⇆	**Normal & High power**	
Barrier(s):	Lack of smart charging infrastructure			

N2	Register EVs and infrastructure		Score:	4.0
Create a register of technical capabilities of installed charging stations and available EVs on the road				
EU or MS	**Private & Public**	←⇆	**Normal, High & Ultrahigh power**	
Barrier(s):	Lack of coordinated strategic planning			

N3	Test high and ultra-high power charging		Score:	4.0

[5] https://ec.europa.eu/growth/sectors/automotive/technical-harmonisation/faq-auto_en#:~:text=Type%20approval%20describes%20the%20process,placed%20on%20the%20EU%20market.

Support pilot projects aiming to complement high and ultrahigh recharging points with stationary storage to jointly offer service to assure grid stability, within funding programs such as CEF or InnovFin			
EU	**Private & Public**	⟵	**High & Ultrahigh power**
Barrier(s):	Inadequate and unclear business case for charging point operators		

N4	**Give recommendations based on best practices**	**Score:**	**5.0**
EU level recommendation on use cases and share of normal/high/ultrahigh recharging points based on best practices from countries with high uptake (Netherlands, UK, Norway)			
EU	**Private & Public**	⟵⇆	**Normal, High & Ultrahigh power**
Barrier(s):	Inadequate and unclear business case for charging point operators and aggregators		

4.3.2. Functionalities of smart chargers

Depending on the chosen definition of the smart charger, the options for functionalities of smart chargers can be defined. All chargers, public or private, should be at least smart unidirectional charging capable. Smart unidirectional charging must at least include that charging is remotely monitored and charging time remotely controlled. This smart functionality is the same as what most implemented smart meters have. It is recommended that this functionality is mandated for all normal power chargers. For high and ultrahigh power chargers smart functionality should be available, but used only in emergency situations.

Next step for smart unidirectional charging would be that not only time but also power and current can be remotely modulated and controlled. EC can decide if this should be involved in the definition of smart unidirectional charging.

Increased functionality is smart bidirectional charging, where the charger can be remotely monitored and time, power, current and charging/discharging can be remotely controlled.

The functionalities discussed in policy measures below do not include two relevant characteristics that have been addressed during the interviews and the workshop: need for installation of distribution smart meter at the smart charger and granularity of available charging data. Distribution smart meter/digital meter is installed at every point of connection to the grid. Currently smart meters need to have specific certification to be accepted for operation and integration with the grid by the DSO. Smart chargers have integrated the same functionality. However, chargers can be installed behind the meter/grid connection point as is case for private charging at the house or fleet charging. Therefore, at this point it is advisable that the DSO smart meter is installed at the connection point as before. In case where there is one charger at the grid connection, this indeed creates additional unnecessary costs. Pilots should be introduced that test and define best techno-economic solutions for integration of chargers and answer the question of how the costs should be divided among DSO, OEM, CPO and user.

The data granularity is treated by defining the access to real-time data. EMD defines “near real-time” as obligation for the data granularity of a smart meter. The same definition can be used for smart chargers as well, leaving it to market to define what data granularity is optimal for different use cases.

Four policy measures are proposed to regulate functionalities of smart charging points:

Legislative policy measures:

- L6 – Functionalities of unidirectional smart charger
- L7 – Functionalities of bidirectional smart charger

Non-legislative policy measures:

- N5 – Testing bidirectional use cases and standards
- N6 – Analyse interoperability of chargers and EVs

L6	**Functionalities of unidirectional smart charger**		**Score:**	**5.0**
Unidirectional smart recharging point should have following functionalities: • remote monitoring/metering and real-time data access assuring data security; • remote control of electric vehicle charging through recharging point, which time, and if cost-effective, power and current parameters are controllable; • interoperable and able to bidirectionally communicate with electric vehicle, energy management system and other devices using open communication standards; • type of socket EN in existing Annex 2 and referring to EN 62196 stays - not limited to AC for normal power charging.				
EU AFID	**Private & Public**	⟵	**Normal & High power**	
Barrier(s):	Lack of standard interoperability Lack of communication standards providing real time charging information Inadequate and unclear business case for charging point operators and aggregators			

L7	**Functionalities of bidirectional smart charger**	**Score:**	**5.0**
Bidirectional smart recharging point should have following functionalities: • remote monitoring/metering and real-time data access assuring data security; • remote control of electric vehicle charging through recharging point, which time, power and current parameters are controllable • allow bidirectional flow of electricity from and to electric vehicle • interoperable and able to bidirectionally communicate with electric vehicle, energy management system and other devices using open communication standards . • type of socket EN in existing Annex 2 and referring to EN 62196 stays - not limited to AC for normal power charging.			

EU AFID	**Private & Public**	⇆	**Normal power**
Barrier(s):	Lack of standard interoperability Lack of communication standards providing real time charging information Inadequate and unclear business case for charging point operators and aggregators		

N5	**Testing bidirectional use cases and standards**	**Score:**	**5.0**
• Support pilots across EU that test bidirectional smart charging for different public and private use cases to test relevant standards			
EU	**Private & Public**	⇆	**Normal power**
Barrier(s):	Lack of standard interoperability Lack of stakeholder awareness of benefits of smart charging		

N6	**Analyse interoperability of chargers and EVs**	**Score:**	**4.0**
• Support study on overview of market available recharging point technology, their functionalities, use cases (business case for public/private) and interoperability with different marker available EVs.			
EU	**Private & Public**	⟵⇆	**Normal, High & Ultrahigh power**
Barrier(s):	Lack of standard interoperability Lack of stakeholder awareness of benefits of smart charging		

4.3.3. Smart charging and renewable energy synergy

Electrification of road transport on its own decreases GHG emissions. However, unless EVs are charged using electricity from renewable energy sources, the set targets for decrease of GHG emissions by 2050 will not be reached. The AFID has as objective the deployment of alternative fuels infrastructure, with the aim of reducing the transport sector's dependence on oil, and its associated GHG emissions.

Aside from this, use of aggregated flexibility from EVs through unidirectional and bidirectional smart charging can be used to assure easier and increased integration of renewable (intermittent) energy in the electricity grid.

To achieve the policy objective of creating synergy between smart charging infrastructure and renewable energy sources following measures are proposed:

Non-legislative

- N7 – Testing coupling of smart charging and renewable energy generation
- N8 – Testing grid integration of bidirectional smart charging and renewable energy

N7	Testing coupling of smart charging and renewable energy generation		Score: 5.0
• Support pilot projects in relevant and well-selected environments[6] aiming to develop on-site smart recharging points directly connected to renewable energy sources and if possible in combination with stationary storage, within funding programmes such as CEF or InnovFin			
EU	**Private & Public**	⟵⇆	**Normal, High and Ultrahigh power**
Barrier(s):	Lack of connection between electric mobility and renewable energy generation Lack of stakeholder awareness of benefits of smart charging		

N8	Testing grid integration of smart bidirectional charging and renewable energy		Score: 5.0
• Support pilots in relevant and well-selected environments where real-time data is collected for the installation that include smart bidirectional recharging points, renewable energy and with optional stationary storage, to assess needed requirements for assuring power quality of the grid and eventual network codes for such application.			
EU	**Private & Public**	⇆	**Normal power**
Barrier(s):	Inadequate and unclear business case for charging point operators		

4.3.4. Open access to data

Open access to data (subject to the consent of the EV user) that are needed for development of unidirectional and bidirectional smart charging in competitive market should be discussed from three different aspects. Namely, open access to:

1. Charging data that includes time, power, current and direction of charging/discharging (if possible), charger capability;
2. EV battery data, i.e. state of charge, battery capacity, voltage, current, roundtrip efficiency, self-discharging rates, etc.;
3. Any other data needed for management of charging and the battery (e.g. requirements set by the user, potential dynamic grid status data).

[6] A lot of pilots so far took place where no grid issues occurred or in unrealistic settings (non-replicable regulatory sandboxes), leading to information on technical matters, but less on grid interaction and potential contribution to resolving grid challenges.

Points 1 and 3 could be regulated with in the AFID in a similar way as the data access for smart meters is dealt with in EMD.

Point 2 on EV battery state of charge data could be regulated within the Regulation 2018/858 on access to vehicle on-board diagnostic (OBD) and repair and maintenance information (RMI) for independent service providers (ISPs).

Following four policy measures are proposed to address open access to data, relevant to smart charging:

Legislative measures

- L8 – Access to charging data (options 1 and 3 above)
- L9 – Access to EV battery data (option 2 above)
- L10 – Third party access to data (points 1 and 3 above) for energy services according to Art 23 (data management)-and 24 (interoperability requirements and procedures for access to data) of EMD
- L11 – Assure cyber security in relation to security of charging data

L8	**Access to charging data**	**Score:**	**5.0**
• Ensure that **EV users and third party service providers, upon consent of EV users,** have free and open access to their charging data.			
EU AFID	**Private & Public**	←⇆	**Normal, High & Ultrahigh power**
Barrier(s):	Lack of access to relevant data		

L9	**Access to EV battery data**	**Score:**	**5.0**
• Ensure that EV users and third party service providers, upon consent of EV users, have free and open access to their EV battery data.			
EU	**Private & Public**	←⇆	**Normal, High & Ultrahigh power**
Barrier(s):	Lack of access to relevant data Inadequate and unclear business case for charging point operators		

L10	**Third party access to data for energy services according to Art 23-24 of EMD**	**Score:**	**5.0**
• Ensure that **third party service** providers (aggregator (demand response), energy manager) have free and open access, upon user consent, to recharger data and recharging point's grid			

connection data needed for providing services in accordance to Article 23 and 24 of Electricity Market Directive.			
EU AFID	**Private & Public**	←⇆	**Normal, High & Ultrahigh power**
Barrier(s):	Lack of access to relevant data Inadequate and unclear business case for charging point operators		

L11	**Assure cyber security in relation to security of charging data**[7]	**Score:**	**5.0**
• The security of the smart recharging point data communication and services shall comply with relevant Union security rules, having due regard of the best available techniques for ensuring the highest level of cybersecurity protection while bearing in mind the costs and the principle of proportionality.			
EU AFID	**Private & Public**	←⇆	**Normal, High & Ultrahigh power**
Barrier(s):	Data privacy concern of EV owners		

4.3.5. Enabling energy markets and interoperability

Proposed policy measures are discussed with existing regulatory framework, EMD and Electricity Regulation in mind. Hence, most proposed measures are non-legislative and assure follow up on transposition or implementation of the EMD and Electricity Regulation or studies and pilots to clarify technical and economic aspects of smart charging as flexibility service in the DSO flexibility markets.

Aside from this, current efforts to update and finalise a number of standards relevant to smart charging, and discussed in section 3.1, should be accelerated in order to allow for timely preparation and testing through pilot projects.

To assure development of smart charging in competitive markets open and industry supported communication protocols are important. Only with interoperability of smart chargers, EVs and other connected devices can new players enter the market and innovate existing business models and technologies.

Following are proposed policy measures related on EU and MS level to achieve the policy objective of enabling energy markets and device interoperability:

Legislative measures

- L12 – Use of open standards and protocols assuring interoperability and cybersecurity
- L13 – On MS level standardize access of small assets to TSO electricity markets
- L14 – Removal of double taxation for EV battery and other storage devices.

[7] This proposal is in line with Article 20 of the EMD.

Non-legislative measures

- N9 – Uniform distribution level flexibility market in EU
- N10 – Assure social acceptance of smart charging
- N11 – Political support for needed standards
- N12 – Follow up implementation by national regulatory authorities of EMD and Electricity Regulation
- N13 – Study of technoeconomic value to smart charging services for DSO flexibility market

L12	**Use of open standards and protocols assuring interoperability and cybersecurity**		**Score:**	**4.0**
• Recommend the use of open and industry supported communication protocols and standards for unidirectional and bidirectional smart recharging infrastructure to assure interoperability, taking into account need for cybersecurity.				
EU AFID	**Private & Public**	⟵⇆	**Normal, High & Ultrahigh power**	
Barrier(s):	Risk of EV car manufacturers becoming monopoly like actors on the energy and mobility market (due to lack of open access to data and lack of use of open standards and device interoperability) creating the opposite effect of the "power to the people" concept intended with the Clean Energy Package.			

L13	**On MS level standardize access of small assets to TSO electricity markets**		**Score:**	**5.0**
• Standardize access to TSO markets in terms of connection and prequalification for the small scale assets.				
MS	**Private & Public**	⟵⇆	**Normal power**	
Barrier(s):	Lack of clear business case for aggregators			

L14	**Removal of double taxation for EV battery and other storage devices**		**Score:**	**5.0**
• Revise Energy Taxation Directive to assure EV battery and other energy storage is categorized separately from classical energy supply so that double taxation is avoided.				

EU ETD	**Private & Public**	⇆	**Normal, High & Ultrahigh power**
Barrier(s):	Double taxation for bidirectional charging		

N9	**Uniform distribution level flexibility market in EU**	**Score:**	**5.0**
• Mandate an expert team from MSs to work with DSOs, aggregators, energy communities and alike to define requirements needed for developing uniform distribution level flexibility market based on EMD and Electricity regulation. Ensure that the requirements for service provisions for recharging points, such as response time and duration, are not exceeding the necessary level to provide service to the grid through local flexibility market.			
EU	**Private & Public**	⇆	**Normal power**
Barrier(s):	Unclear business case for charge point operators and aggregators Lack of clear priorities/conditions among stakeholders (DSO, aggregator, CPO) with regards to participating in the electricity market(s)		

N10	**Assure social acceptance of smart charging**	**Score:**	**5.0**
• Study or large size pilot, in the relevant grid condition where there is a real need for flexibility, to find new business models to overcome social barriers and aspects of potential battery degradation and the roles of different stakeholders.			
EU	**Private & Public**	⟵⇆	**Normal power**
Barrier(s):	Lack of awareness on the use of smart charging of EVs for all stakeholders Complex communication on smart charging technology (Accelerated) battery degradation due to bidirectional charging		

N11	**Political support for needed standards**	**Score:**	**5.0**
• Push forward in time update and adoption of standards needed for integration of bidirectional smart recharging infrastructure in a way that does not disturb the electricity network. Standards identified in Chapter 3 of this report.			
EU	**Private & Public**	⟵⇆	**Normal power**

Barrier(s):	Lack of standard interoperability Lack of communication standards providing real time charging information

N12	**Follow up implementation by national regulatory authorities of EMD and Electricity Regulation**	**Score:**	**5.0**
• Follow up (through a study or alike) the transposition and implementation by national regulatory authorities (especially with regards to the timing of availability to end consumers) of dynamic commodity pricing, network charges and double network tariffing from EMD and Electricity Regulation.			
EU	**Private & Public**	←⇆	**Normal power**
Barrier(s):	Lack of dynamic pricing and optimal network tariffing . Double network tariffing.		

N13	**Study of technoeconomic value to smart charging services for DSO flexibility market**	**Score:**	**5.0**
• Study to analyze the effective value of the service offered by smart (unidirectional and bidirectional) charging in the upcoming DSO service market			
EU	**Private & Public**	←⇆	**Normal power**
Barrier(s):	Inadequate and unclear business case for charging point operators and aggregators Lack of awareness on the use of smart charging of EVs for all stakeholders Complex communication on smart charging technology		

4.3.6. Stakeholder awareness raising

As discussed in Chapter 3 three of the most important other barriers identified through the survey included: awareness raising of the stakeholders, complexity of information communicated with the stakeholders and EV user hesitance to grant access to the battery. Clear communication of operation and benefits of smart unidirectional and bidirectional smart charging are crucial for user acceptance and large scale rollout of smart charging. Moreover, open political support and incentives for use of smart charging will create an interest from general public to learn more and find ways to implement the use of smart charging in their daily routine.

