EV Grid Synergy Analysis

France

Final report

for

ECF

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Contents

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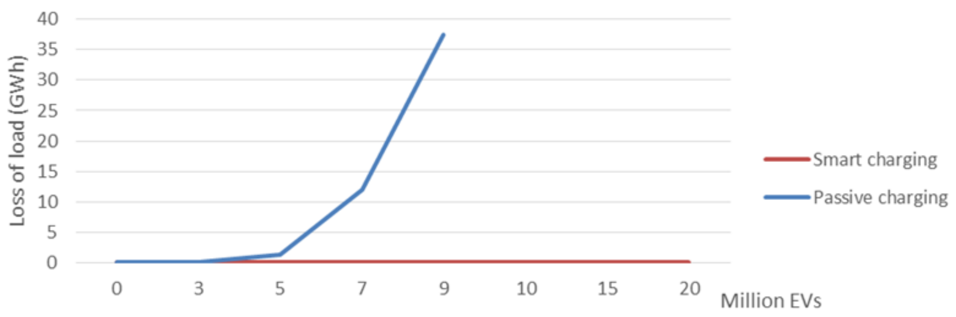
1 Executive Summary

The European Climate Foundation commissioned Element Energy and Artelys to carry out this study, to better understand the maximum deployment of EVs in France that is possible without creating additional generation capacity requirements, to quantify the overall value of synergies between EVs and the electricity system and better understand the potential impact on distribution networks.

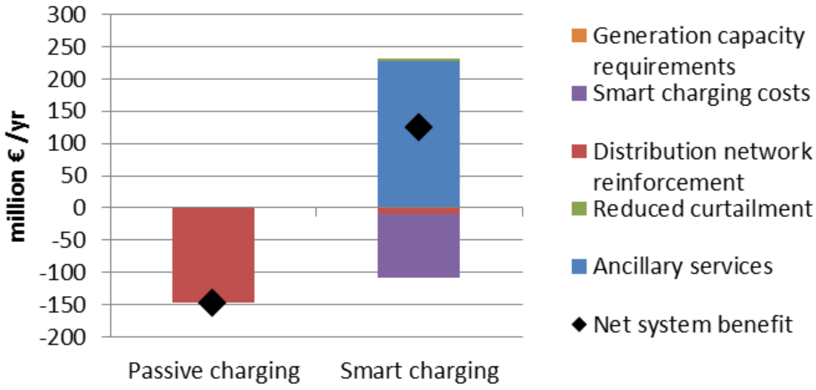
The analysis carried out for this study was developed through a combination of literature review, techno-economic modelling of ancillary services provision and impacts on the distribution network, and electricity generation optimisation modelling. The analysis is based on the EV deployment scenarios in the ECF TESCH scenario and furthermore uses the RTE Nouveau mix scenario to assess the impact of EV deployment on the generation system

The analysis shows that large uptake of EVs may impact the electricity system, particularly if charging is un-managed. If EV owners charge on arrival at home or at work (passive charging), this will introduce peaks in charging demand in the evening and in the morning.



The level of EV deployment in the ECF TECH scenario of 4.1 million EVs in 2030 represents the maximum number of EVs that can be deployed with passive charging in 2030 without requiring additional generation capacity. For any further increase in EV deployment, significant investments in additional generation capacity would be required in order to meet the increase in peak demand caused by EV charging. For the 6.9 million EVs in RTE's Nouveau Mix scenario in 2030, passive EV charging would require 3GW of additional generation capacity in 2030. Due to the high peak in EV charging demand, this would likely need to be met by peak generation units, rather than mid-merit or baseload plants. The large peak in EV demand also results in increased running hours for peaking plants, with relatively high CO_2 emissions.

By using smart charging strategies to shift EV charging demand from peak periods to periods of low system demand, the challenges posed on the electricity generation system by EVs can be largely mitigated. Smart charging prevents any requirements for additional generation capacity, with the 2030 electricity system capable of accommodating over 20 million EVs, five times the projected uptake in the ECF TECH scenario. This shift in EV demand also results in EV demand being met to a larger extent by mid-merit and baseload plants with lower CO_2 emissions than peaking plants.



The potential benefits of smart charging are higher than the costs of implementing smart charging, resulting in a 125 million €/yr net benefit for smart charging in 2030, compared to a 150 million €/yr cost for passive charging. Smart charging mitigates the costs of distribution network reinforcements to a large extent and provides additional benefits for EVs by providing ancillary services and reducing renewable curtailment. These potential benefits are larger than the costs of implementing smart charging, which consist of additional hardware, communications and telemetry infrastructure and operation.

Passive charging increases distribution network peak load by 3 GW in 2030, corresponding to 150 million €/yr reinforcement costs. Smart charging has the potential to reduce the required distribution network reinforcements on average by a factor of ten, resulting in annual reinforcement costs of €10 million per year in 2030.

In addition, smart charging EVs have the potential to benefit the electricity system, by reducing the curtailment of renewable generation, and by providing ancillary and balancing services to the system operator. Smart charging acts as a flexibility provider for the transformation of the French power system. It may reduce the need for CO_2 intensive thermal peak generators, supporting the integration of further intermittent renewable generation, especially photovoltaic production in the middle of the day, mitigating their curtailment. Renewable curtailment, which is relatively low in France due to existing energy storage in the form of hydro, could be further reduced through smart charging, resulting in a benefit of €4 million per year in 2030.

Ancillary and balancing service provision by smart charging EVs represents a technical potential equivalent to €228 million per year in revenues in 2030.

While the opportunity for smart charging EVs is large, with a significant potential overall benefit, this is diluted on an individual EV level. This is a key challenge in developing this opportunity, as efficient commercial models are needed to incentivise participation by EV owners. Access to services and the ability to combine the provision of multiple services to different actors are therefore key aspects in maximising the benefit available at an individual EV level. Developing these services moreover requires installation of charge points that support the required control and communication signals, as well as development of the telemetry and communication platforms between aggregators and EV charge points.

2 Introduction

2.1 Impact of passive EV charging on the electricity system

Large uptake of electric vehicles (EVs) may impact the electricity system, particularly if charging is un-managed. If EV owners charge on arrival at home or at work (passive charging), this will introduce peaks in charging demand in the evening and in the morning. Public charging is typically spread out over the day. As shown in Figure 1, the peak in electricity demand by home charging EVs coincides with the peak in system demand, and may increase system demand. In the 2030 projections EV home charging increases the total winter evening peak by 7% which is already the system's most critical period (with the annual highest demand). This may result in a need for additional generation capacity to meet peak demand. Peak demand is typically provided by thermal plants with high CO_2 emissions, and this may result in an increase in system CO_2 intensity. Work EV charging does not coincide with system peak demand, but with high deployment of EVs they may contribute to overall system demand increase. Passive EV charging may also result in increases of peak load on the electricity network, potentially requiring parts of electricity networks to be reinforced.

