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ELECTRICITY FOR EUROPE

SMART CHARGING:
steering the charge, driving the change

A EURELECTRIC paper, March 2015

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We speak for more than 3,500 companies in power generation, distribution, and supply.

We Stand For:

Carbon-neutral electricity *by 2050*

We have committed to making Europe’s electricity cleaner. To deliver, we need to make use of **all low-carbon technologies**: more renewables, but also clean coal and gas, and nuclear. Efficient electric technologies in **transport and buildings**, combined with the development of smart grids and a major push in **energy efficiency** play a key role in reducing fossil fuel consumption and making our electricity more sustainable.

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We support well-functioning, distortion-free **energy and carbon markets as** the best way to produce electricity and reduce emissions cost-efficiently. Integrated EU-wide electricity and gas markets are also crucial to offer our customers the **full benefits of liberalisation**: they ensure the best use of generation resources, improve **security of supply**, allow full EU-wide competition, and increase **customer choice**.

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Europe’s energy and climate challenges can only be solved by **European – or even global – policies,** not incoherent national measures. Such policies should complement, not contradict each other: coherent and integrated approaches reduce costs. This will encourage **effective investment to** ensure a sustainable and reliable electricity supply for Europe’s businesses and consumers.

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Smart Charging: steering the charge, driving the change

A EURELECTRIC paper *March 2015*

This paper presents the potential of smart charging and related benefits for customers, the power system and society more generally. Shedding light on industry examples and projects, it concludes by outlining key actions to ensure the effective roll-out of smart charging, thus contributing towards the implementation of a low-carbon energy system and sustainable transport. This paper addresses EU policymakers, regulators, electricity and e-mobility stakeholders, as well as customers. It is divided into four main parts:

- First, it explains **the challenges that increasing numbers of electrical vehicles loads can pose** for electricity distribution grids.

- Second, it shows that **by coordinating the charging process, the risk of technical bottlenecks can be overcome and investments can be avoided or at least minimised**. The flexibility that such 'smart charging' can provide will ultimately benefit customers as energy costs are reduced and new services are created. Smart charging will also benefit society at large, in that it optimises the use of the power system and supports renewables integration.

- Third, the paper looks at **different examples of how the industry is engaging in smart charging** – ranging from using simpler load management techniques to using electric vehicles as decentralised storage and spare balancing capacity. In this regard, the paper benefits from latest RD&D activities carried out by EURELECTRIC members in Europe.

- Finally, the paper sets out **seven key recommendations and actions for policymakers, regulators and e-mobility industry stakeholders** to ensure that smart charging becomes a reality in Europe.

The content of this paper is supported by the results of a EURELECTRIC survey on the effects of e-mobility and smart charging in particular, carried out in autumn 2014 and based on a modelling tool developed by Endesa. Respondents from 11 countries participated, including distribution system operators, retailers and industry associations.

The main aspects covered by the survey included long-term e-mobility market estimates, smart charging trends and active customers, the impact on the distributions grids, as well as power mix trends and emissions. The survey questions and results can be found in the annex of this paper.

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Executive Summary

The power system is in the midst of transformative change. The EU’s short-term 2020 and medium-term 2030 agenda for emissions reductions, increased renewables penetration and efficiency improvements is fostering the development of decentralised generation and electric vehicles (EVs). To integrate the flows of the new sources of supply and the new forms of demand, the power system will need to become smarter.

Likewise, the EU’s transport sector is undergoing substantial changes towards sustainable mobility. Transport is responsible for about a quarter of EU emissions and is almost exclusively dependent on oil. EVs provide an important part of the solution towards more sustainable transport. They are cleaner, quieter and three times more energy efficient than their conventional counterparts.

As the share of EVs grows, the electricity distribution grids at local level will most likely be first affected. Even at low market shares, EVs could easily congest local transformers and disrupt voltage levels. Faced with this situation, as networks were designed to meet demand at all times, the traditional “fit-and-forget” approach to distribution network development would imply building more lines and transformers. But this approach may no longer be the most cost-effective as it involves high technology adoption costs that might be burdening the national power systems and preventing e-mobility from truly hitting the mass market.

Another solution also exists. In electricity and transport, the key enabler for electric vehicles is ‘smart charging’. Smart charging involves the intelligent charging of the batteries in electric vehicles: charging them in a way that avoids excessive and costly spikes in power demand and also – in the years to come – using the batteries of the cars as storage to deliver valuable services to the electricity system, as well as maximising local integration of renewable energy sources (RES).

Smart charging can deliver numerous benefits for customers, the power systems and society as a whole:

- **Customer participation in smart charging is only possible if customers receive clear financial benefits that can lead them to play a more active role**

With 90% of the charging estimated to take place at household and workplace locations, it is important that smart charging measures are adopted and made available to customers. With smart charging, customers will be able to charge their EV at home without having to increase the building’s maximum grid connection power and thus manage their own load. This reduces the need to reinforce the grid leading to lower energy costs. The same argument can also apply for fleets (e.g. corporate fleets) that can benefit from advanced pricing models building on the smart charging concept.