Aside from general public, other stakeholders, such as investment bodies and service industry need to be better informed on the operation and use of smart charging and its potential benefits. Therefore results of pilot studies implemented across EU should be clearly communicated and best practices recommended and often updated.

Since social aspect of development of smart charging and its market is not the main focus of this report, the following non-legislative measure was proposed. However, if smart charging market is to be competitive more effort needs to be placed on understanding social aspect of smart charging and encouraging involvement of all stakeholders.

N14	**Awareness raising of use of smart charging for general public**	**Score:**	**5.0**
• Assure through an EU level action that results of the pilot studies and best practices are clearly communicated to general public to transfer the message of the potential use and functioning of the smart charging of EVs			
EU & MS	**Private & Public**	←⇆	**Normal, High and Ultrahigh power**
Barrier(s):	Lack of awareness on the use of smart charging of EVs for all stakeholders Complex communication on smart charging technology		

4.3.7. Integrated planning

Development of smart charging has been mainly demand driven. Such approach does not show negative impact while the EV uptake is low. However, as number of EVs on roads increase and the need for higher implementation of smart charging infrastructure increases, the need for coordinated planning on implementation of charging infrastructure is crucial. Based on analysis of the best practices in chapter 2 and discussion with stakeholders involved in smart charging development, the common aspect of successful implementation examples is coordinated planning of authorities on local, regional and national level, as well as inter-sectoral (electricity network, urban planning, mobility) alignment.

While the aspect of strategic planning of smart charging development and its effects on the development of the competitive market have not been the main focus, the following non-legislative policy measure from EU level, as a recommendation to MS, is nevertheless recommended.

N15	**Collaboration of all government levels for planned smart charging rollout**	**Score:**	**5.0**
• Recommendation for MS to assure communication and collaboration between national, regional and local governmental levels and DSOs to plan roll out of smart charging infrastructure			
EU	**Private & Public**	←⇆	**Normal, High and Ultrahigh power**
Barrier(s):	Lack of intersectoral planning and long term planning for roll out of smart charging infrastructure		

5. Definition of objectives and policy options

The purpose of this chapter is to present the objectives associated with the cost-efficient integration of electric vehicles into the electricity grid, as well as comprehensive policy options, derived from the long list of policy measures presented in Chapter 4. While previous chapters addressed best practices (Chapter 2), barriers (Chapter 3) and policy measures (Chapter 4) related to public and private charging infrastructure, policy options detailed in this chapter and impact assessment presented in Chapter 6 focuses on public charging infrastructure. The narrowed focus from all charging infrastructure to public charging infrastructure is intended to provide a more in-depth analysis of specific issues regarding public charging infrastructure, and possible policy options to address these.

These comprehensive options are described here qualitatively. Their respective costs and benefits were assessed as part of Task 4, and the results of this assessment are presented in Chapter 6.

5.1. General and specific objectives for the cost-efficient integration of electric vehicles into the electricity grid

Following the principles of the Better Regulation Guidelines[8], the analysis distinguishes between general, specific and operational objectives to guide the development of policy options. The objectives should be read in the context of a cost-efficient integration of electric vehicles into the electricity grid, as per the terms of reference. Figure 11 below presents these objectives and illustrates the linkages between general, specific and operational objectives.

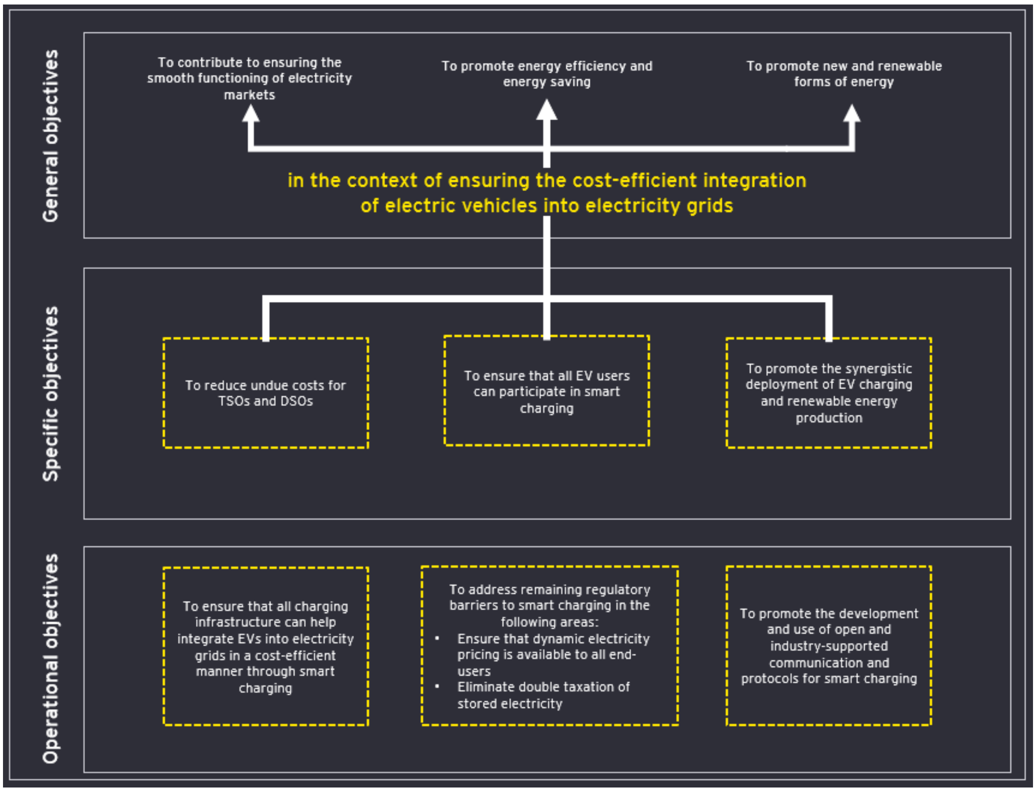

Figure 11: Objective tree

[8] In particular the principles set out in Tool #16, "How to set objectives", available online at https://ec.europa.eu/info/sites/info/files/file_import/better-regulation-toolbox-16_en_0.pdf

5.2. Definition of the policy options

The policy options are the following:

- *Policy option A*: Baseline scenario;
- *Policy option B*: Mandatory unidirectional smart chargers;
- *Policy option C*: Mandatory unidirectional and bidirectional smart chargers.
- *Policy option D*: Support to pilot projects across the EU to better understand the factors affecting potential benefits of unidirectional and bidirectional smart charging. Policy option D is presented as an add-on to the other policy options B and C.

The fourth policy option, policy option D, is a horizontal policy option, complementing either policy option B or policy option C. While policy options B and C include comprehensive, legally binding actions taken by the EU, policy option A represents a scenario wherein current and expected future policies hold throughout the time horizon in scope. With regards to option D, it is expected to evolve following impact assessments of implemented directives.

The policy options were determined based on a careful examination of the expected impacts of all policy measures considered in this study, and discussed in section 4 of this report. Each measure was rated according to its expected effectiveness, to achieving the objectives discussed above. Policy options B to D were developed on the basis of this assessment.

5.2.1. Option A, baseline

The baseline option assumes no change in policy, relative to what is currently in place or expected to be realised in the near future. Assumptions made as regards to the deployment of charging infrastructure, and the degree to which smart charging will develop under the baseline scenario, carry a relatively high level of uncertainty. This uncertainty is mainly due to the continued existence of regulatory and technical barriers affecting the development of smart charging, the lack of agreements on open data and (the adoption of) interoperability standards, as well as to the emergent nature of markets for smart charging services, of the technologies that support them, and of competing energy storage technologies[9] whose development may affect the business case for smart charging as a flexibility option for the electricity grid.

Nevertheless, it is assumed that, under the baseline scenario, an estimate of 80 % of all vehicle chargers in 2025 will be capable of smart charging, of which 90 % is unidirectional smart charging capable and 10 % will be capable of bidirectional smart charging[10]. In 2030 and under the baseline scenario, it is assumed that nearly of all vehicle chargers will be capable of smart charging, of which 70 % is unidirectional smart charging capable and 30 % will be capable of bidirectional smart charging.

5.2.2. Option B, mandatory unidirectional smart chargers

Policy option B aims at removing remaining barriers to smart charging services and at fully enabling smart charging services in competitive markets. In comparison to policy option A, it aims at setting a legally binding framework for the roll-out of public infrastructure for unidirectional smart charging, and setting common definitions and standards on a legal basis for all EU Member States. This includes legislative and non-legislative policy measures applicable to public unidirectional smart charging on coupling with renewable energy

[9] E.g. second life batteries or so-called “green hydrogen”.

[10] https://www.utilitydive.com/news/2021-outlook-the-future-of-electric-vehicle-charging-is-bidirectional-bu/592957/

production (section 4.3.3), binding agreements on open data (section 4.3.4), clear and uniforms standards on interoperability and further developed energy markets (section 4.3.5) and non-legislative measures addressing raising of stakeholder awareness (section 4.3.6) and integrated planning (section 4.3.7).

This policy option is built on the following operational policy objectives:

- The definition of a “smart charger” should be enshrined legally, applicable to all Member States and should at least cover monitoring and controlling functionalities (Option 3 of L1 in section 4.3.1);
- All chargers up to 22 kW should be at least smart unidirectional chargers (Option 1 of L2 in section 4.3.1 and L6 in section 4.3.1).

In order to meet these objectives, this policy includes the following operational measures to be decided and implemented on EU level:

- Define, within AFID, the meaning of smart charging--i.e. A smart recharging point is a recharging point that can, at the minimum, be remotely monitored (charging data (electricity exchange with the grid, charging power, time, current), remotely controlled to start or stop the charging (charging time, power or current) used at least for recharging the electric vehicle's battery.
- Require all new public recharging points under 22 kW to be at least smart unidirectional recharging points from 2025 (Option 1 of L4 in section 4.3.1) .

Furthermore, this policy option includes legislative measures that establish policy support for mandating smart charging for public procurement, notably:

- Require MS to assure that recharging infrastructure purchased through public procurement consists of at least unidirectional smart recharging points (Option 1 of L4 in section 4.3.1).

As described above, this policy measures consists of legislative measures, aiming at: (1) a clear definition of the functionalities of a unidirectional smart charger; (2) the exclusive roll-out of at least unidirectional smart charging points from 2025 on; and (3) stimulating the market for smart charging by mandating the public procurement of smart charging infrastructure.

5.2.3. Option C, mandatory bidirectional smart chargers

Policy option C aims to go beyond policy option B, in order to fully capture the potential benefits of smart charging through bidirectional smart charging. In comparison to policy option B, it aims at setting a legally binding framework for promoting the roll-out of bidirectional smart charging.

This includes legislative and non-legislative policy measures applicable to public bidirectional smart charging on coupling with renewable energy production (section 4.3.3), binding agreements on open data (section 4.3.4), clear and uniforms standards on interoperability and further developed energy markets (section 4.3.5) and non-legislative measures addressing raising of stakeholder awareness (section 4.3.6) and integrated planning (section 4.3.7).

This policy option is built on the following operational policy objectives:

- The definition of a “smart charger” should be enshrined legally, applicable to all Member States and should at least cover monitoring and controlling functionalities (Option 4 of L1 in section 4.3.1);
- All chargers up to 22 kW should be at least bidirectional smart chargers (Option 3 of L2 in section 4.3.1 and L6 and L7 in section 4.3.2);.

In order to meet these objectives, this policy includes the following operational measures to be decided and implemented on EU level:

- Define, within AFID, the meaning of smart bidirectional charging--i.e. a smart bidirectional recharging point is a recharging point that allows electricity flow in two directions, used for recharging and discharging the electric vehicle's battery with functionalities defined in Annex II.
- Require all new public recharging points under 22 kW to be at least unidirectional smart recharging points and bidirectional smart recharging points where cost-effective, from 2025.

Furthermore, this policy option includes legislative measures that establish policy support for mandating smart charging for public procurement, notably:

- Require MS to assure that recharging infrastructure purchased through public procurement consists of at least bidirectional smart recharging points, where cost-effective (Option 2 of L4 in section 4.3.1).

As described above, this policy option consists of legislative measures, aiming at: (1) a clear definition of the functionalities of a bidirectional smart charger; (2) the exclusive roll-out of at least unidirectional smart charging points, and bidirectional charging points where cost-effective from 2025 on; and (3) the stimulation of the respective markets by incentivising (private) / mandating the procurement (public) of bidirectional smart charging infrastructure.

5.2.4. Option D, support to pilot projects across the EU to better understand the factors affecting potential benefits of unidirectional and bidirectional smart charging

Policy option D is considered as an add-on to both options B and C option B. Specifically, the following policy measures defined under Chapter 4 are included in option D:

- N3[11] - Support pilot projects aiming to complement high and ultrahigh recharging points with stationary storage to jointly offer service to assure grid stability, within funding programs such as CEF or InnovFin
- N5[12] - Support pilots across EU that test bidirectional smart charging for different public and private use cases to test relevant standards;
- N7[13] - Support pilot projects in relevant and well-selected environments aiming to develop on-site smart recharging points directly connected to renewable energy sources and if possible in combination with stationary storage, within funding programmes such as CEF or InnovFin;
- N8[14] - Support pilots in relevant and well-selected environments where real-time data is collected for the installation that include smart bidirectional recharging points, renewable energy and with optional stationary storage, to assess needed requirements for assuring power quality of the grid and eventual network codes for such application;

[11] Applies to only unidirectional smart charging

[12] Applies to only bidirectional smart charging

[13] Applies to both unidirectional and bidirectional smart charging

[14] Applies to only bidirectional smart charging

- N10 - Study or large size pilot, in the relevant grid condition where there is a real need for flexibility, to find new business models to overcome social barriers and aspects of potential battery degradation and the roles of different stakeholders[15].

The factors impacting the cost-effectiveness of bidirectional smart charging are expected to include the following:

- Share of variable renewable energy production (section 4.3.3);
- Risk of grid congestion issues (sections 4.3.4, 4.3.5 and 4.3.7);
- Market uptake of smart charging and EV chargers in general (sections 4.3.1 and 4.3.6);
- Effective uptake of open data and interoperability standards (sections 4.3.4 and 4.3.5).

This policy option therefore includes non-legislative measures supporting research and development of unidirectional and bidirectional smart charging, through pilot projects.

6. Cost-benefit analysis and comparison of policy options

This chapter presents the methodology for and the results of the cost-benefit analysis of proposed policy measures for the cost-efficient integration of EVs into electricity grids.

6.1. Key assumptions for the cost-benefit analysis

For the purpose of a consistent analysis of costs and benefits for all policy options, it is important to define some key figures and assumptions that all the following three options may refer to. Such data are presented in the following figure and will serve as the basis for the calculation of costs relevant to the individual policy options B and C.