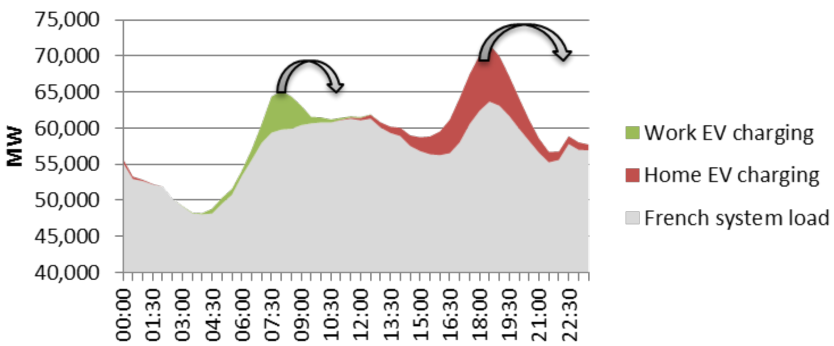


Figure 1 Illustrative French system load with home and work passive EV charging demand. EV demand may be shifted so that it occurs during times of low system demand, indicated by the arrows

2.2 Potential for smart charging to mitigate electricity system challenges and provide further system benefits

These challenges may be addressed by implementing smart charging strategies. Smart charging comprises a broad range of charging strategies aimed at managing the timing of EV charging to minimise negative system impacts or provide other services. EV charging may be managed by responding to price signals, other control signals or through direct control. Home and work charging EVs are typically plugged in for a much longer period than is necessary to fully charge the battery, and their charge times can therefore be shifted to minimise the impact on the electricity system. For EVs charged at home, the evening peak in demand can be moved to the night time, when system demand is low. Work charging can be spread out over the day to minimise the day time peak. This is shown by the arrows in Figure 1. This shifting of demand may mitigate the need for additional generation capacity and mitigate the need for distribution network reinforcements. Compared to passive charging, shifting demand away from the peak may also reduce system fuel costs and CO_2 emissions, as demand is met by mid-merit, rather than peaking plants.

In addition, smart charging may shift EV demand to periods of high renewable generation, thereby reducing the need to curtail excess renewable generation and supporting higher levels of renewable penetration. Smart charging EVs also have the potential to benefit the electricity system by providing ancillary and balancing services to the system operator, thus supporting supply-demand balancing on the system..

3 Impact of EV deployment with passive charging – results

3.1 Challenges for the electricity system

3.1.1 Generation capacity adequacy

The reference supply mix used for these analysis is based on the RTE "Nouveau mix" scenario for the year 2030. The RTE Nouveau mix scenario meets the objectives of the French energy transition law, especially limiting nuclear plants' share in the generation mix to 50% and high CO2 cost. The French 2030 power system modelling allows to perform simultaneous optimization of generation dispatch (including hydro storage management, RES generation, imports/exports) and of EV charging under constraints of arrival and departure, at an hourly time step over one year. This model has been studied with different levels of EV deployment with the passive charging strategy in order to evaluate the maximum deployment of EVs without creating additional generation capacity requirements. The generation mix is the same for all the simulations even if the number of EVs deployed increases.

The Figure 2 presents the evolution of the loss of load related to the EV number. The loss of load is the quantity of power and energy not supplied by the system. The maximum power of loss of load represents the additional capacity needed by the system to cover the entire demand.

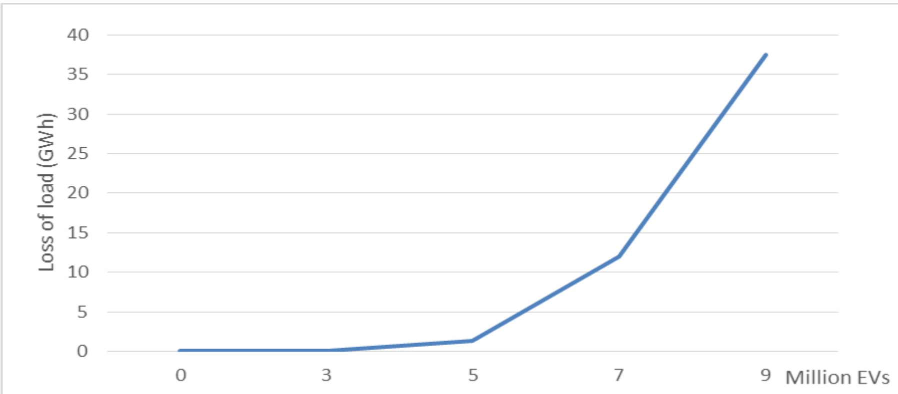


Figure 2 - Evolution of loss of load related to the EV number

The Table 1 presents in details the quantity of loss of load resulting from the number of EVs. The base assumption for almost all simulations is the annual consumption per EV proposed by the RTE Nouveau Mix scenario (2.1 MWh), except for the TECH scenario which proposes an annual consumption per EV of 1.5 MWh. Finally, beyond 3-4 millions of EVs (associated to a demand of 6-7 TWh), an additional generation capacity is required.

Base scenario	NMX	TECH	NMX	NMX	NMX
Number of VE (M)	3.5	4.1	5.2	6.9	8.6
Demand VE (TWh)	7.3	6.1	10.9	14.5	18.1
Loss of load (hours)	0	0	3	9	17
Loss of load sum (GWh)	0	0	1	12	38
Loss of load max (GW)	0	0	1	3	5

Table 1 - Evolution of loss of load related to EV number

3.1.2 Distribution networks

Passive charging results in 3.2 GW additional network peak load in 2030, resulting in annualised reinforcement costs of 150 million €/yr in 2030, increasing further out to 2050

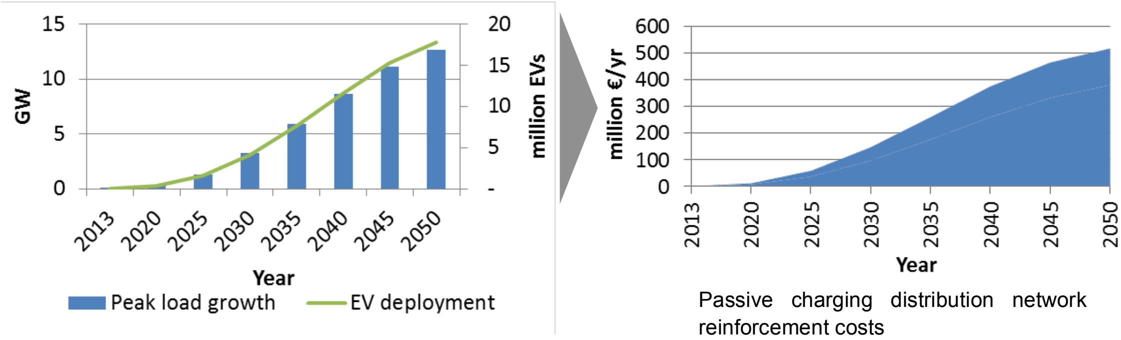


Figure 3 Passive charging EV deployment and network peak load growth, and corresponding distribution network reinforcement costs

EV deployment with passive charging increases network peak loads and may pose challenges for distribution network management. Network peak load increases with increasing EV deployment from 3.2GW in 2030 to 13GW in 2050. This corresponds to annualised distribution network reinforcement costs of 150 million €/yr in 2030, increasing to over 500 million €/yr in 2050.

Home charging has the highest impact on reinforcement requirements with passive charging, followed by work charging.

In the passive charging case, home charging comprises on average 80% of the total reinforcement costs. This is driven by the projected high fraction of charging at home, and the coincidence of the sharp home passive EV charging peak and system load peak, as depicted in figure1. This also results in high average network reinforcements costs per home charging EV, as shown in **Error! Reference source not found.**.