Moreover, **customers will be able to save on their energy bill by agreeing to shift their consumption to off-peak hours with cheaper electricity tariffs**. In doing so, and adding further savings from fuel switching, **car owners can benefit from a reduction of 23% in an electric car’s total cost of ownership (TCO)** as compared to a conventional fuel car. These savings also easily outweigh the EV’s higher purchasing price. To make smart charging attractive for customers, it is important that customers are incentivised and made aware of the financial benefits involved. Regulation should also be adapted to support smart charging.

- **Smart charging can enable EVs to act as flexible loads and decentralised storage resource that can benefit the power system as a whole and minimise or eventually avoid grid reinforcements**

Our analysis shows that even if all the cars on the road today were electric the current electricity system could cope with the resulting increase in electricity demand: i.e. a corresponding 802 TWh or 24.3% increase in the total demand – but only if the charging of those cars is carefully managed. Indeed, while providing a fully electrified fleet is possible in terms of energy used (kWh), in case of uncoordinated charging, EVs could have a huge impact on demand (kW) of electricity at certain times.

By coordinating the loads, smart charging can help avoid major overloads while optimising the use of the grid and generating capacity. In this way, investments in distribution grids can be minimised by avoiding major grid reinforcements. In addition, smart charging can help to tap the significant storage potential of EVs - especially at the household level when the whole integration of EVs, storage and solar power system is put in place. Indeed, it can enable electric vehicles to be charged when there is surplus renewable capacity available e.g. solar at noon and wind at night. In the long-term and mass rollout of EVs, electric vehicles could act as distributed storage resource to support power system integration.

- **Ultimately, smart charging can deliver important sustainability gains for society at large**

E-mobility brings important societal benefits as it improves energy efficiency, air quality and urban noise, and reduces CO2 emissions. As an indication, with a power sector carbon intensity of 330 g CO2/kWh in 2010, a typical electric car would result in emissions of around 66 g CO2/km, compared to an average of 126 g CO2/km for new cars in 2013. Electricity as a transport vector is thus an extremely effective way of solving the EU’s transport emissions challenge while lowering the annual cost of the EU’s oil import bill.

The uptake of electric mobility and smart charging is expected to establish a positive loop with renewables integration, given that e-mobility is a power-dense, mobile and controllable load. In this regard, **smart charging could lead to almost decarbonisation of electric transport** as less emitting power plants outside peak hours are used and more renewable capacity is utilised - **achieving in addition annual savings of 1,863 million EUR as a result of avoided costs on CO2 emissions** in 2050[1].

In addition, the EV potential in terms of reducing energy consumption is also significant. **Electric vehicles can be three times more energy efficient than conventional cars**, **with a potential to achieve a net reduction of 137 Mtoe (million tons of oil equivalent) per year**. Smart charging will help boost these values, as it reduces societal costs and benefits the environment, while increasing power system efficiency.

Seven key actions for policymakers and e-mobility stakeholders

1. **Set up supportive policies for e-mobility and smart charging**: Provide a stable, supportive framework for e-mobility roll-out which has to include, from the outset, supportive measures for smart charging.
2. **Incentivise innovative smart charging solutions through smart regulation:** Incentivise distribution system operators (DSOs) and electric mobility market participants to invest in smart charging solutions and services, including innovative grid fees and/or ICT infrastructure financing models, depending on the market model in place.
3. **Support the customer who has the right to be informed and empowered:** Work on winning strategies for the customers through efficient price signals and smart contract based control signals. Understand customer behaviour and create awareness of the possibilities to use load management.
4. **Develop innovative smart charging technologies and services:** Develop energy and power flow management systems that allow for optimal EV charging and most cost-efficient solutions, including investments in ICT systems, intelligent charging infrastructure or advanced algorithms for local integration with distributed energy sources.
5. **Prioritise demonstration and commercialisation:** Private and public actors have to increase cooperation to enable the roll-out of large scale demonstration and pilot projects.
6. **Ensure EU-wide interoperability, common standards and efficient exchange of information:** Agree and develop common interoperable standards (both at physical and ICT layers) and on clear actor definitions and roles for smart charging.
7. Create win-win synergies and exchanges between electricity, automotive and manufacturing sectors: The electricity industry should increasingly engage with e-mobility stakeholders in raising awareness and developing best practices with a focus on customer opportunities.

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[1] Based on 15 €/ton assume in 2050; smart charging results in BEV emissions of 10g CO2/km and PHEVs of 45g/km

Introduction

E-mobility and electric vehicles[2] are a great opportunity for the electricity industry. But they can also represent a big challenge as they can disrupt the power system in a major way, adding additional peaks to the already observed peaks created by variable RES. At the same time, EVs can act as flexible loads and decentralised storage resources that can provide additional flexibility to support power system operation.

The answer to the negative and the positive scenario is the same: smart charging, as a way of coordinating the charging process according to conditions regarding customers' preferences, distribution grids constraints or local RES availability. Only smart charging helps to avoid major overloads, and lets e-mobility contribute to an improved power system.