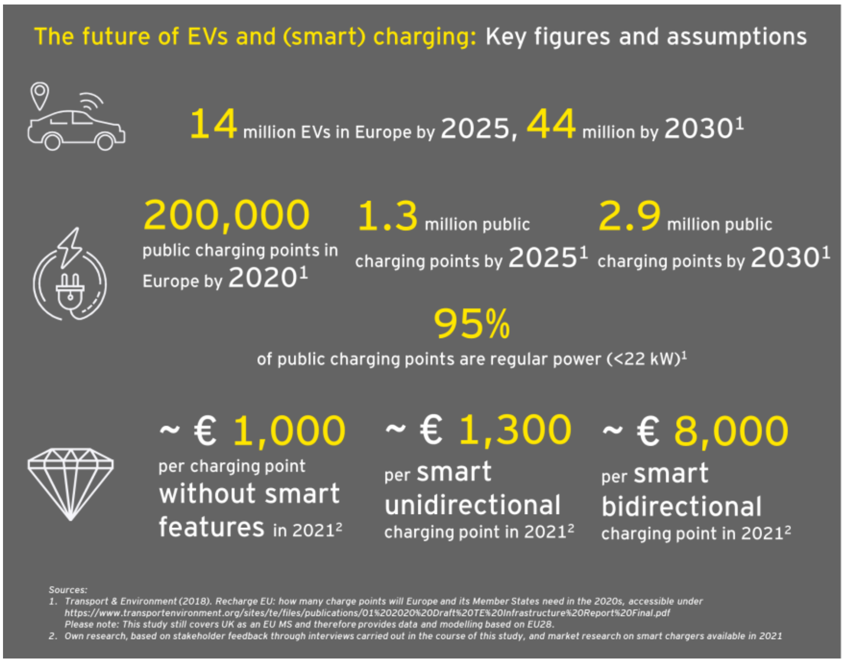

Figure 12: The future of EVs and (smart) charging: Key figures and assumptions (Source: EY, based on data from Transport & Environment (2018)

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[15] Applies to both unidirectional and bidirectional smart charging

The assumptions presented above, as regards the growth of the EV fleet in Europe, are based on scenarios aiming for climate neutrality in the EU by 2050. The contribution of decarbonisation of road transport to this objective would require to achieve 14 million EVs in Europe by 2025, and 44 million by 2030. EVs will be mostly charged in private locations, mainly at EV users' homes or offices, approximately 80% of charging activity is expected to occur at private accessible charging points [test][16]. Additionally, the need for public charging points has been estimated[17] to be 1.3 million by 2025, and 2.9 million by 2030. The majority of these would be normal power, i.e. <22 kW chargers.

The costs for unidirectional and bidirectional smart charging points presented in the figure above are given for the year 2021 and are based on a survey of currently available charging points. The estimates have been validated through the stakeholder interviews conducted for this study. The estimate for the cost premium of a unidirectional smart charging point, relative to a non-smart charging point, is assumed to cover the following:

1. Communication device—whether wired or wireless, the charging point must be able to communicate with third parties such as aggregators or DSOs in order to remotely start and stop the charging process and modulate the power at the charging point;
2. Metering capability—the charging point must be able to measure the volume of electricity delivered in real time, in order to track electricity consumption at different times of day.

6.2. Cost-benefit analysis for policy option B

Type of costs	Quantification / explanation
Hardware costs	Unidirectional smart chargers require additional hardware, including communications and metering devices, in order to implement smart functionalities. The cost premium for a unidirectional smart charger, over a non-smart charger, is estimated at approximately € 300 in 2021.
Software costs, including costs of ensuring protocols	Smart chargers must comply with certain protocols in order to fully utilise smart charging capabilities. These protocols include communication standards, including between vehicles and chargers, and between chargers and third parties such as aggregators and grid operators. Software costs may represent a significant share of the total costs of smart charging. Nevertheless, numerous software platforms for smart charging are market-ready as of 2021[18]. Chargers developed under the impulse of policy option B can be expected to use mostly off-the-shelf software solutions. The costs of these software solutions, per charge point, are expected to scale down with the growth in the smart charging market.
Costs of developing smart charging protocols	Besides these monetary investment needed for the roll-out of smart chargers, the measures presented in the beginning of this section also produce costs in terms of required work capacity and time for negotiating definitions of "smart

[16] https://phev.ucdavis.edu/wp-content/uploads/a-review-of-consumer-preferences-and-interactions-with-electric-vehicle-charging-infrastructure.pdf

[17] https://www.transportenvironment.org/sites/te/files/publications/01%202020%20Draft%20TE%20Infrastructure%20Report%20Final.pdf

[18] E.g. Nuvve, Jedlix, Greenflux

	charger" (functionalities) and communication protocol standards. Nevertheless, most of the work in these areas is underway, as a result of market adoption of smart charging. While policy option B would possibly accelerate the work on developing smart charging protocols, it is not expected to result in significant additional costs in this regard.
Operational costs	The management of smart charging will entail operational costs throughout the smart charging value chain, most importantly for aggregators. The operational management of smart charging will include negotiating contracts with end-users and procurers of flexibility, monitoring the status of networks of smart chargers, and supporting business functions. These costs essentially constitute a pass-through cost, and are expected to decline, on a per-charger basis, as a result of a greater roll-out of smart charging, and with increased digitalisation allowing for a higher degree of automation.

The main point of costs for implementing this policy option from a quantitative perspective is the comprehensive roll-out of smart chargers. As stated above, studies assume that there will be a need for 1.3 million public charging points in Europe by 2025 and for 2.9 million by 2030. These numbers imply that in addition to the approximately 200,000 public chargers existing today in Europe, an additional 1.1 million charging points would need to be installed by 2025, and 2.7 million by 2030.

Important to note is that, according to the selected definition of "smart chargers", a charger able to communicate even if not according to agreed protocols is considered smart ready/capable. It can be expected that, even under policy option A, the non-smart chargers will become a niche market of both public and private chargers given the implementation of concepts such as capacity tariffs as well as the emphasis on self-consumption at building or community level as per the recast of the Renewable Energy and the EMD. As a consequence, policy option B will only have a minor impact on the number of smart chargers[19]. While policy option B is therefore expected to have a limited impact on costs, the impact of this policy option on benefits is expected to be substantial.

	2025	2030
Number of unidirectional smart charging points, policy option A	988,000	2,479,500
Number of unidirectional smart charging points, policy option B	1,049,750	2,569,750
Cost premium for a unidirectional smart charging point, policy option A	€ 136	€ 113
Cost premium for a unidirectional smart charging point, policy option B	€ 134	€ 112

[19] Regardless of them being used for the activity of smart charging.

The current cost premium for a unidirectional smart charging point, compared to a non-smart charging point, is assumed to be € 300. This amount covers the costs for hardware providing communication and metering capabilities, allowing to remotely start and stop the charging process and modulate the power at the charging point[20]. This cost can be expected to decline with the roll-out of unidirectional smart charging points, leading to economies of scale and increased innovation.

Based on a learning curve model assuming a learning rate of 13%[21], and an average annual growth rate in smart charger deployment of just below 63% to 2030, the cost premium for a unidirectional smart charger in 2025 is estimated to be € 136, and in 2030 to be € 113 under the baseline scenario.

Policy option B is expected to lead to a small increase in the roll-out of smart chargers. Based on a greater annual growth rate of just above 63% in smart charger deployment, the cost premium for a unidirectional smart charger in 2025 is estimated to be € 134, and in 2030 to be € 112 under policy option B.

Almost 2.5 million unidirectional smart charging points are expected to be deployed from 2021 to 2030 under the baseline scenario. Policy option B would result in the deployment of just below 2.6 million unidirectional smart charging points in the same time frame, i.e. in 90,250 additional unidirectional smart charging points. Policy option B would result in total additional costs of approximately € 9.5 million between 2021 and 2030 for installing additional unidirectional smart charging points.

Apart from these costs, it is necessary to mandate the roll-out of at least unidirectional smart charging under a shared definition of functionalities and communication protocol standards, the measures included in this policy option have also decisive benefits. These are presented below.

Benefits of policy option B

The benefits of mandating the roll-out of unidirectional smart chargers can be clustered into the following categories:

- Benefits accruing to EV users applying price arbitrage;
- Benefits stemming from services to DSOs, corresponding mainly to avoided or reduced grid infrastructure investments;
- Benefits stemming from services to TSOs, corresponding to frequency reserve services;
- Support of the integration of renewable energy sources into the European power system;
- Reduction of CO_2 emissions.

Table 4 below provides a quantification (where possible) or explanation of the different benefits of smart charging[22]. The monetised estimates presented for each category of benefits are to

[20] As discussed above, the main additional costs for a smart unidirectional charging point, relative to a non-smart charging point, comprises the hardware costs for communications and metering capabilities. Other costs such as software costs, or costs for developing communications protocols and network codes, are not considered within the cost-benefit analysis of policy options.

[21] The learning rate of 13% is in line with other comparable reports, including a report by Element Energy (Element Energy, 2019, VG2B – Requirements for market scale-up, available online at http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/06/V2GB_WP-4-report-Requirements-for-market-scale-up.pdf).

[22] Monetised benefits presented in this table were derived from a triangulation of a number of sources, including a report by Elia (Elia, Accelerating to net zero: redefining energy and mobility, 2020, Available online at https://www.elia.be/-/media/project/elia/shared/documents/elia-group/publications/studies-and-reports/20201120_accelerating-to-net-zero-redefining-energy-and-mobility.pdf), a report by Elaad (Elaad, Smart Charging Guide, 2020, Available online at https://www.elaad.nl/uploads/files/Smart_Charging_Guide_EN_single_page.pdf) and a report by Element Energy (Element

be understood as the average benefits that are expected to accrue for each EV participating in smart charging. These estimates will be used to derive, ultimately, an estimate of the net benefits expected from unidirectional smart charging under policy option B (i.e. total benefits less total costs), relative to the net benefits under the baseline.

The estimates provide an average figure across all Member States. They are, nevertheless, expected to vary significantly from one region to the other, depending on the state of local distribution networks, on the share of renewables in the electricity mix, and a number of other factors. Additionally, these benefits may be shared in different proportions across the smart charging value chain. CPOs, either directly or through aggregators, will reap the benefits of unidirectional smart charging, and are expected to pass on a share of these benefits to end users, e.g. by offering lower rates to EV users opting in to smart charging programmes.

Table 4: Benefits of smart charging

Type of benefits	Quantification / explanation
Arbitrage benefits	EV users may, directly or indirectly, benefit from unidirectional smart charging by paying lower prices of electricity or for charging services thanks to arbitrage opportunities. Unidirectional smart charging allows EV users, or third parties acting on their behalf, to shift EV charging to periods of low—or even negative, at times—electricity prices. Unidirectional smart charging could contribute to benefits in the range of € 51[23] per EV per year, as regards benefits from arbitrage.
Benefits stemming from services to DSOs	As stated in section 1, DSOs can procure services from third parties in order to: • Address grid congestion issues • Maintain voltage quality of distributed electricity Each EV participating in unidirectional smart charging could contribute to benefits in the range of € 26[24] per year, as regards benefits from services to DSOs. As discussed in section 1 above, the markets for DSO services are often imperfect or non-existent. Even when well-functioning markets do end up materialising, they are expected to have highly variable price points for flexibility services. Prices paid will vary in time, according to observed congestion levels and the status of competing flexibility suppliers, and across regions, depending on the strengths of distribution grids.
Benefits stemming from services to TSOs	As stated in section 1, TSOs procure services from third parties in order to maintain the stability of their electricity transmission networks. These services include: • Frequency containment reserves (aka fast frequency reserves) • Automatic frequency restoration reserves • Manual frequency restoration reserves

Energy, 2019, VG2B – Requirements for market scale-up, available online at http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/06/V2GB_WP-4-report-Requirements-for-market-scale-up.pdf)

[23] This value is the average of the values mentioned in reports by ELIA and ELAAD (see footnote 22)

[24] https://www.ce.nl/publicaties/2268/slim-laden-must-have-bij-groei-elektrisch-vervoer-onderzoek-naar-kosten-en-baten-van-slim-laden

	Unidirectional smart charging could contribute to benefits in the range of € 6[25] per EV per year, as regards benefits from services to TSOs. As discussed in section 1 above, the value of benefits provided to TSOs is expected to fall concurrently with declining prices of battery storage.
Support of the integration of renewable energy sources into the electricity grid	Unidirectional smart charging has the potential to help integrate more renewable energy production into electricity grids. Renewable energy, and in particular solar and wind electricity, is generally characterised by a variable output. The variability in production cannot easily be matched to an inflexible demand. As of 2021, many MSs have experienced numerous periods of negative wholesale electricity prices, notably due to at times high level of production of renewable energy, inflexibility of coal and nuclear plants, and inflexible demand. Smart charging has the potential to shift EV charging demand to periods of peak production and low demand, thereby optimizing the consumption of energy from renewable sources. This demand shifting reduces the need for conventional power plants that would otherwise be needed to meet the needs of EV chargers.
Reduction of CO_2 emissions	The benefits referred to above, as regards the integration of renewable energy production into the electricity grid, directly translates into lower CO_2 emissions. It is estimated that each EV participating in smart charging can help prevent over 50 kg of CO_2 emissions by this means[26]. Additionally, the benefits earned by EV users from smart charging can help offset the higher costs of purchasing an EV, compared to a traditional internal combustion engine vehicle. This could help accelerate the deployment of EVs across the EU.

Based on the combined benefits from arbitrage, and providing services to DSOs and TSOs, each EV using smart charging could result in benefits of up to € 83 per year[27] per vehicle. The following section will present the calculation of benefits that are expected to accrue from unidirectional smart charging, per recharging point, as well as the calculation of net benefits specifically resulting from policy option B, relative to the baseline.

As discussed above, policy option B would result in a small increase in the number of deployed unidirectional smart charging points, regardless of them being used for the activity of smart charging. While there is a limited difference in the amount of charging points that are smart, the legislative measures proposed in policy option B would ensure more charging points are **making use of smart charging**. It follows that smart charging points under policy option B will generate an increased amount of benefits compared to the baseline.

Above, the annual economic benefit of 1 EV was calculated to be 83€. This benefit per car needs to be linked to the benefit per charger. Therefore, the paths are taken:

- How much of the annual benefit of one car can be allocated to public charging;

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[25] http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/06/V2GB_WP-4-report-Requirements-for-market-scale-up.pdf

[26] Elia, Accelerating to net zero: redefining energy and mobility, 2020, Available online at https://www.elia.be/-/media/project/elia/shared/documents/elia-group/publications/studies-and-reports/20201120_accelerating-to-net-zero-redefining-energy-and-mobility.pdf

[27] Please note that it may not be possible to fully realise the combined benefits from arbitrage, services to TSOs, and services to DSOs. Smart charging can be directed to target lower electricity prices (arbitrage), or to provide services to TSOs and DSOs, but it is likely that these objectives are not always fully aligned.

- How many cars can be linked to one public charger.

For the first aspect, the financial benefit that could be linked to the public charging of a single vehicle, the share of public charging per car is 15%[28]. It is estimated that 50% of that is destination charging, i.e. charging where more time is available compared to “on the go” charging. The above calculated annual benefit for an EV to participate in smart charging is therefore allocated for 7.5% to the public charging (50% of the 15% of public charging) resulting in 6€ per EV that can be allocated to a public charging point.

The second aspect requires a more elaborate calculation, that is schematically presented in Figure 13 below. The calculation is divided in 2 parts: (1) how many hours is a car connected to a public charger and (2) how many hours is a public charger available for charging. By dividing the latter by the former, the number of cars allocatable to one public charger can be estimated.