Work charging has a limited contribution to total network reinforcement costs in the earlier years, but this increases after 2025, when the numbers of work charging EVs are sufficient to create a new load peak, as can be seen in figure 1. This new peak increases network reinforcement requirements.

Public charging is more spread out over the afternoon load plateau, resulting in two and a half time lower reinforcement costs per EV compared to home charging.

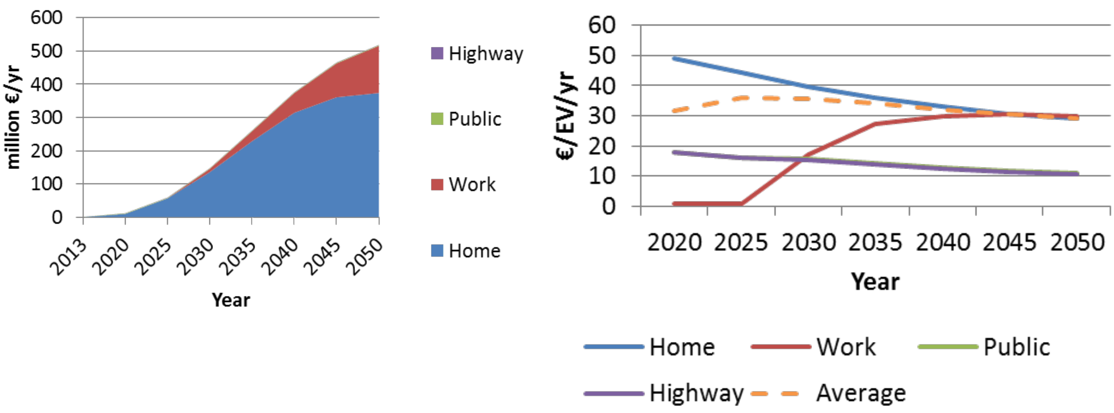


Figure 4 Passive charging distribution network reinforcement requirements, total (left) and per EV (right)

3.2 Further impacts on generation

As said in the previous section, the integration of EVs with passive charging has an impact on the system peak demand, and so additional generation capacity is required to supply this higher demand. Since the generation mix is fixed and no additional capacity could be added in our simulation (assumption of an existing mix for the year 2030), thermal peaking plants, with high CO2 emissions rates, are used to provide the additional generation. The Table 2 presents the load factors (hours of use) of all generation units. Thermal units' usage, especially OCGT, which is the most expensive technology, increases considerably in order to cover the higher evening peak of demand.

	Full power load (hours)		
Technology	**No EVs**	**EVs with passive charging**	
Renewable energies	2707	2707	0,0%
Pumped storage	747	865	15,9%
Nuclear	6841	6901	0,9%
OCGT	180	426	136,8%
CCGT	3112	4088	31,3%
Coal	913	1188	30,1%
Max	8760	8760	

Table 2 - Comparison of load factors between no EV scenario and TECH scenario

Such thermal units usage impacts both production costs and CO2 emissions. Actually, the total production costs for the year 2030 have increased by 7% (from 7171 million euros to 7670 million euros). The CO2 emissions have also increased by 9% (from 28 million tonnes to 30.5 million tonnes).

4 Opportunities of smart EV charging – results

4.1 Mitigation of electricity system challenges through smart charging

The benefits of smart charging are higher than the costs of implementing smart charging, resulting in a 125 million €/yr net benefit for smart charging in 2030, compared to a 150 million €/yr cost for passive charging. Smart charging mitigates the costs of distribution network reinforcements to a large extent and provides additional benefits for EVs by providing ancillary services and reducing renewable curtailment. These benefits are larger than the costs of implementing smart charging, which consist of additional hardware, communications and telemetry infrastructure and operation.

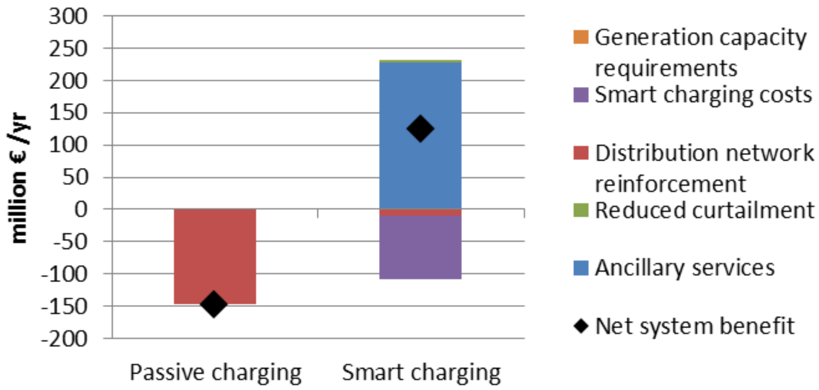


Figure 5 Cost and benefits for passive and smart charging in 2030

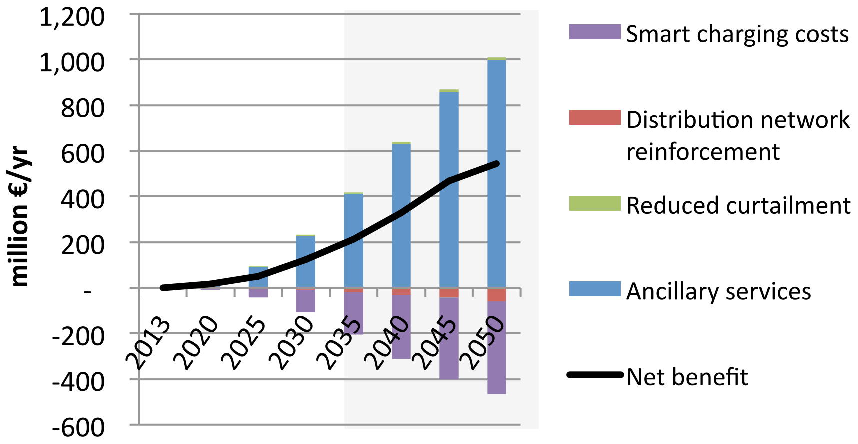


Figure 6 Cost and benefits for smart charging. After 2030 EVs show the technical potential to supply a large proportion of ancillary services. These levels may not be achievable commercially, due to competition with other low cost providers of services, incumbent providers and impacts on pricing and procurement if demand side sources provide a large part of ancillary services.

4.1.1 Capacity adequacy

Contrary to passive charging, smart charging allows the charge to be optimally managed during the period of the EV stays at the charging location. Smart charging provides flexibility to the system and allows it to shift EV demand away from the peak. This flexibility is directly visible on the maximum deployment of EVs without creating additional generation capacity requirements. The Figure 7 presents the evolution of the loss of load related to the EV number for passive and smart charging. With the smart charging strategy, a large number of EVs could be deployed (until 20 million of EVs) with no additional generation capacity.