1. The number of hours of public charging of a single car

It is known that the average EU car drives 12 000 km annually[29]. It is assumed that the average consumption per km is 164Wh for an EV[30]. It is further assumed that for smart charging both the chargers of 11kW and 22kW can modulate between 0kW and their maximum[31]. Hence, the average EV charged 285 kWh per year using a public charger and is connected to a charger for a minimum of 34.5 hours. The number of hours of availability for charging of a charger:

2. The number of hours of charging for a single charger

The occupation rate of public charge points is typically about 15% during daytime (8 hours) and 30% during night-time (16 hours)[32], where the latter typically has more idle hours. The public charger is assumed to effectively be occupied for charging or grid exchange during 3.6 hours a day, but only 1.8h is used for effectively charging:

- 1.2 h of the 8 hours during the daytime the charger is occupied, it is assumed that 50% of that is idle and 50% is effectively charging → 0.6 h of charging during the 8 hours of daytime
- 2.4 h during the 16 hours of nighttime, i.e. during 30% of the nighttime the charger is occupied. It is assumed that 25% of the time, the charger is effectively charging. This implies 1.2 hours of smart EV charging per charger per nighttime.

On an annual basis, this implies 657 hours that a single charger is being used for charging.

Hence, 19 cars can be allocated to a single charger for their public charging. However, only 50% of that charging is considered destination charging and only this type of charging is considered to be relevant for participating in services that could deliver financial benefits. Therefore, the above estimated 6€ can be valorised for each of the 19 cars, resulting in a benefit of 114.3€[33] per charger per year.

[28] https://avt.inl.gov/sites/default/files/pdf/arra/PluggedInSummaryReport.pdf

[29] https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/distance-travelled-by-car.html

[30] https://ev-database.org/cheatsheet/energy-consumption-electric-car

[31] Hence the average power of a smart charging point is 8.25 kW (the average of (0,11,0,22)

[32]https://www.idolaad.nl/gedeelde-content/publicaties/publicaties-algemeen/managing-parking-pressure-concerns-relatedto-charging-stations-for-electric-vehicles.html

[33] 114,3 euro = 6 euro per car * 19 cars that are allocated to one public charge point

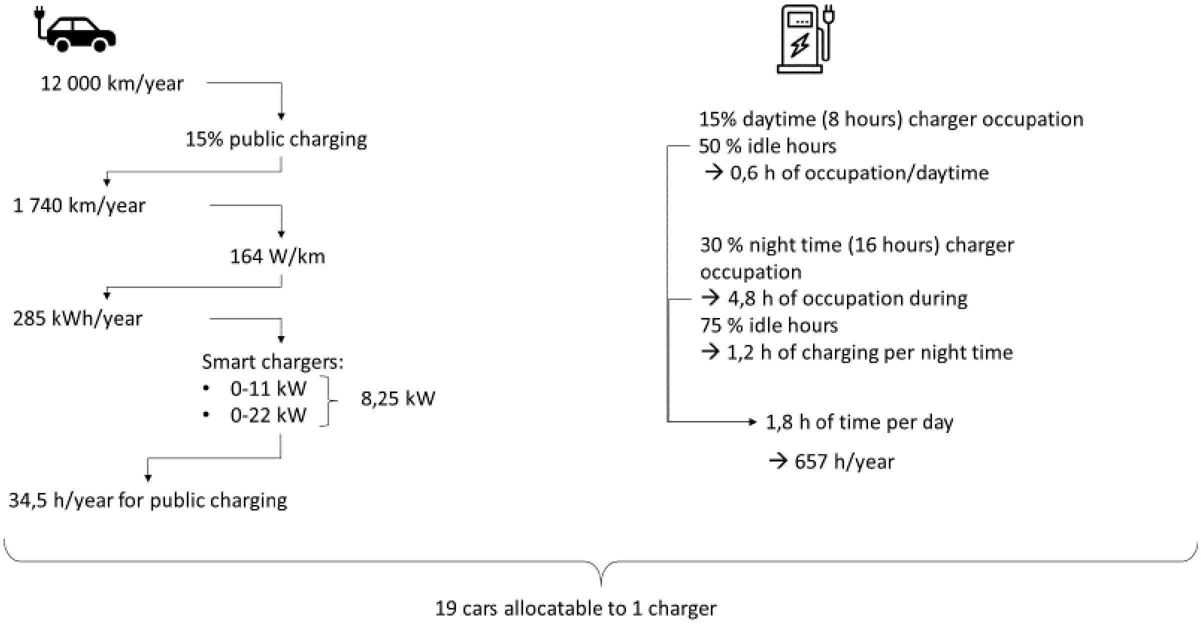

Figure 13: Schematic representation of EV-charger calculation

The above calculation provides an average figure across all Member States. As described in the introduction of this section this is expected to vary significantly from one region to the other, depending on the state of local distribution networks, on the share of renewables in the electricity mix, and a number of other factors.

With regards to the uptake, it is assumed that a linear increase is foreseen from nearly no participation in smart services to a 100% participation by 2030. That implies that the benefits allocated per public charge point[34] relative to the benefits generated by 1 EV[35] are gradually increasing from 14% in 2021 to 69% in 2025 and further to 138% in 2030. Under these assumptions the 3 million public charging points in 2030 would lead to benefits of 14 million per year compared to the baseline scenario. For the period 2021 to 2030 this results in 50 million additional benefits.

Net benefits of policy option B

In order to derive the net benefits of policy option B, the net benefits from unidirectional smart charging—i.e. the total benefits, less investment costs—for each year from 2021 to 2030 were derived in a first step. More specifically, these net benefits were derived for the share of additional chargers resulting from policy option B, relative to the baseline scenario. The net present value, as of 2021, of these net benefits was then derived in a second step. The net present value uses a discounting factor for future net benefit flows in order to account for the time value of money[36].

Policy option B would result in the roll-out of an additional 90,250 unidirectional smart charging points, by 2030, relative to the baseline scenario. Based on the assumptions outlined above, the **net present value of total net benefits accruing from the deployment of additional**

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[34] 114,3 euro as in the above calculation

[35] 83 euro as in footnote 42

[36] The use of discounting values future benefits at a discounted, i.e. lower rate than current benefits. We have used a discount rate of 4% in our calculations, in line with the Better Regulation Guidelines on cost-benefit analysis.

unidirectional smart charging points under policy option B would amount to over 29 million € [37].

The period in scope for the determination of costs and benefits is 2021 to 2030. However, the ramp-up of public charger deployment is such that many charging points are expected to be installed in the latter half of the decade. Given a 10-year lifespan for EV charging points, they would contribute to benefits well into the 2030s. These benefits were not counted, partly due to the uncertainty in the rapidly changing flexibility markets and the EV charging ecosystem. Nevertheless, our estimates represent a lower bound estimate for net benefits as a result.

These benefits, however, represent an average value expected across the EU. It is likely that the cost-benefit ratio will vary significantly from one region to the next, and from one charging point to the next, depending on a number of factors such as:

- Local grid conditions: in areas with strong distribution grids that are currently underutilised, unidirectional smart charging may not result in sufficient monetised benefits to cover the investment costs;
- Charge point use cases: the cost-benefit analysis presented here builds on assumption of a minimum level of occupancy for charge points. Should charge points be underutilised, they may not be able to leverage the full benefits of flexibility.

In summary, these benefits enable an increased flexibility of the European power system and the reduction of stress in the power system due to (1) lowering the peak demand, and (2) supporting power supply during periods with low solar and wind infeed. They also support the emergence of new revenue streams within this system, the creation of new jobs as well as of new business models not directly related to smart charging and its surrounding ecosystem (e.g. for commercial properties).

6.3. Cost-benefit analysis for policy option C

Type of costs	Quantification / explanation
Hardware costs	Bidirectional smart charging points require additional hardware, including communications and metering devices, in order to implement smart functionalities, similarly to unidirectional smart functionalities. In order to feed electricity back into the grid, bidirectional smart charging points must also include an inverter, allowing for the conversion of DC current flowing from the battery into AC electricity[38]. The cost premium for a bidirectional smart charging points, over a non-smart charger, is estimated at approximately 7,000€ in 2021. This cost mainly comprises the inverter required to provide AC current to the grid, from the DC current delivered by EV batteries.

[37] The total, non-discounted costs of policy option B over 10 years, relative to the baseline scenario, are estimated at € 9.5 million, while the total benefits are estimated at € 51 million.

[38] Integrating inverters into chargers is one of two main ways of deploying smart bidirectional charging. The other means would require additional capabilities from the inverters existing in cars. While the unit cost of the latter option is lower than the unit cost for integrating inverters into chargers, this cost would have to be borne by all (or a significant portion) of EVs sold. Stakeholders overwhelmingly agree that both solutions will likely coexist, and that it would be incautious to favour one solution over the other. Nevertheless, for the sake of coherence, and considering the attention given in this study to AFID—which concerns itself with EV infrastructure rather than EVs—our cost estimates are based on the former, i.e. on the premise that the bidirectional charging capability would be integrated in charging points.

Software costs, including costs of ensuring protocols	Similarly to unidirectional smart charging points, bidirectional smart charging points must comply with certain protocols in order to fully utilise smart charging capabilities. Charging points developed under the impulse of policy option C can be expected to use mostly off-the-shelf software solutions. The costs of these software solutions, per charging point, are expected to scale down with the growth in the smart charging market.
Costs of developing smart charging protocols	Similarly to unidirectional smart charging points, there are costs associated with development smart charging protocols, which would nevertheless materialise regardless of the choice of policy option.
Operational costs	Similarly to unidirectional smart charging, the management of bidirectional smart charging will entail operational costs throughout the smart charging value chain, most importantly for aggregators. The operational management of smart charging will include negotiating contracts with end-users and procurers of flexibility, monitoring the status of networks of smart chargers, and supporting business functions. These costs essentially constitute a pass-through cost, and are expected to decline, on a per-charger basis, as a result of a greater roll-out of smart charging, and with increased digitalisation allowing for a higher degree of automation.

The main point of costs for implementing this policy option from a quantitative perspective is the comprehensive roll-out of bidirectional smart charging points. Requiring all chargers to be bidirectional smart chargers as of 2025 would lead to a significant uptick in their development, as they are not expected to be deployed in large numbers without policy intervention, unlike unidirectional smart charging points. This is largely due to the high cost premium for bidirectional smart charging points, relative to the cost premium for unidirectional smart charging points.

	2025	2030
Number of bidirectional smart charging points, policy option A	37,050	165,300
Number of bidirectional smart charging points, policy option C	61,750	1,581,750
Cost premium for a bidirectional smart charging point, policy option A	€ 3,854	€ 2,854
Cost premium for a bidirectional smart charging point, policy option B	€ 3,478	€ 1,813

Referring to the average costs of a charging point without smart features (1,000€) and a bidirectional smart charging points (8,000€) presented in the section above, the cost premium for a unidirectional smart charger in 2021 is assumed to be 7,000€. This cost can be expected to decline with the roll-out of smart chargers. Based on a learning curve model assuming a learning rate of 13%[39], and an average annual growth rate in smart charger deployment of 56% to 2030, the cost premium for a bidirectional smart charging point in 2025 is estimated to be € 3,854, and in 2030 to be € 2,854 under the baseline scenario.

Policy option C is expected to lead to an accelerated roll-out of bidirectional smart charging points, spilling over to private chargers as well. Based on a greater annual growth rate of 96% in bidirectional smart charging point deployment, the cost premium for a bidirectional smart charger in 2025 is estimated to be 3,478€, and in 2030 to be 1,813€ under policy option C.

Just over 35,000 bidirectional smart charging points are expected to be deployed from 2021 to 2025, and an additional 128,250 from 2025 to 2030 under the baseline scenario. Policy option C would result in the deployment of nearly 60,000 bidirectional smart charging points from 2021 to 2025, prior to the policy measure coming into force. One expected benefit of policy option C would be to increase awareness of the benefits of bidirectional smart charging, leading to increased voluntary adoption prior to 2025. All public charging points installed as of 2025 would be bidirectional smart charging points. Policy option C would result in **total additional costs of approximately 2.8 billion€** between 2021 and 2030 for installing additional smart bidirectional charging points, relative to the baseline scenario.

Benefits of policy option C

The benefits of mandating the roll-out of bidirectional smart chargers are largely similar to those accruing from the deployment of unidirectional smart chargers. The main difference resides in the fact that bidirectional charging allows for discharging electricity to the grid, leading to greater potential for providing flexibility services and for arbitrage, as evidence by the following:

- Arbitrage: using bidirectional smart charging, EV users can charge when electricity is relatively affordable, and discharge back to the grid when electricity is more expensive.
- Flexibility services: EVs connected to a bidirectional smart charging point can provide up- and down-regulation services. With unidirectional smart charging, the amount of flexibility that can be provided to the grid is limited by the battery's discharge level—once the battery is charged, it can no longer provide flexibility services. With bidirectional smart charging, the battery may be charged and discharged multiple times while the EV remains plugged in, leading to a greater potential for providing flexibility services.

[39] The learning rate of 13% is in line with other comparable reports, including a report by Element Energy (Element Energy, 2019, VG2B – Requirements for market scale-up, available online at http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/06/V2GB_WP-4-report-Requirements-for-market-scale-up.pdf). It results in cost estimates generally in line with expected market developments, including for instance with the announcement of the Wallbox Quasar which is expected to retail for USD 4,000.

The following table provides a quantification (where possible) or explanation of the different benefits of bidirectional smart charging[40]:

Type of benefits	Quantification / explanation
Arbitrage benefits	As stated above, bidirectional smart charging allows for greater arbitrage benefits than unidirectional smart charging. Bidirectional smart charging could contribute to benefits in the range of 86€[41,42], per EV per year, as regards benefits from arbitrage.
Benefits stemming from services to DSOs	As stated above, bidirectional smart charging may allow for greater benefits as regards services to DSOs than unidirectional smart charging, in the presence of well-functioning flexibility markets. In their absence, however, the analysis applies a conservative estimate of the value of bidirectional smart charging benefits as regards services to DSOs, assuming them to be equal to those for unidirectional smart charging. Bidirectional smart charging could contribute to benefits in the range of under policy option B mentioned € 26 per EV per year, as regards benefits from services to DSOs. As discussed above in the discussion on the benefits of policy option B, prices paid for DSO services will vary in time, according to observed congestion levels and the status of competing flexibility suppliers, and across regions, depending on the strengths of distribution grids.
Benefits stemming from services to TSOs	As stated above, bidirectional smart charging allows for greater benefits as regards services to TSOs than smart unidirectional charging. Bidirectional smart charging could contribute to benefits in the range of 55€[43] per EV per year, as regards benefits from services to TSOs. As discussed in section 1 above, the value of benefits provided to TSOs is expected to fall concurrently with declining prices of battery storage.
Support of the integration of renewable energy sources into the electricity grid.	Similarly but with a higher impact potential compared to unidirectional smart charging, bidirectional smart charging has the potential to help integrate additional renewable energy sources into the electricity grid.

[40] Monetised benefits presented in this table were derived from a triangulation of a number of sources, including a report by Elia (Elia, Accelerating to net zero: redefining energy and mobility, 2020, Available online at https://www.elia.be/-/media/project/elia/shared/documents/elia-group/publications/studies-and-reports/20201120_accelerating-to-net-zero-redefining-energy-and-mobility.pdf), a report by Elaad (Elaad, Smart Charging Guide, 2020, Available online at https://www.elaad.nl/uploads/files/Smart_Charging_Guide_EN_single_page.pdf) and a report by Element Energy (Element Energy, 2019, VG2B – Requirements for market scale-up, available online at http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/06/V2GB_WP-4-report-Requirements-for-market-scale-up.pdf)

[41] http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/06/V2GB_WP-4-report-Requirements-for-market-scale-up.pdf

[42] Elia, Accelerating to net zero: redefining energy and mobility, 2020, Available online at https://www.elia.be/-/media/project/elia/shared/documents/elia-group/publications/studies-and-reports/20201120_accelerating-to-net-zero-redefining-energy-and-mobility.pdf

[43] http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/06/V2GB_WP-4-report-Requirements-for-market-scale-up.pdf

Reduction of CO_2 emissions	Similarly but with a higher impact potential compared to unidirectional smart charging, bidirectional smart charging has the potential to help reduce CO_2 emissions through the greater integration of renewable energy sources into the electricity grid.

Based on the combined benefits from arbitrage, and providing services to DSOs and TSOs, each EV using bidirectional smart charging could result in benefits of up to 167€ per year[44]. As discussed above, policy option C would result in the deployment of over 1.4 million bidirectional smart charging points, over and above what is expected to occur under the baseline scenario. By considering the same utilisation rate of the charging points as per option B, these 1.4 million bidirectional smart charging points could lead to benefits of almost 1 billion € per year in 2030.

Net benefits of policy option C

In order to derive the net benefits of policy option C, the net benefits—i.e. the total benefits, less investment costs—for each year from 2021 to 2030 were determined in a first step. More specifically, these net benefits were determined for the share of additional chargers resulting from policy option C, relative to the baseline scenario. In a second step, the net present value, as of 2021, of these net benefits was detemined. The net present value uses a discounting factor for future net benefit flows in order to account for the time value of money[45]. Policy option C would result in the roll-out of an additional 1.4 million bidirectional smart charging points, by 2030, relative to the baseline scenario. Based on the assumptions outlined above, the **net present value of total net benefits accruing from the deployment of additional bidirectional smart charging points under policy option C would be negative of 1.4 billion €[46].**

6.4. Cost-benefit analysis for policy option D

The costs and benefits of policy option D will add to those of policy option B. Policy option D includes an additional measure calling for the support to pilot projects for bidirectional smart charging. This support is somehow accounted for within current funding programmes. Horizon 2020 funded projects such as Invade[47] are currently exploring the potential for demand-side flexibility, including through bidirectional smart charging. However, the above described cost-benefit model shows that either a nearly-prohibitive 25% year-on-year increase on R&D spending would be required as of 2024 to achieve a break-even for the discounted net benefit by 2030, or an substantial increase of the value of flexibility that can be offered through bidirectional smart charging needs to increase to above 500 euro.

This confirms the statements by stakeholders consulted throughout the course of this study who generally agree that bidirectional smart charging may not be sufficiently beneficial to justify its costs in all jurisdictions. Prior to calling for a broader roll-out of bidirectional smart charging infrastructure, it would be necessary to determine the optimal conditions for bidirectional smart charging through well-selected pilot projects in areas where the value of flexibility services is expected to increase substantially in the near-future. Different solutions may apply to different

[44] Please note that it may not be possible to fully realise the combined benefits from arbitrage, services to TSOs, and services to DSOs. Smart charging can be directed to target lower electricity prices (arbitrage), or to provide services to TSOs and DSOs, but it is likely that these objectives are not always fully aligned.

[45] The use of discounting values future benefits at a discounted, i.e. lower rate than current benefits. We have used a discount rate of 4% in our calculations, in line with the Better Regulation Guidelines on cost-benefit analysis.

[46] The total, non-discounted costs of policy option C over 10 years, relative to the baseline scenario, are estimated at € 2.8 billion, while the total benefits are estimated at just under € 2 billion.

[47] https://h2020invade.eu/

cases, as bidirectional smart charging can be implemented in two main ways, as discussed in sections 3.1 and 6.3 above.

The pilot projects supported should focus on areas where smart bidirectional charging is expected to be most relevant. A common example of such areas would be densely populated cities, where grid connection upgrades are costly. Annex 9.1 presents the main conclusions of a bidirectional smart charging project in Denmark. The project demonstrated that there can be a positive business case for EV users participating in bidirectional smart charging, and for the intermediaries facilitating their participation in TSO and DSO flexibility markets[48]. One key finding of the project is that jurisdictions where the grid upgrades necessary to accommodate growing electricity demand are costly, relative to other jurisdictions, are the most suitable candidates for smart bidirectional charging.

Carrying out pilot projects with the express aim of shedding light on the optimal conditions under which bidirectional smart charging leads to greater benefits than its costs would help determine the feasibility of bidirectional smart charging. From this, more targeted policy measures could be developed, allowing for a potentially accelerated roll-out of bidirectional smart charging.

7. Concluding comparison of policy options and recommendations

This section presents the expected impacts of the policy options discussed above. The impacts are assessed according to the following criteria:

- Effectiveness: to which extent does each policy option contribute to achieving the specific objectives presented in section 5.1 above?
- Efficiency: do the benefits associated with these policy options outweigh their costs?
- Proportionality: are the measures foreseen under these policy options proportional to the objectives, or do they go beyond what is needed to achieve the objectives?
- Feasibility: is there a general consensus among business, civil society and other stakeholders on the desirability of implementing the policy options?

The below table using a scale from 0 (very low) to 5 (very high) in line with the criteria above.

[48] In this case, an aggregator acted as the CPO, managing the charging stations providing bidirectional smart charging

Criterion	Policy option A	Policy option B	Policy option C	Policy option D
Effectiveness	**Policy option A is neutral by design, as regards effectiveness.** A share of chargers developed from 2021 to 2030 are expected to have smart functionalities despite a lack of policy intervention, thanks to a **positive business case** and **overwhelming stakeholder support** throughout the EV charging ecosystem. Additionally, some MS have **already enacted legislation mandating smart charging**, such as France, where as of 2019, all new publicly accessible charging points must have smart capabilities[49]. Without policy intervention, a significant share of newly installed EV chargers would, nevertheless, be non-smart, particularly in cost-sensitive jurisdictions. This would lead to **significant investment costs across the EV charging ecosystem**.	**Policy option B is ranked 3, on a scale of 0 to 5, as regards effectiveness.** Overall, this policy option would contribute significantly to achieving the objective of **reducing undue costs for DSOs and TSOs**. The requirement for public chargers to have unidirectional smart functionality, as of 2025, would send a strong signal to the EVSE market. Policy option B would lead to a greater share of smart chargers being developed, relative to the baseline scenario. In the case of public chargers, this share would amount to 100% of the regular power (i.e. <22 kW) chargers developed as of 2025. For private and semi-public areas[50], the development of smart chargers in the public space would be expected to lead to lower hardware costs for smart chargers, and accrued publicity as to the benefits of smart	**Policy option C is ranked 4, on a scale of 0 to 5, as regards effectiveness.** Policy option C builds on the impacts of policy option B, with an additional requirement for a share of EV chargers to be capable of bidirectional smart charging. The cost premium for bidirectional smart chargers, relative to a non-smart charger, is significantly greater than the cost premium for a unidirectional smart charger. Nevertheless, under certain conditions, the benefits expected from bidirectional smart charging far outweigh these costs. Mandating the roll-out of smart, under policy option C, would be highly effective at achieving the objective of **reducing undue costs for DSOs and TSOs**.	**Policy option D is ranked 5, on a scale of 0 to 5, as regards effectiveness.** Policy option D builds on the impacts of policy option B or C. In addition, policy option D would allow for an accelerated and targeted roll-out of bidirectional smart charging, thanks to the lessons learned from pilot projects on bidirectional smart charging. This accelerated roll-out of bidirectional smart charging would lead to increased benefits, thanks to the greater ability to provide flexibility services through bidirectional smart charging. This would contribute to reaching the objective of cost-efficient integration of EVs into electricity grids.

[49] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000037248291/

[50] Semi-public chargers comprise chargers located on private, but publicly accessible property such as parking garages, grocery store lots and hotels.

	The integration of electric vehicles into electricity grids through means other than smart charging (e.g. reinforcement of local grids, investments in additional peak power generation capacity) would not be as cost-efficient as smart charging in many jurisdictions. In particular, the investments in additional peak power generation capacity, to address peak demand for uncoordinated EV charging, would generally be incompatible with decarbonisation targets, as peaking power plants are typically powered by fossil fuels.	charging. This is expected to **contribute to the uptake of smart charging in private areas**, beyond the legislative requirement for public charging. Therefore, policy option B is expected to be **highly effective**, considering its impacts on both public, and semi-public and private charging.		
Efficiency	**Policy option A is neutral by design, as regards efficiency.**	**Policy option B is ranked 5, on a scale of 0 to 5, as regards efficiency.** The cost-benefit analysis for policy option B presents a positive outcome. The benefits of the policy option outweigh the costs. Mandating public smart charging appears to be the most efficient way to achieve the objectives.	**Policy option C is ranked 0, on a scale of 0 to 5, as regards efficiency.** The cost-benefit analysis for policy option C presents a strongly negative outcome. The costs of the policy option far outweigh the benefits.	**Policy option D is ranked 3, on a scale of 0 to 5, as regards efficiency.** Building on the assessment of policy option B or C, it appears that policy option D could further help achieve the objectives, provided financial support is dedicated to pilots in well-selected areas where there is expected to be a viable business case.
Proportionality	**Policy option A is neutral by design, as regards proportionality.**	**Policy option B is ranked 4, on a scale of 0 to 5, as regards proportionality.** Policy option B is proportional in relation to the objectives. It does	**Policy option C is ranked 2, on a scale of 0 to 5, as regards proportionality.** Similarly to option B, option C is rated as proportional in relation to	**Policy option D is ranked 3, on a scale of 0 to 5, as regards proportionality.** The assessment follows that of option B or C. The additional

		not go beyond what is needed to achieve the objectives. A recommendation, rather than an obligation to install unidirectional smart chargers could potentially contribute to the objectives as well. However, a recommendation in this case would be expected to fall short. Taking the example of digital smart meters, it appears that even a legislative obligation—albeit a partial one—can fall short of reaching initial deployment targets. Therefore, a recommendation is not expected to be sufficient, and a legislative obligation is not disproportionate.	the objectives. A recommendation to install bidirectional smart chargers could potentially contribute to the objectives as well. However, it would also be expected to fall short, particularly given the high cost premium for bidirectional smart chargers relative to non-smart chargers. Nevertheless, it is likely that the costs of bidirectional smart chargers would outweigh their benefits if not applied in well-selected areas.	measure calling for support to pilot projects related to bidirectional smart charging is proportional with regards to the objectives, if rolled out in well-selected areas.
Feasibility	**Policy option A is neutral by design, as regards feasibility.**	**Policy option B is rated 4, on a scale of 0 to 5, as regards feasibility.** While the cost premium for unidirectional smart chargers may at first be a deterrent, it can be expected to drop substantially with more widespread adoption. In comparison with the roll-out of smart digital meters, the deployment of unidirectional smart chargers affects far fewer consumers, and results	**Policy option C is rated 2, on a scale of 0 to 5, as regards feasibility.** Policy option C has a low feasibility rating. On the one hand, it is the highest cost option, and the high cost of the option would make it more difficult to justify, vis-à-vis civil society, MS, and other stakeholders. More importantly, stakeholders in the EV charging ecosystem are	**Policy option D is rated 4 on a scale of 0 to 5, as regards feasibility.** The assessment follows that of option B or C. The additional measure calling for support to well-selected pilot projects related to bidirectional smart charging is considered feasible. . Stakeholders across the EV charging ecosystem have voiced support for measures in favour of pilot projects for

		in more immediately tangible benefits across the entire electricity sector. Based on stakeholder consultation carried out throughout the course of this project, unidirectional smart charging is overwhelmingly supported by DSOs, TSOs, EV and EVSE manufacturers, and other stakeholders in the EV charging ecosystem.	divided as to the question of how bidirectional smart charging will be implemented practically. Most agree, however, that requiring all chargers to be bidirectional smart capable would likely be imprudent, and would possibly create excessive burden and/or lead to market distortions.	bidirectional smart charging. It is to be highlighted that pilot projects will be set-up in well-selected locations.

Our comparative analysis of policy options above builds on the policy measures described in Chapter 5, building on policy measures defined in Chapter 4, the assessment work regarding the technical and regulatory barriers to unidirectional and bidirectional smart charging described in Chapter 3, and the assessment of best practices presented in Chapter 2. While Chapters 2-4 of the study have a wider scope, Chapters 5 and 6 focus on public charging infrastructure. The analysis was also informed by the cost-benefit analysis of policy options, which reveals significant net benefits from the roll-out of unidirectional smart charging points in Chapter 6.

As discussed in Chapter 6 above, these cost-benefit estimates provide an average figure across all Member States. They are, nevertheless, expected to vary significantly from one region to the other, depending on the state of local distribution networks, on the share of renewables in the electricity mix, and a number of other factors. The policy recommendations in this report rest not only on an analysis of the cost-benefit ratio for smart charging, but on a number of additional factors, including the following:

- Coherence with EU policy: the Directive on common rules for the internal market for electricity (EU) 2019/944, in its recital 41, states that "[demand] response is pivotal to enabling the smart charging of electric vehicles and thereby enabling the efficient integration of electric vehicles into the electricity grid which will be crucial for the process of decarbonising transport."[51] Additionally, the EU Strategy for Energy System Integration[52] states that storage technologies are expected to provide flexibility to energy systems, helping to integrate additional shares of variable renewable energy, in line with the goal of decarbonising the EU economy by 2050. EVs could represent 20% of our daily flexibility needs by 2050[53].
- Stakeholder support: the call for public chargers to be at least capable of unidirectional smart charging is supported by a wide range of stakeholders consulted through this study, including EV and EVSE manufacturers, TSOs, and aggregators. The analysis encompasses the results of the entire project as a result.

Based on this comparison, policy option B should be considered, combined with policy option D. As discussed earlier, these recommendations are based on a thorough assessment of stakeholder opinions as well as an impact assessment of the policy options, considering among others their coherence with EU policy. Nevertheless, these recommendations may be nuanced in light of the differences between Member States as regards the state of their distribution and transmission networks, shares of renewable energy in the electricity mix, and level of EV deployment. These differences, as discussed, may affect the business case for smart charging. Therefore, it may be advisable to consider formulating policy measure L2 in the following way:

- In Member States where this would be cost-beneficial, require all new public recharging points under and including 22 kW to be at least smart unidirectional charging points from 2025 onwards.

Nevertheless, nuancing the policy measure as above is not recommended based on the analysis. The overwhelming majority of stakeholders consulted in the context of this support the development of smart unidirectional charging as a minimum. The main argument in favour of a strong policy measure concerns stranded assets: should Member States choose to opt out of a mandate for smart unidirectional charging, this may lead to a large number of non-smart charging points being developed in certain areas. With increasing shares of variable renewable energy sources in Member States' electricity mix putting pressures on grids,

[51] Directive on common rules for the internal market for electricity (EU) 2019/944

[52] COM(2020) 299 final

[53] Ibid.

demand response is growing increasingly important as a tool to enable flexibility. The presence of a possibly significant number of non-smart charging points would hinder the ability of EV users and third parties to participate in demand response. This infrastructure could effectively comprise stranded assets. In order to avoid Member States being locked into inadequate infrastructure, a strong mandate at EU level is recommended.

Additionally, we formulate the following recommendations:

- Define, in EU legislation, the meaning of smart charging--i.e. a smart recharging point is a recharging point that can, at the minimum, be remotely monitored (charging data, electricity exchange with the grid, charging power, time, current), remotely controlled to start or stop the charging (charging time, power or current) used at least for recharging the electric vehicle's battery.
- Recommend the use of open and industry supported communication protocols and standards for unidirectional and bidirectional smart recharging infrastructure to assure interoperability, taking into account the need for cybersecurity.
- Recharging infrastructure purchased through public procurement should consist of at least unidirectional smart charging points.
- Support should be provided to pilot projects across the EU with a view to assessing the impacts of certain factors on the cost-effectiveness of bidirectional smart charging in well-selected areas.