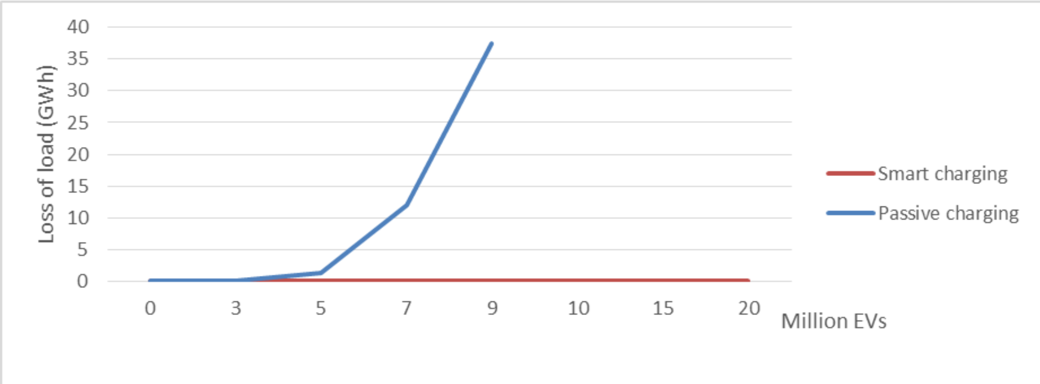


Figure 7 - Evolution of loss of load related to the EV number for smart charging

The Figure 8 presents the power demands for an average winter day with and without EV demands (grey and blue curves, to refer to the left axis) and the EV demands for a home charging and for a work charging (purple and red curves, to refer to the right axis). The EV demand for a home charging is shifted to the night period, when the demand is lower, in order to avoid a large increase on the evening peak. The EV demand for a Work charging is shifted to the afternoon to avoid increasing the morning peak and to take advantage of the solar production.

With a highest EV demand, this opportunity of shifting is still possible and so implies that the winter evening peak demand remains unchanged. Since, in France, the winter evening peak (being the annual peak) sets generation capacity requirements, no additional generation capacity will be needed.

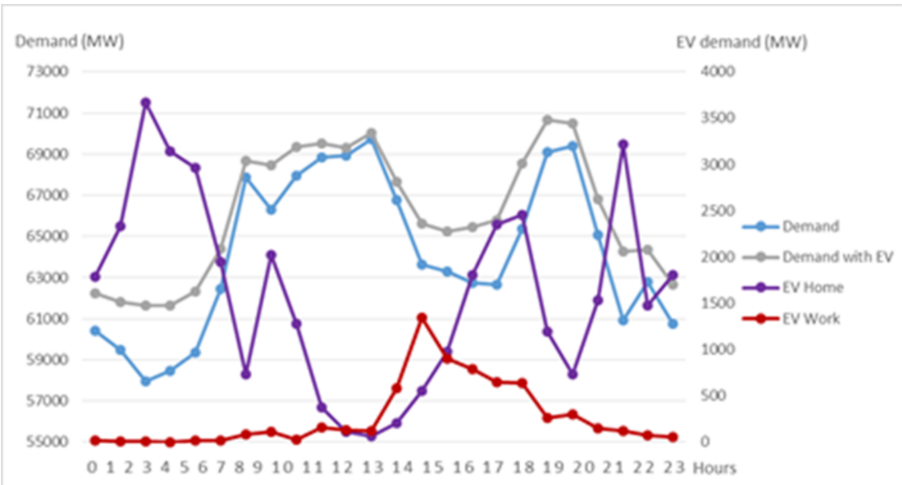


Figure 8 - Power demand for an average winter day with smart charging

As the generation mix is the same for all the simulations with a different level of deployment of EVs, EV demand increase is handled by higher thermal peaking production levels. The Figure 9 presents the generation distribution between nuclear, RES, OCGT and other thermal units for each level of EV demand simulated. Nuclear plants are basically used at their maximum available capacity, which is the same in all scenarios. Useful energy provided by renewable systems increases due reduction of renewable curtailment. Deploying a higher number of EVs will therefore mainly impact thermal units'. OCGT units, having the highest variable cost, are the latest to be called to produce, which makes them especially dependent on demand peaks, and therefore on EVs deployment. Finally, EVs can be deployed up to a large number without additional capacity, although this would require using thermal peaking units, with high CO2 emission rates.

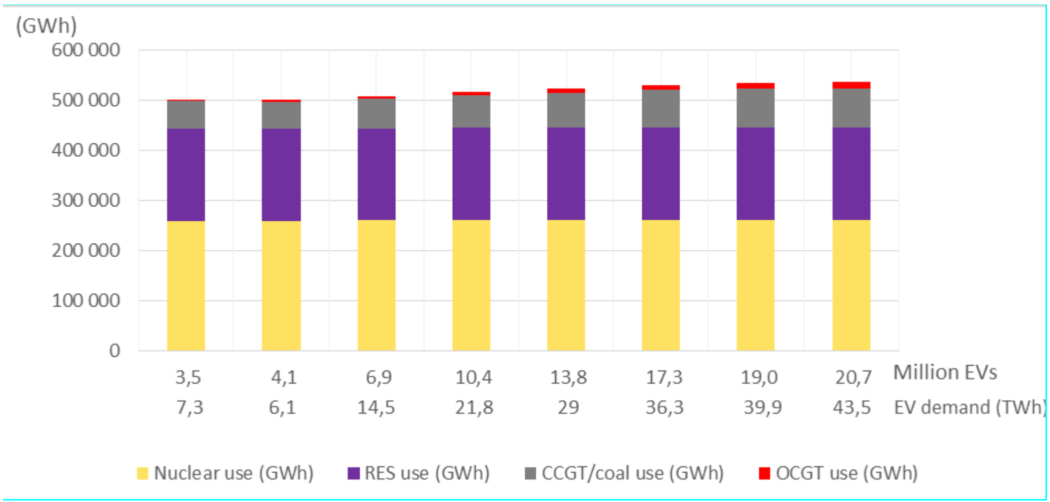


Figure 9 - Evolution of generation with the number of EVs

4.1.2 Distribution networks

Smart charging may reduce annual distribution network reinforcement costs due to EV charging on average by a factor ten compared to passive charging, resulting in 10 million €/yr reinforcement costs in 2030 for smart charging

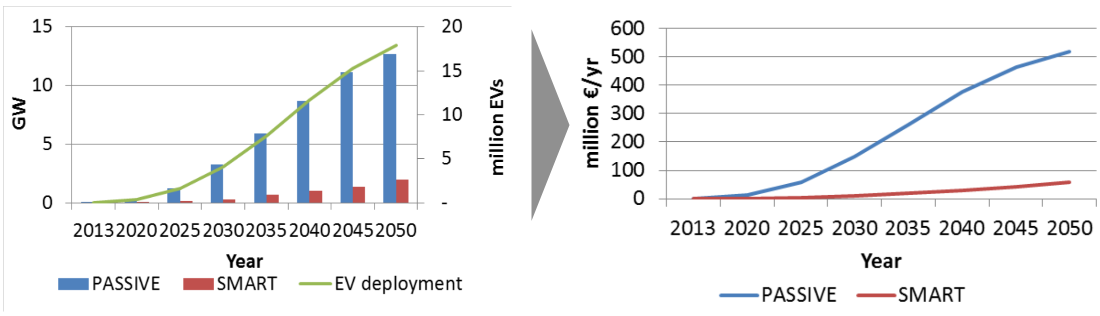


Figure 10 Active charging EV deployment and network peak load growth, and corresponding distribution network reinforcement costs

Smart charging may mitigate the increase in distribution network peak load to a large extent. With smart charging the 2030 distribution network peak load increase is limited to 0.3GW, compared to 3.2GW with passive charging. This 0.3GW network peak load increase for smart charging corresponds to annualised reinforcement costs of 10 million €/yr in 2030.

Smart charging may almost fully mitigate reinforcement costs for home charging and reduce reinforcement costs for work charging by 55%

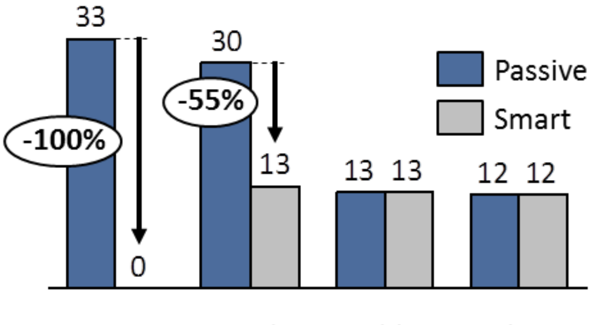


Figure 11 Potential for smart charging to reduce distribution network reinforcement costs per archetype

The distribution network impact of home charging may be almost fully mitigated through smart charging. Home charging EVs are plugged in overnight for significantly longer than their required charging time, and system load reduces significantly overnight after the evening peak. This allows for shifting of the home EV charging demand into the night time period.

For work charging the network reinforcement costs may be reduced by approximately 55% through smart charging. In work charging EVs are similarly plugged in during the day for significantly longer than the required charging time. The morning work EV charging peak can be spread out over the afternoon load plateau. However this provides less reduction potential compared to home charging; the charging may be spread out, but not completely shifted to a low demand period, due to the extended afternoon load plateau close to system peak.

There is limited potential to reduce the impact of public charging on network load increase through smart charging. The EV residence time is usually of similar length as the charging time, resulting in limited potential to shift charging demand in time or spread it out. Moreover the public charging is already spread out over the afternoon load plateau, with limited potential for valley filling or further spreading out. Siting may be a key factor in limiting public charge point impact on distribution networks. Locating public charge points on parts of networks with sufficient capacity will limit reinforcement requirements, while the physical locations may be very close. This requires collaboration of local municipalities and developers with DNOs. DNOs are already consulted for large charge point projects in recent law change.

Realising the potential to reduce distribution network reinforcement costs posed by passive charging requires developing smart charging capabilities for the residential sector and commercial sector. This may be especially challenging for the residential sector, due to the large number of small loads with limited individual contributions. Smart charging requires Electric Vehicle Supply Equipment (EVSE) capable of supporting these charging strategies. Not all homes with EVs currently have a dedicated charge point, and not all charge points (especially mode 2) support this type of charging. Moreover this requires the development of new commercial models by DNOs, and smart charging operational infrastructure, including telemetry and power metering, developed by aggregators or other parties.

HV reinforcements represent approximately 30% of costs with passive charging, and may be almost completely mitigated by smart charging

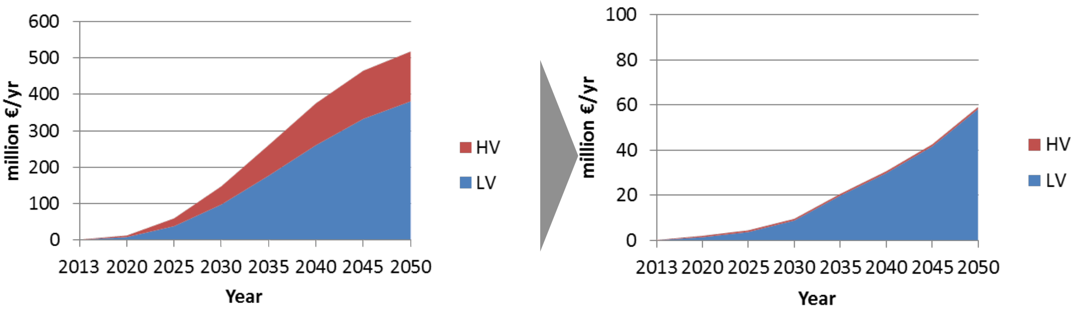


Figure 12 Potential for smart charging to reduce LV and HV distribution network reinforcement costs

Smart charging may be very effective in mitigating increases in system peak load, which will result in lower HV investment requirements. However, on a local level where the types of loads are not as varied, work charging and public charging may cause an increase in the local peak, leading to some LV network reinforcement requirements.

This analysis assumes a constant peak load. However, the overall electricity demand is projected to decrease more strongly than the increase in EV electricity consumption. The reduction in overall electricity demand could result in a reduction of peak demand. This would limit the projected HV reinforcement costs for passive EV charging, as EV demand could fill the available capacity on the network. On the other hand further electrification of other sectors (e.g. heating) may also contribute to an increase in peak demand. More detailed system analysis would be required to assess the overall integrated impact on peak electricity demand of these different drivers.

4.2 Further potential benefits of smart EV charging

4.2.1 Reduced curtailment and integration of intermittent renewable generation

Reduced renewable curtailment

Smart charging allows our model to optimize the EV charge simultaneously with the power generation system. By doing that, the optimally managed charge could be located at the best hours and benefit from the renewable energies generation. Energy provided by renewable systems is a fatal energy lost if there is not enough demand to match its level. The scenario with no EVs demand present an overproduction of 215 GWh due to this loss of renewable energy. With the smart charging strategy for the TECH scenario, there is still an overproduction but decreased by 32% compared to the no EVs scenario resulting in a total loss of 146 GWh.

The **Error! Reference source not found.** presents the reduction of renewable curtailment due EVs with smart charging, compared to a no-EVs scenario. Most of the reduction occurs during the afternoon and confirms the fact that the EV demand at work is shifted to take advantage to the overproduction of the solar groups.

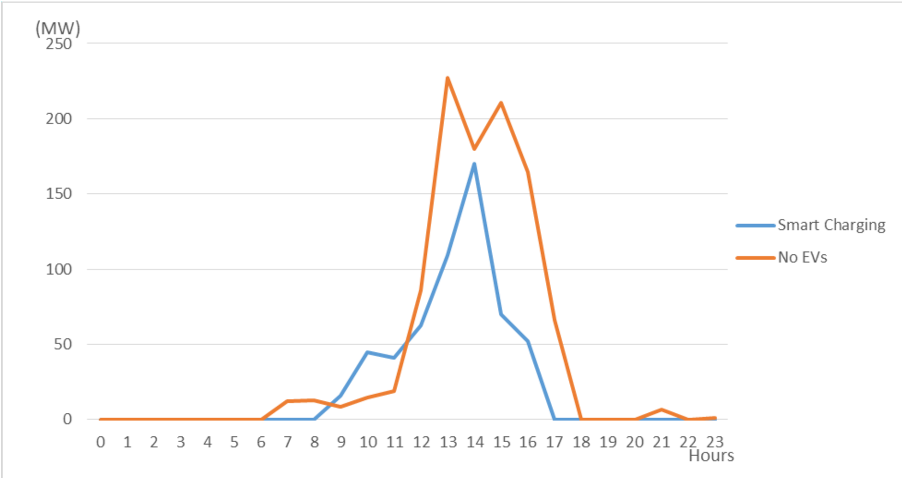


Figure 13 - Comparison of renewable curtailment

Integration of intermittent renewable generation

Smart charging gives the flexibility to reduce the peak and to take advantage of the renewable energies generation, leading to a different generation planning. The **Error! Reference source not found.** presents the load factors (hours of use) of all generation units. Thermal generation use generally decreases, as illustrated by OCGT units' load factor which is reduced by 8%. Smart charging provides a kind of storage to the whole system and that is why the use of pumped storage is less necessary.