These recommendations, and the main focus of our cost-benefit analysis, extend only to public charging points. Nevertheless, in order to achieve the cost-effective integration of EVs into the electricity grid, it is crucial that private charging points be at least unidirectional smart charging points as well. According to most estimates, the majority of charging activity - approximately 80% - will occur in private locations such as EV users' homes or offices[54]. It is therefore highly recommended that action is taken, for instance within the current process of revising the Energy Performance of Buildings Directive, to make sure that all new chargers installed in private locations are smart as well.

[54] Smarten, Making electric vehicles integral parts of the power system, 2019, Available online at https://www.smarten.eu/wp-content/uploads/2019/07/FINAL-smartEn-White-Paper-E-Mobility.pdf.

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9. Annexes

9.1. Best Practice case studies

This annex presents a selection of reports on best practices for the development of smart charging.

Project
SEEV4-CITY - Flexpower Project, Netherlands
Power Your Drive, United States
The Electric Nation Project, United Kingdom
Charge Forward Project, United States
The Smart Electric Urban Logistics Project, United Kingdom
Mayor of London / Gnewt Cargo Electric Vehicle Trial, United Kingdom
Smart Solar Charging Network, Netherlands
The Parker Project, Denmark

SEEV4-CITY, Flexpower Project*, Netherlands

About the project

Project Type

Operational Pilot

Duration

2016-2019

Project actors

- City of Amsterdam
- Nuon/Vattenfall
- Liander
- ElaadNL

Type of charging

Smart public charging

Expenditure

5 million for all 6 SEEV4-City pilots, including Flexpower

Funding

European Regional Development Fund

Project objectives & description

Large-scale public smart charging pilot aiming to reduce the impact of EV uptake on the grid through smart charging, and to integrate renewable energy production. The pilot features a first phase with 52 public charging stations with a static charging profile and a second phase with 432 charging stations with a flexible and renewable capacity profile.

- Reduce EVs grid impact and peak loads by adapting EVs charging speeds
- Match charging demand with renewable energy generation
- Assess the business case for smart charging
- **52 charging stations** with a static charging profile (from Amsterdam's public charging stations network)
- **432 charging stations** with a flexible capacity profile (from Amsterdam's public charging stations network)
- **Flexpower capacity profiles** to adapt charging patterns to expected sun intensity
- All EVs using Amsterdam's public charging stations network considered

Key lessons learned

Peak Load Reduction

The Flexpower charging profile proved to be a viable solution for balancing the load on the electricity grid. By reducing charging speeds at peak demand times and injecting higher current levels during off-peak hours, an average peak reduction of 470 kW per evening was generated during the trial. This exercise had very limited impact on EV users and did not lead to a change in their charging behaviours in terms of preferential charging stations.

Avoided grid investments

The project was based on strong cooperation with the local DSO, Liander, and highlighted clear benefits from its perspective. It demonstrated that an average reduction of 1.1 kW per charging station was realised from the Flexpower profile during the pilot. This reduction was translated into €47,000 of avoided investments for strengthening the grid on the long term. From this, it was concluded that the application of a time dependent smart charging profile should first be implemented in weak parts of the grid infrastructure.

Charging from renewables

The project aimed at providing a better match between charging demand and solar generation by increasing charging current limits during sunnier days. The objective was to investigate to what extent EVs can be used to absorb peaks in local solar power generation. The project highlighted that, to further match charging demand with renewables generation, more dynamic profiles, stringent current limits (e.g. in the morning) and consumer incentives are needed (e.g. price incentives).

Replicability & maturity assessment

Technical maturity

The project proved most successful for advanced BEV models with higher charging speeds. The project's technical potential in other contexts will therefore increase as fleet compositions move to fast charging BEVs. In parallel, on open standards, the project successfully implemented the OSCP and OCPP and developed a generic process that can be applied to other contexts using the same protocols.

Market maturity

Applied in other contexts, the Flexpower model is primarily expected to benefit DSOs by avoiding costly grid investments. For CPOs, the business case depends on the additional cost incurred for upgrading grid connections. In the pilot's case (Amsterdam), the upgrade to 3x35 A connections costs around €700 per charging station annually. This cost varies greatly per grid operator and country. The project's model is therefore most applicable in areas where grid connection costs are limited.

Regulatory maturity

The Flexpower model relies on open protocols such as OSCP and OCPP. To replicate the model, public charging stations must be made smart ready, with smart meters and firmwares allowing for the integration of protocols. Further, even though beneficial to grid operators, the electricity network tariff design in the Netherlands makes high capacity grid connections expensive and does not provide incentive for their instalment. This will be key for the development of the model in the Netherlands and beyond, being based on faster charging during off-peak hours.

*SEEV4-CITY, Flexpower Project. (2020). https://www.seev4-city.eu/wp-content/uploads/2020/07/SEEV4-City-Flexpower-Operational-Pilot-Final-Report.pdf (2019). https://www.elaad.nl/uploads/files/SEEV4_city_OP_Amsterdam_Flexpower_1.pdf

Power Your Drive*, United States

About the project

Project Type	Duration	Project actors	Type of charging
Operational Pilot	2016 - ongoing	• San Diego Gas & Electric (SDG&E) • ChargePoint	Smart public charging and at the workplace
Expenditure	**Funding**		
US$70 million	California Public Utilities Commission (CPUC)		

Project objectives & description

Power Your Drive (PYD) is aimed at integrating electric vehicles with the grid through a day-ahead hourly rate promoting charging during grid friendly hours and supporting charging from renewable energy. It aims at increasing the adoption of electric vehicles at the workplace and multi-unit dwelling properties by installing 3,040 charging stations at 254 sites across San Diego, with a special focus on disadvantaged communities. A total of 4,112 EV drivers are enrolled in the program.

- Utility-driven project aimed at integrating electric vehicles with the grid
- Special pricing plan and billing options incentivizing grid-friendly EV charging
- Focus on disadvantaged communities
- **3,040 charging stations** at 254 sites across San Diego (Workplaces, Multi-unit dwelling properties, Schools)
- **4,112 EV drivers** enrolled in the program

Key lessons learned

Dynamic hourly pricing

PYD uses a dynamic hourly pricing scheme (VGI rate), shared with users a day ahead for them to optimize their charging times through an app. Customers are able to set a maximum charging price, when the hourly price exceeds the set maximum price, charging is interrupted (higher prices at times of peak demand and with less renewable energy generation). This dynamic pricing has motivated participants to optimize their charging schedules: 86% of charging in the pilot took place off-peak.

Charging from renewables

Through the project's special pricing, PYD managed to optimize charging with high renewable penetration during off-peak hours. Overall, PYD offered a more renewable load profile than SDG&E's (70% renewable for PYD against 45% for SDG&E). Workplace charging during the pilot proved to be 72% renewable compared to 63% for multi-unit dwellings, primarily due to the alignment of workplace charging with renewable energy generation. In this context, the program successfully resulted in GHG emission reductions of 4,050 MT and replaced 1.7 million L of fuel.

Locational pricing

PYD offers charging at multiple sites and locations including workplaces, multiple-unit housing and schools notably across San Diego area. PYD incorporated circuit level pricing to provide equitable pricing at different locations, as pricing may vary between locations primarily due to differences in transmission costs between sites. Peak load times may also vary between sites e.g. homes and workplaces. By applying the same price to every circuit, PYD guarantees equitable pricing: each location has the same pricing structure, although at different times.

Replicability & maturity assessment

Technical maturity

The project proved viable from a technical point of view and demonstrated that price incentives can support peak load management and renewables integration. Issues were raised related to submeters data processing due to the lack of standardized data formats and business processes. The program would nevertheless be replicable across vehicle types and locations and SDG&E has launched an extension of the project: PYD for fleets for medium and heavy-duty vehicles.

Market maturity

The project was widely accepted by the users and proved to be beneficial from the EV user and utility perspectives. The project estimated an average saving for drivers of $0.26 per kWh, benchmarked with comparable fuel costs. Nevertheless, users also incurred important administrative costs to participate in the project. The project received significant customer interest and 2926 drivers have purchased or leased an EV because of the program. Demand for an additional 470 sites was also expressed from workplaces and multi-dwellings properties during and after the PYD enrolment period. To accommodate for the high demand, an extension of the program has been filed by SDG&E for an additional 2,000 chargers.

Regulatory maturity

At this stage, the project did not raise any regulatory issues that would prevent its development. Overall, the project would be replicable in a context where electricity providers offer dynamic pricing contracts.

*Power Your Drive Results. (2018). https://www.sdge.com/sites/default/files/regulatory/R.18-12-006 [illegible].pdf

The Electric Nation Project*, United Kingdom

About the project

Project Type

Operational Pilot

Duration

2017-2018

Expenditure

£5.9 million

Funding

UK Network Innovation Allowance

Project actors

- Western Power Distribution (WPD)
- EA Technology
- DriveElectric
- Affen
- eVolt
- GreenFlux
- Crowdchange

Type of charging

Smart public charging

Project objectives & description

Large-scale smart charging trial aiming to analyse domestic EV charging patterns, their impact on the grid and the role of financial incentives on the technology's uptake and acceptance. The project relied on 673 EV drivers from Western Power Distribution's region and was supported by a wide-reaching awareness raising campaign.

- Analyse domestic EV charging patterns and their impact on the grid
- Establish a flexibility assessment of these charging patterns
- Assess the impact of ToU pricing as incentive for smart charging uptake
- **673 EV drivers** from Western Power Distribution's regions
- **45 EVs** of different types from 18 vehicle manufacturers incl. BMW, Nissan, Tesla & Mercedes-Benz
- Smart charging operation system provided by Greenflux and Crowdchange

Key lessons learned

Time of Use ("ToU") pricing

ToU pricing proved effective at moving demand away from the evening peak, particularly when supported by smart charging (with an app). The typical early evening peak in EV charging demand was eliminated during the project, to the extent that demand management was no longer required following the introduction of the smart charging scheme. Smart charging successfully supported the management of the ToU tariff.

User acceptance

Clearly communicated financial incentives (in the form of reward vouchers from ToU pricing) proved to be effective means to remove the social barrier of smart charging and to alter participants' charging behaviours. Similarly, the active communications campaign ran as part of the project helped raising awareness about the benefits of smart charging. The technology was widely accepted in the pilot: 76% of the GreenFlux participants stated they would sign up to a smart ToU scheme like the trial one if it was available.

DSO cooperation

The project was led by WPD, the DSO, in cooperation with the different project actors such as the aggregators. Data collected from the smart chargers proved key to WPD. It provided WPD with a strong evidence base to identify which parts of its network were likely to be most affected by the wider uptake of EVs. It was able to assess where smart charging could be used as a cost-effective solution to replace large reinforcement grid investments.

Replicability & maturity assessment

Technical maturity

The project proved to be viable from a technical point of view. It demonstrated that smart charging of EVs at home can provide flexibility to DSOs, by addressing congestion issues, and that smart charging is a viable form of demand management. No particular technical issues were reported as barriers preventing the replication of the pilot.

Market maturity

From the EV user and DSO perspectives, the project proved to be economically viable and could be replicated / tested across other contexts where the implementation of ToU pricing is possible. For the DSO, the project and scaled-up use of smart charging could replace costly investment upgrades in its network to adapt to the rising EV uptake. For the EV user, the ToU pricing rewards proved to be an appropriate incentive to adopt the technology for the pilot. On average, participants received £21 from the nine-week trial.

Regulatory maturity

The project would be replicable in a context where electricity providers offer dynamic pricing contracts together with smart meters. The EU has taken action in this direction through the recast of its Electricity Directive (EU) 2019/944. Incentives for the wider uptake of smart charging infrastructure will also be necessary. In the UK, the recent 'Automated and electric vehicles Act 2018 aims at ensuring that newly installed electric charging points have smart functionalities.

*The Electric Nation Project. (2019). https://www.greenflux.com/wp-content/uploads/ElectricNationProjectSummaryGreenFlux.pdf ; https://www.greenflux.com/wp-content/uploads/ElectricNationSummaryBrochure.pdf

Chargeforward Project*, United States

About the project

Project Type

Operational Pilot

Duration

Phase I (2015-2016)
Phase II (2017 - 2020)

Project actors

- BMW
- Pacific Gas and Electric Co. (PG&E)
- UC Berkeley Transportation Sustainability Research Center

Expenditure

US$4 million (Phase II)

Funding

California Energy Commission's Electric Program Investment Charge

Type of charging

Smart charging at home

Project objectives & description

The pilot explored the potential of smart charging to lower grid operations costs, support renewable energy integration and the role of consumer incentives to encourage the technology's uptake. The project relied on over 400 BEV and PHEV BMW drivers in Northern California, a vehicle telematics data system allowing for the management participants' charging times and a smartphone application.

- Lower costs associated with operating and maintaining the grid
- Support renewable energy integration into the electric grid
- Assess the role of consumer incentives in adopting smart charging
- 400 BMW drivers in Northern California
- BMW vehicle data telematics system for smart charging

Key lessons learned

Charging from renewables

The pilot used a day-ahead renewable energy forecast which was fed to the smart charging system to optimize participants' charging to hours with high renewable energy generation. Based on an awareness raising campaign around the benefits of daytime charging, special messaging and financial incentives in the form of bonuses, over 55% of ChargeForward participants charging came from renewable energy, compared to the 2017 national average of 23%.

Avoided grid investments

BMW together with Kevala analytics calculated the Distribution Deferral Value (value from avoided capital costs related to distribution infrastructure and operations) of 21 smart charging sites under the project. The study found that, through smart charging, vehicles charging during the day (9AM - 5PM) generated around US$67.54 of annual DDV (per year per site). The highest DDV amongst the 21 charging sites reached $461.33.

Incentives to participants

Financial incentives were the greatest motivator for participants to adapt their charging times. A higher price incentives used as part of the Pilot's Earth Week study generated a 225% increase in daytime charging, against a 21% increase when 'High Renewable' messages were sent. Survey results indicated that 31% of respondents were motivated by the financial incentive compared to 17% for the environmental impact. Environmental impacts were motivations for participants to shift their charging times, although not as effective as cash incentives.

Replicability & maturity assessment

Technical maturity

The project successfully used BMW's vehicle telematics system to send optimized charging signals to the vehicle. This system offers key advantages by being mobile, linked to the car directly and not requiring additional hardware, as opposed to charging stations. The project highlighted that vehicle telematics data provides a more complete picture of the vehicle charging, compared with household utility meters. With that said, the pilot was restricted to BMW vehicles and for the model to be replicable at a larger scale, in-vehicle data have to be made accessible to other actors of the smart charging ecosystem.

Market maturity

The project proved to be economically viable from EV user and Utility perspectives. Through the estimation of the Distribution Deferral Value, it was demonstrated that the pilot and smart charging in general can replace costly grid investments for the DSO. For the EV user, it was estimated that drivers could earn around $325 annually if they were to access some of the value streams identified in the study, including demand response and energy price arbitrage through charging optimization.

Regulatory maturity

At this stage, the project did not raise any regulatory issues that would prevent its development. Overall, the project would be replicable in a context where electricity providers offer time of usage pricing policies.