	Full power load (hours)		
Technology	**Passive charging**	**Smart charging**	
Renewable energies	2707	2707	0,0%
Pumped storage	865	641	-26,0%
Nuclear	6901	6907	0,1%
OCGT	426	393	-7,9%
CCGT	4088	4051	-0,9%
Coal	1188	1189	0,1%

Table 3 - Comparison of load factors between passive and smart charging for TECH scenario

The decrease in these thermal unit use impacts both production costs and CO_2 emissions. Actually, the total production costs for the year 2030 have decreased by 30 million euros.

The CO_2 emissions have also decreased by 200,000 tonnes. Average CO_2 intensity of generated energy drops to 51g/kWh from 60g/kWh in passive charging.

Previous analyses showed that a large fleet of EVs could be deployed without needs of additional capacity. However, this implies higher use of existing gas units and high CO2 emissions. However, if the deployment of EVs is accompanied with new renewable energy capacities, the impacts in terms of CO2 emissions could be very limited.
The following example studies the deployment of 6.9 millions of EVs (with smart charging), combined with an increase of the solar energy capacity from 24 GW to 36GW (which gives 16GWh extra generation).
The Figure 18 presents the results comparison between this new scenario and the reference one without EVs. The left bar chart shows the different sources of energy used to charge EVs: 87% of EV demand is produced with solar units and only 13% is produced with thermal units. The right bar chart shows how the extra 16GWh of PV energy is used: 13.7 TWh is used for EV demand and 2.3 TWh replaces nuclear energy generation.
The total impact in terms of CO2 is very limited : 29 Mt CO2 for 14.5 TWh of EV charging.

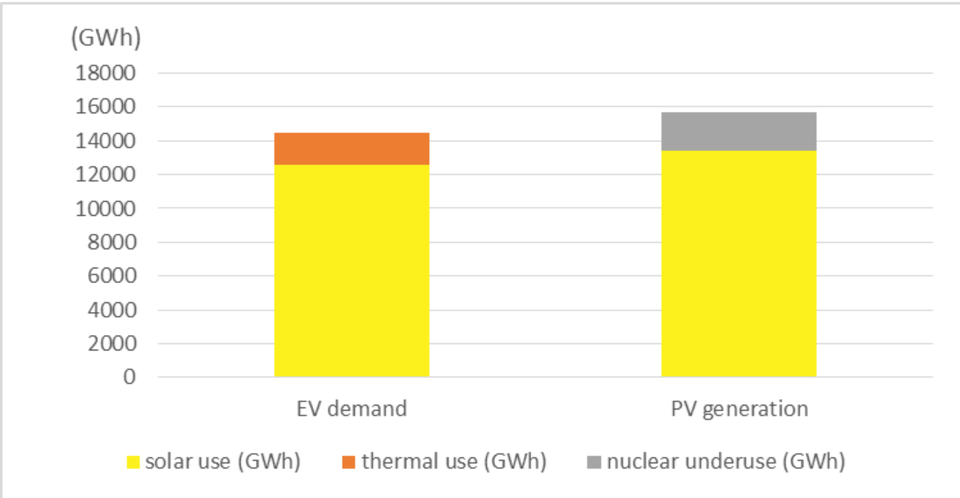


Figure 14 - Benefits on EV demand and solar generation use between additional solar capacity scenario and no EVs scenario

4.2.2 Provision of ancillary services

With smart charging EVs have a technical potential to supply 18%-33% of system requirements for various services in 2030, representing revenues of €228 million per year.

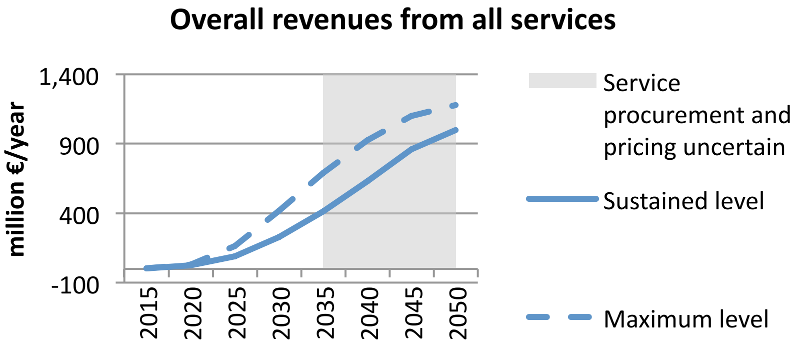


Figure 15: Overall revenues corresponding to the technical potential of EVs to supply ancillary services, based on current service pricing[1]. After 2030 EVs show the technical potential to supply a large proportion of ancillary services. These levels may not be achievable commercially, due to competition with other low cost providers of services, incumbent providers and impacts on pricing and procurement if demand side sources provide a large part of ancillary services.

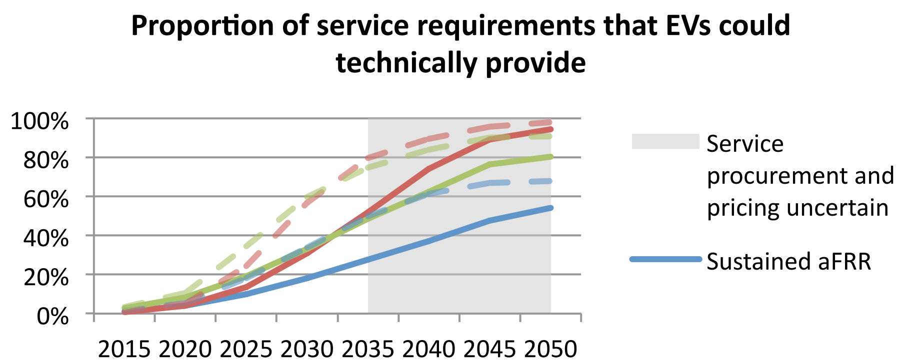


Figure 16: Proportion of service requirements EVs could technically provide[2] out to 2050. After 2030 EVs show the technical potential to supply a large proportion of ancillary services. These levels may not be achievable commercially, due to competition with other low cost providers of services, incumbent providers and impacts on pricing and procurement if demand side sources provide a large part of ancillary services

Figure 15 shows the potential overall EV revenues from ancillary and balancing services out to 2050. This includes revenues for the provision of primary and secondary response and balancing mechanism services by interrupting or scheduling charging (excludes transfer of energy back to the grid). These increase with EV uptake and with increasing

[1] Current prices for ancillary services are scaled with future electricity production costs.
[2] Shows the proportion of holding requirements for FCR and aFRR and the proportion of average utilisation requirements for RR.

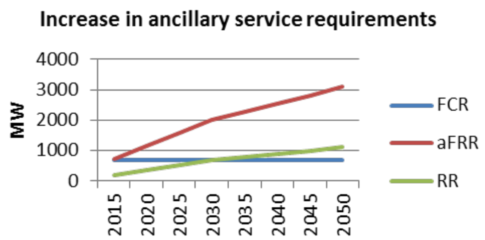
service requirements, and correspond to the technical potential for EVs to provide response.

The base case technical potential refers to the sustained level of response EV could technically provide throughout the day. There are periods when EVs could supply higher levels of response, which, if accessed, could provide up to 60% of requirements for some services in 2030.