* Chargeforward project final report. (2020). https://bmwmovement.org/bmwreleases-chargeforward-report/

The Smart Electric Urban Logistics Project*, UK

About the project

Project Type
Operational Pilot

Duration
2017-2019

Project actors
- UPS
- UK Power Networks
- Cross River Partnership

Type of charging
Smart Fleet Management

Expenditure
£2,597,644

Funding
Office for Low Emission Vehicles, Innovate UK

Project objectives & description

The project was designed to support the electric transition of UPS' commercial fleet in London. The project relied on 52 electric trucks as part of UPS' 170-vehicle fleet, a smart system integrating energy storage and grid capacity assessment tools in an operational environment.

- Support the wider transition to electric vehicles for larger commercial fleets
- Increase the depot charging capacity through smart charging
- **72 plugin electric trucks** of UPS 170-vehicle central London fleet
- 20 mid-life UPS diesel urban distribution trucks were converted to fully electric models
- High-speed power meter, Active Network Management system, Energy Storage System and smart charge posts

Key lessons learned

Increased charging capacity

By converting 20 of its existing diesel vehicles to fully electric trucks, UPS brought the number of vehicles able to charge at the depot above the maximum of 63 that the charging infrastructure allows for. Through the development of a smart charging system coupling an Active Network Management system and an Energy Storage System, local demand can be dynamically controlled. UPS has proved able to charge its entire electric fleet on a 1,250kVA connection instead of the initially required 2,200kVA.

Grid support

By increasing the connection capacity, the project has demonstrated that smart charging favours the optimisation of existing grid assets. Without smart charging, the increased EV fleet would have required additional, costly electrical equipment and reinforcement of the local grid network. The project, which relied on strong cooperation with the DSO generated important avoided investment costs.

Business-as-usual testing

The project highlighted that smart charging testing is possible and well understood in a fully operational business environment, in a manner that does not negatively impact the fleet operator's activities. Business continuity was key as part of the project as the unavailability of charging could have important financial and reputational consequences. The smart charging system was carefully designed with fail-safe mechanisms ensuring the EVs are fully charged when needed in the morning.

Replicability & maturity assessment

Technical maturity

The project proved successful in addressing UPS' technical requirements and provided a replicable and scalable system design. The system will allow UPS to electrify its entire north London fleet with half of the connection capacity initially required. UK Power Networks aims at expanding its flexible connection offering developed in the project to other customers with large EV charging needs.

Market maturity

The project proved viable for the DSO providing for avoided grid upgrades. For UPS, the company developed a 5-year vision around the project and has developed a methodology to replicated it across other sites but also to transfer the project's learnings to other fleet operators. One aspect raised in the project is the high upfront cost to purchase electric vans compared to internal combustion vehicles. While UPS is a large corporation able to take on these costs, it might prove more difficult for smaller fleet operators.

Regulatory maturity

The project results from the introduction of City of London as an Ultra Low Emission Zones. Such initiatives and policies to improve air quality in urban areas could play an important role in encouraging the uptake of smart charging EVs by fleet operators.

*Smart Electric Urban Logistics project factsheets. (2018). https://crossriverpartnership.org/projects/smart-electric-urban-logistics/

Mayor of London / Gnewt Cargo Electric Vehicle Trial*, UK

About the project

Project Type
Operational Pilot

Duration
2017-2019

Expenditure
Undisclosed

Funding
Office for Low Emission Vehicles, Innovate UK

Project actors
- Mayor of London
- Gnewt Cargo
- UK Power Network
- Innovate UK

Type of charging
Smart Fleet Management

Project objectives & description

The project aimed at examining the benefits of introducing larger EVs as part of Gnewt Cargo's delivery and urban logistics operations, managed through smart charging, and to assess the associated impacts on London roads and power networks. The project relied on 40 EO smart chargers powering Gnewt Cargo's fleet of 70 EVs. The project should deploy an additional 23 smart chargers.

- Assessment of Gnewt Cargo's EVs fleet performance in London
- Analysis the impact of smart charging on the grid
- Generate insights for the adoption of EVs by fleet operators
- 40 smart chargers
- 70 electric vehicles fleet

Key lessons learned

Increased charging capacity

The smart charging system deployed allowed for fleet charging at periods of low demand in order to ensure reduced charging when the overall site might require stronger power. Without this capability, the increased Gnewt Cargo fleet would not be fully charged in the available time. The system allowed to reduce the required connection size to accommodate the extended Gnewt Cargo fleet by over 100%, charging on a grid connection of 120 kVA instead of the initially required 200 kVA.

Avoided grid investments

Smart charging allowed for peak load reduction during the trial, avoiding the need for costly grid upgrade investments. In this particular trial, 130% increase in capacity would have been required without smart charging. The standing charge to upgrade the grid connection to 200 kVA would have increased by £103 per month and other local changes to the network would have been required, making the electrification of fleet operatives uneconomical.

Replicability & maturity assessment

Technical maturity

Issues were encountered in the communications system between the smart charging stations and telematics system which were resolved though coordination between EO charging and Fleet Carma. Regarding replicability, the project highlights that while this integration of tracking and charging systems allows for more precise oversight over the fleet operations, the process can prove lengthy and effort-intensive to fleet operators.

Market maturity

From the DSO perspective, important benefits were derived from avoided grid upgrades. Gnewt Cargo on the other hand benefited from an important decrease in fuel costs, highlighting that the electricity costs to power the electric vans proved to be 75% lower than the fuel costs to power comparable diesel vehicles. With that said, on replicability, the project notes that fleet operators operating without a depot where charging points can be set-up might be challenged in adopting EV fleets and smart charging technology.

Regulatory maturity

The project highlights that a regulatory framework to incentivise the uptake of EVs and smart charging amongst fleet operators is key. Time-of-use tariff and demand-led charging are identified as possible incentives which could enhance the benefits of the technology. Further, the limited market for electric vehicles suited for fleet operations and their high costs largely impede the development of smart electric fleets. The development of Ultra Low Emission Zones as in London could play an important role in encouraging the uptake of smart charging EV fleets.

*Mayor of London / Gnewt Cargo Electric Vehicle Trial. (2020). http://www.avere-france.org/Uploads/Documents/[illegible]-Final%20Report.pdf

Smart Solar Charging Network*, Netherlands

About the project

Project Type

Operational Pilot

Duration

2015-2021

Project actors

- Utrecht Sustainability Institute
- LomboXnet
- ElaadNL
- We Drive Solar
- Jedlix

Type of charging

V2G fleet management

Expenditure

Undisclosed

Funding

European Fund for Regional Development

Project objectives & description

The project aims at developing a network of solar-powered smart V2G charging stations in the city of Utrecht and surrounding provinces. The overarching objectives are to encourage the uptake of EVs in the region and utilize them to support the local electricity grids. The network, aiming to reach 1,000 V2G chargers, is ran together with a car-sharing fleet of 150 Renault ZOEs.

- Network of solar-powered V2G charging stations in Utrecht
- Encourage the mass uptake of EVs and utilize them as support to the grid
- 15 cities surrounding Utrecht involved in the project
- Ambition to reach 1,000 V2G charging stations
- Car-sharing service of 150 Renault ZOEs as part of the project

Key lessons learned

AC V2G chargers

The project relied on AC V2G chargers instead of DC chargers, having identifying some key disadvantages associated with the latter. AC charging stations benefit from one global charging standard compared with DC systems which all have different plugs, allowing for greater interoperability. Furthermore, AC stations are less costly than DC ones, a saving characterised by a more compact design, greater optimization of the system and reduced operational costs on the grid.

V2G open standards

The project successfully relied on the use of open standards including the Open Charge Point Protocol (OCPP) for EVSE management, including for the (dis)charging process. The project is working with the Open Charge Alliance to develop the OCPP 2.0 that will integrate first V2G specifications.

Consumer benefits

Based on a model developed as part of the project, the potential monetary value of V2G to consumers was simulated, based on minutely settlement prices of the Dutch regulating and Reserve Power. The results demonstrated that expected monetary benefits from V2G are high, ranging between €120 and €750 annually per EV owner, depending on EV and user category.

Charging from renewables

The project aims at installing 10,000 solar panels for EV charging. While only preliminary results were published, the upcoming final assessment will provide insights into combining smart charging with local renewable energy production.

Replicability & maturity assessment

Technical maturity

The project successfully tested a set of technological aspects including AC V2G chargers, new ISO 15118 standard and DSO flexibility amongst others. From a technological perspective, the project would be replicable to other European jurisdictions. Latest project results will allow for a deeper assessment of the current technical maturity of the project.

Market maturity

The project displays ambitious growth plans, aiming to scale-up to a network of 1,000 V2G chargers in and around the city of Utrecht. Project results post-2021 will provide important insights in terms of consumer acceptance of the technology in a large-scale trial, scaling-up and replicability of the business model which was deployed in an operational environment.

Regulatory maturity

From the start of the pilot, the project identified important regulatory barriers to the development of V2G. Some of the identified barriers include: the lack of netting rules for bidirectional charging which lead to double taxation, the lack of incentives to produce local renewable energy in combination with smart charging, the need to establish a level-playing field between public and private charging points and the VAT liability of the EV driver for receiving compensation from bi-directional charging.

* Smart Solar Charging Network. (2017). https://www.elaad.nl/uploads/files/EVS30_paper_-_Smart_Solar_Charging_AC_Vehicle-to-Grid_in_The_Netherlands.pdf (2016); http://nws.eurocities.eu/MediaShell/media/2018AwardsCitiesinactionUtrecht.pdf

The Parker Project*, Denmark

About the project

Project Type

Operational Pilot

Duration

2016-2018

Expenditure

DKK 14,731,471

Funding

ForskEl , Energy Technology Development and Demonstration Program

Project actors

- Nissan
- Mitsubishi Corp.
- PSA
- Insero
- Enel X
- DTU
- Nuvve
- Frederiksberg Forsyning

Type of charging

V2G Fleet Management

Project objectives & description

Operational pilot aiming to test the role of a V2G vehicle fleet in supporting the power grid with a particular focus on frequency regulation services. The project tested technical requirements and standards for V2G and assessed the commercial viability of the technology, based on a fleet of around 35 cars from different vehicle manufacturers.

- Assess the role of V2G in providing grid services
- Specific focus on frequency regulation services
- Test the commercial viability, replicability and scalability of V2G
- Analyse the technical, regulatory and market barriers to V2G deployment
- Cross-brand testing on around 35 cars from different vehicle manufacturers

Key lessons learned

V2G Grid services

The project tested a set of grid services that electric vehicles can provide to the grid through V2G. The project put particular emphasis on frequency regulation services, as the most commercially interesting services. The project demonstrated that the vehicles and charging infrastructure present in Denmark allow for the provision of frequency regulation services.

V2G standards

The project tested a set of technical requirements needed in the EVs and charging infrastructure to support V2G. It determined a list of requirements in terms of controllability, observability and performance which were tested against the different standards and protocols connecting EVs and EVSE. The project found that CHAdeMO is the only standard which currently supports V2G and that other capabilities such as access to battery state-of-charge and vehicle identification through the EVSE need to be considered by all standards to allow for full vehicle-to-grid integration.

Scalability

The project assessed the scalability of providing frequency regulation services by determining the potential earnings generated from performing such services. It was shown that the expected profits largely vary depending of frequency containment regulation prices, V2G charges, energy costs and battery degradation. The maximum estimated profit reached 2,304 Euro per car/year for the best case against -955 Euro per car/year for the worst case, demonstrating the strong variability of the business case.

Replicability & maturity assessment

Technical maturity

The project successfully demonstrated that EVs and V2G allow for the provision of frequency regulation services. It concluded that V2G technology is scalable both in terms of number of EVs, type of FCR (frequency Containment Reserve) service, OEM brands, TSO regions, battery sizes and duration. It identified a set of technical barriers which could nevertheless prevent replicability including: two-way energy loss, long duration frequency bias and battery degradation.

Market maturity

While the project demonstrated a strong business case for V2G and for providing frequency regulation services, it also revealed that this business case is highly dependent on a set of parameters. The project concluded that value streams and the market are ready for these type of services, nevertheless the viability of the business case across different countries is uncertain. Consumers may not be ready to adopt V2G and limited V2G capable cars and chargers are available on the market.

Regulatory maturity

Denmark offered an adequate regulatory environment to run the pilot and Norway, Sweden and France also provide interesting opportunities to offer V2G-based frequency regulation services. Other countries such as Germany could present political and regulatory barriers to the development's technology. The project also identified two key regulatory barriers to the pilot's replicability including the costly requirements for meters which prevent their use in distributed resources but also the required pre-qualification of EVs to provide FCR.

*The Parker Project (2019). https://parker-project.com/wp-content/uploads/2019/03/Parker_Final-report_v1.1_2019.pdf

9.2. List of additional relevant projects

Project Name	Use case	Country	Companies	Type of project	Project dates	Type of charging	Key information
Cranfield centre	Fleet management	UK	E.ON Nissan Virta	Pilot	From 2018	V2G	20 V2G chargers as part of the trial to demonstrate how electric vans and cars could support the UK grid.
Sustainable Porto Santo - Smart Fossil Free Island	Fleet management	Maderia, Portugal	Renault Empresa de Electricidade da Madeira (EEM) The Mobility House	Pilot	From 2018	Smart & V2G	Trial with 20 Renault cars and 40 smart and V2G chargers handed over to public institutions (e.g. police), private companies (e.g. taxi drivers) and private individuals on the island.
City-Zen Smart City	At workplace, public charging	Netherlands	Alliander Enervalis Magnum Cap	Pilot	2014-2019	V2G	Small-scale V2G trial with 4 chargers installed in Amsterdam.
The Outlook	At workplace	Netherlands	EVBox Engie Smappee (Schiphol Real Estate) (Microsoft)	Operational	From 2019	Smart & V2G	40 smart and V2G charging points at the Microsoft Outlook building in Amsterdam.
Bluebird buses	Fleet management	United States, California	Nuvve BlueBird A-Z Bus Sales	Commercial	From 2020	V2G	Commercial Offer for V2G School Buses.
ELBE project (ELectrify Buildings for EVs)	At workplace & public	Germany	Federal Ministry for Economic Affairs and Energy hySOLUTIONS IFB Hamburg Stromnetz Hamburg	Incentive scheme	From 2019	Smart	Incentive scheme for 7,000+ intelligently controlled charging stations to be installed in Hamburg. Prime focus is workplace.
Heritage Hub / Drosso project	Fleet management	Italy	FCA Engie eps Terna	Pilot	From 2020	V2G	Pilot developing a V2G charging plant composed of 32 V2G chargers to connect 64 vehicles. Aim to be extended to interconnect 700 EVs by the end of 2021.
EV Fleet-Centred Local Energy System (EFLES)	Fleet management	UK	UK Power Networks Services UPS Moixa CRP	Pilot	From 2020	V2G	Aim to electrify UPS' 170 fleet. The project builds on the Smart Electric Urban Logistics trial from 2017-19.
Bus2Grid	Fleet management	UK	SSE Enterprise Go-Ahead London BYD	Pilot	2019 - 2021	V2G	Trial on 28 V2G double decker

			Leeds University UK Power Networks				buses in London bus garage.
San Diego Gas & Electric (SDG&E) school buses	Fleet management	United States, California	San Diego Gas & Electric	Pilot	From 2019	V2G	10 V2G school buses trial.
GridMotion	At home, Fleet management	France	PSA Groupe Direct Energie Proxiserve Enel X DTU	Pilot	2017-2020	V2G	Trial with 50 smart unidirectional chargers installed with residential customers around France together with 15 V2G fleet stations in the Paris area.
INEES		Germany	Volkswagen Lichtblek SMA Solar Technology IWES	Pilot	2012-2015	V2G	V2G trial running on 40 bidirectional chargers and with 20 Volkswagen cars in Germany.
Electric Nation Vehicle To Grid	At workplace and home	UK	Western Power Distribution CrowdCharge DriveElectric EA Technology	Pilot	2020-2022	V2G	Pilot recruiting 100 particpants to trial state domestic V2G charging. Follow-up pilot to the Electric Nation smart charging project.
e4Future	Fleet management	UK	Nissan Motors Innovate UK	Pilot	2018 - 2021		V2G pilot to assess the viability for commercial EV fleets to provide energy flexibility.
Invent project	Fleet management	United States, California	San Diego Gas & Electric Nuvve	Commercial pilot	From 2017	V2G	V2G trial developing 50 bidirectional chargers on the University of California San Diego campus.
EDF & Nuvve	Public	UK	EDF Energy Nuvve	Commercial	From 2018	V2G	Partnership announced to roll out 1,500 smart chargers in the UK with V2G capability.