After 2030, EVs have the technical potential to provide a large proportion of ancillary service requirements. These levels may not be achievable commercially, due to competition with other low cost providers of services and incumbent providers. Moreover if demand side sources provide a large part of ancillary services this would likely impact pricing and procurement of these services.

Overview of ancillary and balancing services

EVs could potentially provide primary and secondary response and balancing mechanism services to the electricity system. These services allow the system operator to maintain to balance between electricity supply and demand, and thus keep the system frequency within statutory limits around 50 Hz.



Primary frequency response, also called the Frequency Containment Reserve (FCR), is the fastest responding service. Providers of FCR respond within seconds to a frequency deviation, in order to contain the further deviation of system frequency. Secondary response (or automatic Frequency Restoration Reserve, aFRR) responds on the order of minutes while the balancing mechanism (Replacement Reserve, RR) typically acts over a number of hours to restore the balance between supply and demand. The amounts of aFRR and RR services required by the system operator are predicted to increase with increasing renewable energy capacity, due the increased variability of supply, while the amount of FCR required is predicted to remain constant[3].

[3] Based on literature review findings, confirmed by RTE. Reserve requirement is projected to increase by 9% of the increase in wind generation capacity, based on findings of 2005 German study by DENA.

While the overall opportunity associated with ancillary service provision by EVs is large, this is diluted on an individual EV level, with annual revenues of €57 per EV in 2030.

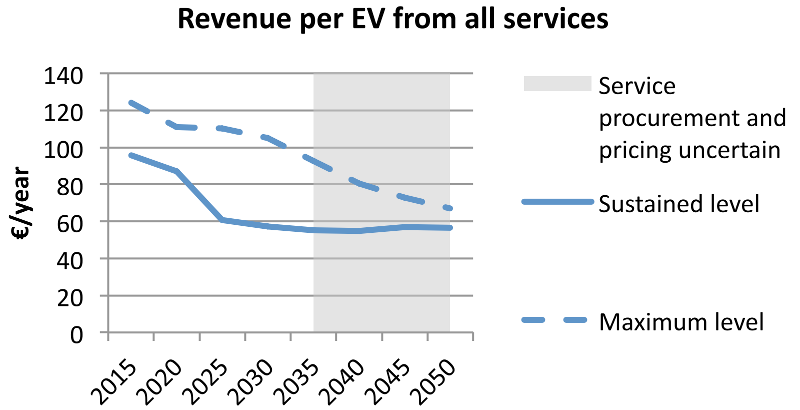


Figure 17: Revenue per EV for provision of ancillary services, corresponding to the EV technical potential based on current service pricing[1].

Figure 17 shows the annual revenue accessible per EV out to 2030[4]. The resulting net benefit to EV owners will be lower, due to the costs associated with service provision. Provision of ancillary services by EVs requires a combination of frequency responsive and controlled smart charging to allow EV charging to be both interrupted and scheduled in response to system needs. This incurs additional costs over conventional EV charging, including hardware costs, operational costs for communications and data processing and overhead business costs for managing the aggregation of response from a large number of small geographically distributed loads. These costs are estimated to be €26/year for an individual private EV and €11/year for an EV that is part of a fleet[5]. This gives a net benefit per EV of €31-€46/year in 2030. This limited incentive at an individual level represents a challenge in capturing this opportunity, and will require efficient commercial models to encourage participation by EV owners.

EVs are most suited to providing short timescale response services like primary frequency response and secondary response. For these, they offer advantages over incumbent providers in both the speed and accuracy of their response. For longer timescale reserve services, EVs have less of a competitive advantage over incumbent providers.

[4] The reduction in revenue over time is due to the projected reduction in average EV energy use, caused by increased EV efficiency, which means that EVs are charging, and thus available for service provision, for a shorter period of time. For some services, notably primary response (FCR), saturation of service requirements also leads to a reduction in revenue per EV.

[5] Hardware costs are based on an engineering estimate for smart charging components for large scale production. Operational and business overhead costs are based on 'Infrastructure in a low-carbon energy system to 2030: Demand Side Response', Grid Scientific and Element Energy, 2013 and Green e-Motion Deliverable 9.4 Part 1, 'Envisaged EU mobility models, role of involved entities, and Cost Benefit Analysis in the context of the European Clearing House mechanism', 2014. Fleet figure assumes fleet of 10 EVs.

4.3 Cost Benefit Analysis for V2G

Vehicle to grid provision of ancillary services could offer a net benefit of €260-€280 per year to EV owners if EVs' full technical potential to provide services is exploited.

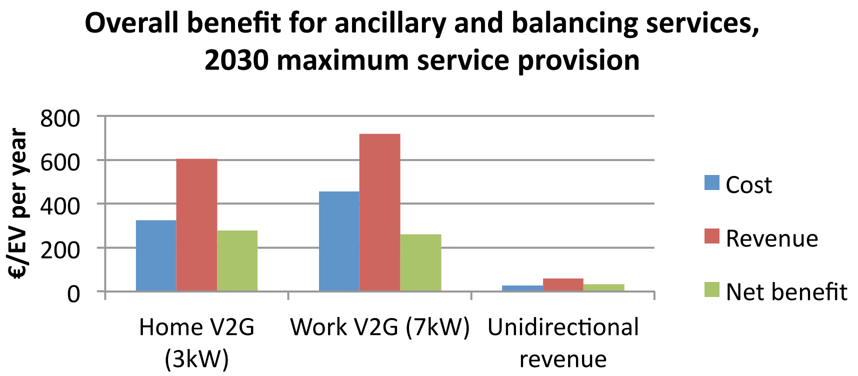


Figure 18: Costs and benefits for ancillary and balancing service provision by vehicle to grid enabled EVs, compared to the unidirectional charging case. Revenues shown here correspond to the full technical potential of the EV.

This level of benefit could cover the cost of EV charging, which may provide a significant incentive to EV owners. As can be seen in Figure 18, the potential revenues for vehicle to grid enabled EVs are significantly higher than in the base unidirectional charging case. This is because they are able to offer their full charge capacity for the duration of their available charge window, subject to the constraint of being fully charged at departure time[6]. There are also additional costs compared to the base case, including hardware costs to enable bi-directional charging[7] and ongoing operational costs due to battery round trip efficiency losses and increased battery degradation[8].

While the benefits could be significant, these may decrease over time if large numbers of EVs supply services. Vehicle to grid service provision also requires further technical and commercial development.

The revenues accessible to vehicle to grid enabled EVs could decrease if a large number of EVs partake in service provision. With vehicle to grid capability, EVs could meet a large proportion of service requirements sooner than in the base case. For example, in 2030, with vehicle to grid capability, EVs could meet 25%-74% of requirements for the different service. This would impact the procurement and pricing of these services, which could decrease the accessible revenues. Saturation of service requirements could also decrease the benefit available per EV. It should also be noted that vehicle to grid is at a

[6] The analysis allows a 'buffer', equal to twice the time needed to charge the EV, where no services can be provided.
[7] Analysis assumes £220/kW for 3kW unit and £180/kW for 7kW unit, with additional 20% installation cost, annualised over 10 years. This is based on prices of solar PV inverters (www.greenagesolutions.co.uk).
[8] Battery characteristics are based on LFP lithium ion batteries and are obtained from supplier quotations, datasheets and "Modelling Lithium Ion Battery Degradation in Electric Vehicles" by Alan Millner. Battery costs are from "Cost and Performance of EV Batteries" report for the CCC, baseline case, C&D BEV.

pre-commercial stage, and requires further technical development and proving of commercial models before ancillary service provision by vehicle to grid enabled EVs becomes possible. Other challenges include the impact of vehicle to grid service provision on the electricity network and on power quality. In addition to these issues, EV owners may perceive an increased risk with vehicle to grid that their battery will not be fully charged at their desired departure time, or may have concerns around battery degradation.

5 Infrastructure for the development of smart charging

In order to access the full benefit of smart charging outlined in this analysis, a combination of dynamically managed and frequency responsive charging needs to be implemented. These provide pricing or control signals to meet varying requirements from the system operator, distribution network operators, suppliers and potentially renewable generation. Some of these services may have minimum capacity requirements or require combining multiple EVs to provide sufficient duration or reliability of services. Aggregators or other third parties may aggregate the potential response from a large number of small geographically distributed assets to manage the varying needs and meet overall service requirements, taking into account individual EV constraints. Not all of these services are currently procured commercially or open to demand side response. Hence this requires the development of commercial models for some services, especially to support distribution networks, and market access for aggregated distributed loads. Alternatively some services may me mandated in the future.

For EV charging to be controlled in this way, the charge point must at least be Mode 3 or Mode 4[9]. Especially in the residential sector, these are currently not installed by default. There are also no standardised communication protocols between EVs and charge points that provide all the required communication capabilities. It furthermore requires telemetry and communication protocols between charge points and aggregators, these platforms are at a demonstration phase and not standardised.

A key challenge to unlocking this opportunity is the diluted benefit on the level of an individual EV. The ability to combine the provision of multiple services to various actors in the electricity system (including the system operator and distribution network operators) is therefore a key aspect in maximising the benefit available to an individual EV. Initial implementations of smart charging solutions could therefore focus on EV archetypes that offer the most favourable net benefit per EV, in order to provide learning and prove commercial models. The analysis shows that although the total potential is largest in the residential sector, the per EV benefit may be higher for work charging due to the potential to utilise common infrastructure.

[9] IEC standard

6 Conclusions

Large uptake of EVs may impact the electricity system, particularly if charging is un-managed. If EV owners charge on arrival at home or at work (passive charging), this will introduce peaks in charging demand in the evening and in the morning.

The level of EV deployment in the ECF TECH scenario of 4.1 million EVs in 2030 represents the maximum number of EVs that can be deployed with passive charging in 2030 without requiring additional generation capacity. For any further increase in EV deployment, significant investments in additional generation capacity would be required in order to meet the increase in peak demand caused by EV charging. For example, in the RTE Nouveau Mix scenario with 6.9 million EVs in 2030, passive EV charging would require 3GW of additional generation capacity in 2030. Due to the high peak in EV charging demand, this would likely need to be met by peak generation units, rather than mid-merit or baseload plants. The large peak in EV demand also results in increased running hours for peaking plants, with relatively high CO_2 emissions.

The increase in peak demand caused by passive EV charging also impacts peak network load, requiring significant investment in distribution network reinforcements. Reinforcements are mainly required on the low voltage network and amounts to €150 million per year in 2030, an increase of 17% over historic annual ERDF network investments.

By using smart charging strategies to shift EV charging demand from peak periods to periods of low system demand, the challenges posed to the electricity system by EVs can be largely mitigated. Smart charging prevents any requirements for additional generation capacity, with the 2030 electricity system capable of accommodating over 20 million EVs, five times the projected uptake in the ECF TECH scenario. This shift in EV demand also results in EV demand being met to a larger extent by mid-merit and baseload plants with lower CO_2 emissions than peaking plants.

Smart charging also reduces the required distribution network reinforcements on average by a factor of ten, resulting in annual reinforcement costs of €10 million per year in 2030.

In addition, smart charging EVs have the potential to benefit the electricity system, by reducing the curtailment of renewable generation, and by providing ancillary and balancing services to the system operator. Renewable curtailment, which is relatively low in France due to existing energy storage in the form of hydro, could be further reduced through smart charging, resulting in a benefit of €4 million per year in 2030. Ancillary and balancing service provision by smart charging EVs represents a technical potential equivalent to €228 million per year in revenues in 2030. These potential benefits are larger than the costs of smart charging, including hardware and operational costs, which are estimated to be €98 million per year in 2030. Ancillary and balancing service provision by EVs could also further support the integration of renewable generation, potentially reducing the need for thermal generation capacity to back up variable renewables.

While the opportunity for smart charging EVs is large, with a significant potential overall benefit, this is diluted on an individual EV level. This is a key challenge in developing this opportunity, as efficient commercial models are needed to incentivise participation by EV owners. Access to services and the ability to combine the provision of multiple services to different actors are therefore key aspects in maximising the benefit available at an individual EV level. Developing these services moreover requires installation of charge points that support the required control and communication signals, as well as development of the telemetry and communication platforms between aggregators and EV charge points.

7 Opportunities for further understanding

The analysis carried out for this study was developed through a combination of literature review, techno-economic modelling and electricity generation optimisation modelling. Whilst the present analysis provides a step forward in understanding the impact of EV charging on the electricity system in France and the potential for smart charging to mitigate these issues and provide further benefits to the energy system, there are a number of dimensions in which additional work could provide further insight.

Detailed assessment of the EV impact on the distribution network in France

This study provided a high level top down estimate of the potential impact of EV charging on distribution network reinforcement costs. The uptake of EVs and their potential impact on distribution network reinforcement requirements may vary significantly between different areas. A more detailed bottom up analysis may increase the confidence and identify particular high and low impact areas. This analysis would provide spatially resolved EV uptake projections, based on consumer statistic. These would be combined with similarly spatially resolved archetype network area representations to assess the potential impact and reinforcement costs for different archetype networks. This would provide detailed insight into the impact on different network areas and dependency on EV penetration.

Integrated analysis of the electricity system

This study looked at the impact and synergies of EVs, taking into account projected developments in electricity generation and ancillary services requirements, but separate from other low carbon technology developments (electrification of heating, electrification of industry, distributed generation, peak load impact of energy efficiency). Further analysis may assess the impact and synergies on the energy system in an integrated system approach, taking into account demand and other low carbon technology developments. The impact of these developments may reinforce each other, or limit their respective impacts, requiring an integrated analysis.

Barriers and commercial potential of EVs to provide ancillary services

This study assessed the technical potential to provide ancillary services from EVs. A further study may assess the key barriers to realise this potential as well as the impact of commercial arrangements and competing providers of response on the commercial potential for EVs to provide ancillary services. This study could furthermore assess which type of EV ownership may be the most effective in providing ancillary services and balancing. This may inform early business model development and services development by the TSO.

Geographically

This study has been carried out for France, and the ECF has earlier carried out a similar study for the UK. The analysis carried out in this study may be extended to other countries, to better understand the potential synergies of EVs in different electricity systems. Key drivers that may affect the potential synergies of EVs with the electricity system include the background electricity demand, electricity generation mix, extent of renewable curtailment, future development of ancillary services requirements and distribution network characteristics.

Extend generation adequacy analysis to 2050

In this study the capacity adequacy and potential renewable curtailment reduction where modelled in detail for 2-3-, and extrapolated to 2050. A follow up study may carry out a more detailed analysis for 2050, providing more robust results on the potential long term impact.