9.3. Selected survey inputs on differences with respect to the barriers between charging at private infrastructure (home charging) and publicly accessible recharging

Some of the identified barriers to smart and bidirectional charging solely apply to either private or public charging or differ depending on which of these applications it applies to. Selected survey inputs on identified differences are presented below.

Table 5: Selected survey responses to the question "Are there differences with respect to the barriers between charging at private infrastructure (home charging) and publicly accessible recharging?" and subsequent suggested actions

Topic	Survey quote	Suggested action
Clear user profitability picture when charging privately	*"The "what do I get for it" question: For home charging, e.g. coupled with a PV installation it is obvious for the user."*	For publicly accessible recharging there need to be some monetary advantage.
Interoperability with other flexible assets when privately charging, e.g. at building level	*"Yes, private charging is often behind the meter and mixed with other DER installed on the premise. Systems operators are reluctant to having mixed assets participate to the system or want to control and monitor every single DER individually behind the meter (including V2G EVs)."*	Assure transparency between aggregator and the grid operator in order to have more system solutions. Otherwise the solutions for behind the grid will be implemented and lead to more individual solutions than system changes.
Long connection duration needed for public bidirectional charging	*"Long duration public charging (e.g. overnight curbside charging from lamppost) is discouraged by excessive requirements. But only long duration connection is interesting for smart charging and V2G."*	This use case for smart-charging could be promoted by supporting specific innovation, for example in curbside lamp-post charging technologies.
Public charging not as relevant for bidirectional charging	*"Electric Vehicles are usually connected to private charging infrastructure for a longer period of time (e.g overnight). Therefore, bidirectional charging makes more sense than at publicly accessible charging points which are used for a shorter period of time. In addition, lower charging voltages/currents at private charging infrastructures (e.g wall box) don't stress the RESS (vehicle traction battery) as much."*	Prioritize supporting private bidirectional charging applications. A problem with public charging mentioned in interview with EnBW is billing, which can be especially complicated for public spaces. Electricity pricing as well as billing needs to be unified across EU so that cars can easily roam around EU and their charges be connected to one billing (e.g. the house bill).
Simpler technical requirements for private charging	*"Connection capacity (kW), availability of digital metering infrastructure, predictability of charging is easier for (semi-) private charging."*	A subscription system and rules would be needed for any sort of smart or bidirectional charging (be it public or private).
Regulatory barriers to charging for collective residential building	*"Private home charging provides valuable use cases, but real technical and governance obstacles remains to equip in collective residential building."*	This is the same issue as for collective self-consumption or energy community which are dealt with under EMD (CEC) and REDII (REC) directives. This is not an exclusive bidirectional charging problem, it rather is a general bidirectional energy usage/energy management problem which is being currently clarified in many member states.

Differences in purpose with private and public charging use cases	*"Private households will aim for independency, public will aim for a better business case."*	Acquire better understanding of the drivers, not only the barriers, to public and private charging. The best approach to wide uptake of smart and bidirectional charging according to interviews is to plan and organize from the system perspective, i.e. not just behind-the-meter, but for the whole energy and mobility nexus.

9.4. Selected survey inputs on significant barriers

Table 6: Selected survey responses to the question "Would you like to elaborate on any of your answers regarding barriers to smart and bidirectional (V2G) charging? For example, but not limited to: Is any barrier much more significant than the others? Are any barriers particularly challenging to address?"

Barrier	Survey comment
Controlled energy markets	*"Enable market and network (DSO) frameworks for flexibility and demand side response services in Electricity Directive (short-term)"* *"Flexibility markets should be open to aggregated resources connected at distribution level and provide long-term price signals in order to reveal a suitable revenue stream and de-risking investors' decisions."*
Lack of awareness of smart charging and the benefits both on public and private sides. Lack of stakeholder knowledge.	*"Few local and regional authorities are aware about the possibilities and few of them only require in the technical specification the charging infrastructure to be V2G/bidirectional compatible."*
Lack of acknowledgement (for example in AFID) that DC charging can be low power	*"Introduce an additional category in AFID directive referring to DC normal charging points (P<=22kW) to formally recognize the existence of such charging points, in particular for V2X use cases, and to define adequate requirements for it."*
Options for bus operators whether or not they want to make use of a charging opportunity - no automatic discharging of public transport vehicles	*"Public transport operators need to be in control of their fleet charging at any time, in order to ensure the smooth execution of their transport services, usually based on a precise schedule. While V2G may offer advantages (either for the operator, or for the grid (stabilization)), it should always be optional for bus operators whether or not they want to make use of this opportunity. There should not be an automatic de-charging of vehicles for the benefit of the grid; rather, such a process should always require a deliberate decision of the bus owner."*

The survey respondents were also asked to name any additional barriers which were not originally included in the survey. In this way, many more up-to-date and unaddressed barriers could be captured. Some of the most relevant additional barriers mentioned by the survey respondents are listed below:

- Legal, not only regulatory, barriers on how to move from consumer to prosumer;
- Lack of frameworks for cyber security;
- Lack of approval of submetering of vehicle and charger data in flexibility markets and effective measures on smart meter allocation;
- Grid connection standards do not cover a certification scheme for "mobile" storage systems (Mode 3 bi-directional charging);
- Existing grid code standards (e.g. EN 50549) do not apply to smart charging;
- Use cases for bi-directional charging dominated by central (privately controlled) eco-systems;
- Lack of stakeholder motivation, especially on the OEM side;
- Rules on flexibility products design and prequalification in existing network codes create an obstacle for independent aggregators to participate to flexibility markets;

- Regulatory incentives favouring the uptake of Plug-in Hybrids (PHEVs), not relevant for smart or bidirectional charging, over Battery Electric Vehicles (BEVs).

9.5. Selected survey inputs on short-term policy recommendations

Table 7: Short-term policy recommendations as provided by selected survey respondents

Stakeholder group	**Policy recommendation**
Suppliers/Aggregators/ EMSP	*"- National: the correct and timely implementation of the Electricity Market Design to ensure EVs are treated as a grid resource and aggregator business models are allowed;* *- EU level with national implications: set mandatory national deployment targets for smart charging, in particular to require smart charging is enabled in both new and renovated residential and commercial buildings;* *- EU: clearly define smart charging and smart charging infrastructure."*
Network operators (TSOs and DSOs)	*"immediate conference table with DSOs to be promoted by EC prio to any structured regulatory or policy decision"*
Civil society	*"1. Rules on metering, flexibility products design and prequalification in existing network codes should be amended to facilitate the entrance of independent aggregators to flexibility markets. This will increase the availability of financially attractive V2G and smart charging offers to consumers.* *2. Rules on data access and interoperability in the electricity sector should be developed in line with GDPR, to give consumers reassurances that their privacy will be protected.* *3. The Energy Taxation Directive should be amended to avoid the risk of double taxation."*
Suppliers/Aggregators/ EMSP	*"1. At the EU level, support the launch of ambitious innovative pilot lines of V2X equipment in order to consolidate technical standards (notably ISO/IEC 15-118-20) and regulatory framework for grid and market access, overcome commercial challenges and promote stronger cross-sectorial cooperation (car manufacturers, automotive suppliers, recharging terminal manufacturers, flexibility operators, …)* *2. At national and EU levels, create dedicated financial supportive schemes (including public grants) for V2X smart-chargers based on interoperable and open communication protocols to help private and public fleets operator and households to equip, car manufacturers to invest: push the volume up in the short-term will drive further cost reductions expected in the mid-term.* *3. At national levels, provide easier grid connection and market access (services to the power system) procedures and requirements to reveal the smart-charging/V2X economic value."*
Network operators (TSOs and DSOs); Suppliers/Aggregators/ EMSP; Charge point operators; Charge point manufacturers; Energy industry	*" - Market design should allow for smart charging, adjust regulation: Avoid double payments of network charges and taxes, Electricity markets should also be developed for non-frequency ancillary services and any other DSO services: e.g. voltage control or synthetic inertia and enable revenue stacking for EVs in different markets (national)* *- Overcome the Lack of access to relevant information on the EV battery allowing mandate access to vehicles data (EU level)* *- Interoperability, harmonised protocols, and standards among the infrastructures and systems should be implemented to enable seamless communication (EU level)"*
Charge point manufacturers	*"1. Government mandates and incentives that all chargers be smart, at least those supported in any way by public funds - and that "smart" means communicating, submetered, remotely controllable, and interoperable (open standards based).*

	2. Access to time of use tariffs or dynamic pricing by all consumers. *3. Smart meters for all consumers to enable TOU and dynamic pricing that provide the economic incentives for smart charging"*
Charge point operators	*"1. removal of double taxation (including levies such as EEG)* *2. clear interfaces and functionality on the vehicle side (ISO 15118-20 including all energy management functionality and optional data points, such as SOC)* *3. accessibility of the V2G functionality for the end user, including low costs, freedom of choice regarding charger and aggregator (non vehicle OEM), and clear implications for warranty"*
Automotive industry	*"AFID has to mandate the need of ISO15118 implementation* *Tax unification for free usage of energy without double taxation* *Funding of private and public DC-Bidi Chargers"*
Standardization bodies	*"National: tariffs to promote smart charging* *EU: enforce standards to guarantee strict interoperability ; define framework for experimenting V2G EU: Connect smart charging regulations with EPBD Directive."*
Other industry and user associations	*" - Appropriate tariff and taxation should be introduced as soon as possible at national level, in an harmonized manner throughout Europe.* *- The EU regulator should introduce requirement for new EV cars to be fitted with V2G functionality.* *- In order to enable the distribution network to reap the benefits of V2G, the smart grids indicators foreseen in art 59.1 (l) of the Electricity directive and to be established at national level could include bidirectional charging.* *- Distribution network development planning (Art 32, Electricity directive) should include the V2G aspect"*
Network operators (TSOs and DSOs)	*"Make V2G mandatory in fe the AFID* *Only green deal money for V2G charging infra via public tenders* *Adopt de facto Charging standards such as OCPP"*

9.6. Selected survey inputs on long-term policy recommendations

Table 8: Long-term policy recommendations as provided by selected survey respondents.

Stakeholder group	**Policy recommendation**
Standards developers	"*We already provide a working standard (IEC/EN) that enables DC V2G, seamlessly integrated with the OCPP back-end communication... We can respond to all the use cases that have been discussed and put in place for the past 6 years or so. Against this backdrop, we believe that no arbitrary technical standardisation is needed at this time, especially political ones, which risk hinder the healthy growth of the market. Especially important is not to limit the types of V2G charging technologies, as there is plenty of room for both DC and AC V2G according to the use case.*"
Suppliers/Aggregators/ EMSP	*"On EU level, define a methodology which considers the status of the electricity system when planning smart charging infrastructure and move from an asset-based approach (where individual assets participate to the system) to a service-based approach"*
Network operators	*"Promote national and EU-wide initiatives to monitor and coordinate the operation of smart / V2G charging"*
Suppliers/Aggregators/ EMSP	*"Building renovation wave should also prepare the ground to achieve ambitious targets in term of private EV charging: it requires to develop the right incentives and ease the deployment of common charging infrastructure providing smart-charging capabilities, especially in collective residential buildings."*
Suppliers/Aggregators/ EMSP	*"Inaction - this is a hugely nascent market. Taking too strong a regulatory position could jeopardise the future of this market."*
Other industry and user associations	*"In five years time, we expect V2G deployment to be in full speed and this will require further regulatory adaptations."*
Civil society	*"Better harmonisation between mobility and energy plans, where clean energy can be managed/bought and sold in a transparent manner - cooperation on all levels."*

9.7. The role of newcomers in the EV ecosystem

Survey participants had a chance to give their input on the role of newcomers, start-ups and innovators in the domain of smart and bidirectional charging. A high share, 75%, of the 50 survey responses believe that newcomers, start-ups and innovators have a very important role to play in the development of smart and bidirectional charging. The reasons why they find them very important are because they: (i) drive innovation and accelerate change; (ii) disrupt traditional energy field where many existing stakeholders are unwilling to make changes to the status quo; (iii) create new business models and use cases, not constrained by existing norms; (iv) empower consumers and (v) collaborate with existing stakeholder to make wider reaching change together.

The role of such actors is seen mainly in the space of business to consumer (B2C), specifically as aggregators and software companies that provide new products and functionalities towards smart energy control and monitoring. However, 26% of the respondents discussed the need for levelling the playing field for these players in comparison to traditional large energy stakeholders. In order for newcomers, start-ups and innovators to flourish and push the smart and bidirectional charging market forward, the following measures have been suggested by survey participants: (i) providing financial support; (ii) adapting energy market to allow for wider stakeholder participation and collaboration, and customer-oriented services; (iii) assuring data access and; (iv) assuring use of open standardized charging protocols. Most survey responders acknowledged the need and/or welcomed the participation of these players in the market development of smart and bidirectional charging.

9.8. Task 3 workshop agenda

Table 9: Agenda for Task 3 stakeholder workshop

'Best practices and assessment of regulatory measures for cost-efficient integration of electric vehicles into the electricity grid'

Workshop on Possible Policy Measures

13 January 2021 – Kick off 10:00 AM CET

This workshop is part of the project "Best practices and assessment of regulatory measures for cost-efficient integration of electric vehicles into the electricity grid", procured by the European Commission, Directorate-General for Energy. The project is led by EY, in consortium with partners Th!nk-E and Sweco.

The objective for this workshop is to explore policy options to address the main barriers to smart and bidirectional (V2G) charging of electric vehicles in the EU. The workshop will feature a presentation of the main barriers identified in the course of our project, as well as preliminary findings on possible policy measures.

Topic	Speakers	Time
1. Welcome, scope and objectives of the workshop	DG ENER	10:00-10:05
2. Introduction to the project	Project team	10:05-10:10
3. Presentation of main technical and regulatory barriers to smart and V2G charging	Th!nk-E & Sweco	10:10-10:30
4. Q&A		10:30-10:40
5. Panel discussion with smart and bidirectional charging service providers	Nuvve, Jedlix	10:40-10:55
6. Short break		10:55-11:00
7. Presentation of best practices and lessons learned regarding policy measures for smart and bidirectional charging	Elaad	11:00-11:15
8. Presentation of and interactive discussion on possible policy measures addressing main barriers to smart and bidirectional charging	Project team	11:15-12:00
9. Final Q&A		12:00-12:20
10. Concluding remarks	Project team & DG ENER	12:20-12:30

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