To optimise mobility and energy use, it is crucial to move towards charging of electric vehicles, as well as other electricity loads, in a smart way. An intelligent exchange of information and connecting electric vehicles and recharging points with the help of smart meters or other intelligent infrastructure will be needed to optimise the system and empower customers with the information they need.

Studies have shown that cars in general, including EVs, are parked for about 90% of their lifetime. This, combined with their significant storage capacity and the fact that the battery is usually not fully spent in the average daily journey, can make EVs an attractive flexibility solution to supporting system operation. There is significant capacity available to be harvested by services enabled through smart charging.

Smart grids could enable electric vehicles to provide flexibility services to the power system in two ways.

First, with load management for electric vehicle charging, the charging process can be controlled by shifting the charging period to times of lower demand, reducing or increasing the charging power, or interrupting the charge of the car's battery in case of emergency situations. The charging can also be scheduled to coincide with available RES such as wind or solar, thereby promoting renewables integration.

Second, in the longer term, EVs could bring even greater flexibility to the system by supplying power back to the grid or home in a Vehicle-to-Grid (V2G) or Vehicle-to-Home (V2H) scenario**.** The cars can be used to store excess power from RES and discharge it at times of high demand. Using EVs as decentralised storage could be attractive in the long term as the numbers of EVs and renewables continue to grow. This could include the full integration of EVs with storage and DERs.

In times of high peak production today loop flows currently upset neighbouring systems. Alternatively generation sources are turned off in order to avoid major disturbance. With e-mobility and smart charging, in contrast, intelligent load management could take place and an extended integration of loads and production systems can be performed.

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[2] Electric vehicles in this report are defined as vehicles that depend on the electricity grid (non plug-in hybrids and fuel cells are not included)

1. Why not just "connect and forget"?

E-mobility market uptake

E-mobility provides an important part of the solution to energy and transport challenges. Clean and energy efficient vehicles have a key role to play in achieving the EU's transport policy objectives of reducing energy consumption, CO2 emissions, and pollutant emissions. Used smartly, electric vehicles with rechargeable batteries play a crucial role in the future electricity system. However, greater links between the transport and the electricity sector will be needed to realise this potential.

Current market growth forecasts for EVs still involve a wide degree of uncertainty and depend on a variety of factors, including government policies, purchasing costs and customers' willingness to buy the new cars. According to the EURELECTRIC survey on smart charging and e-mobility carried out for this paper, a transition scenario would achieve a 10% electric vehicles share in terms of accumulated market shares in 2035. This figure is achieved by following an "S-curve" development of market growth that saturates at 22% by the same year, representing the limit for market growth in annual sales in 2035.

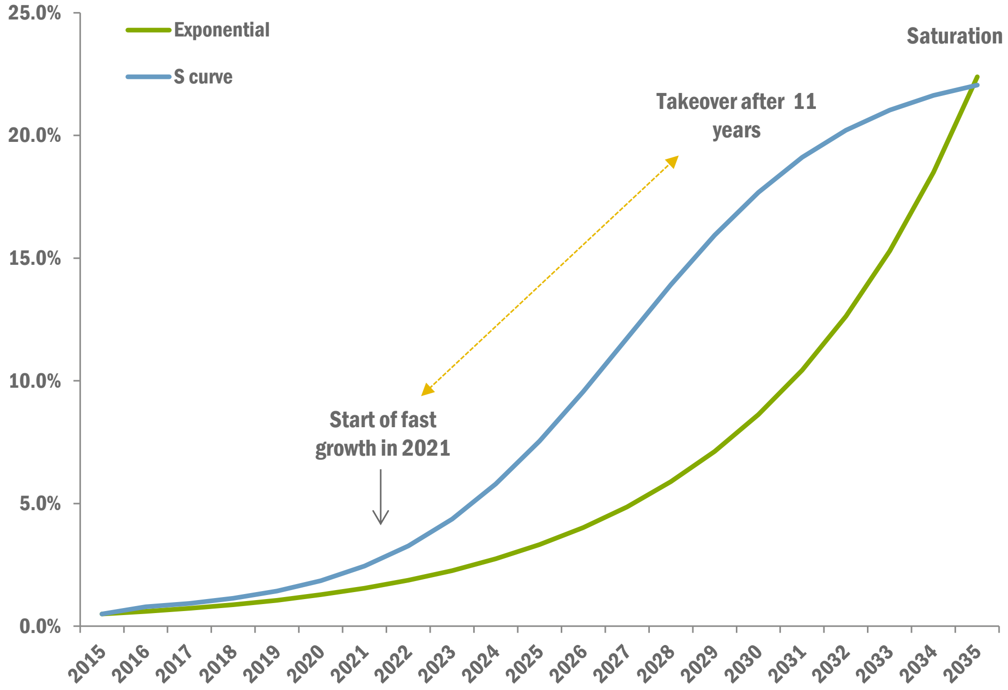
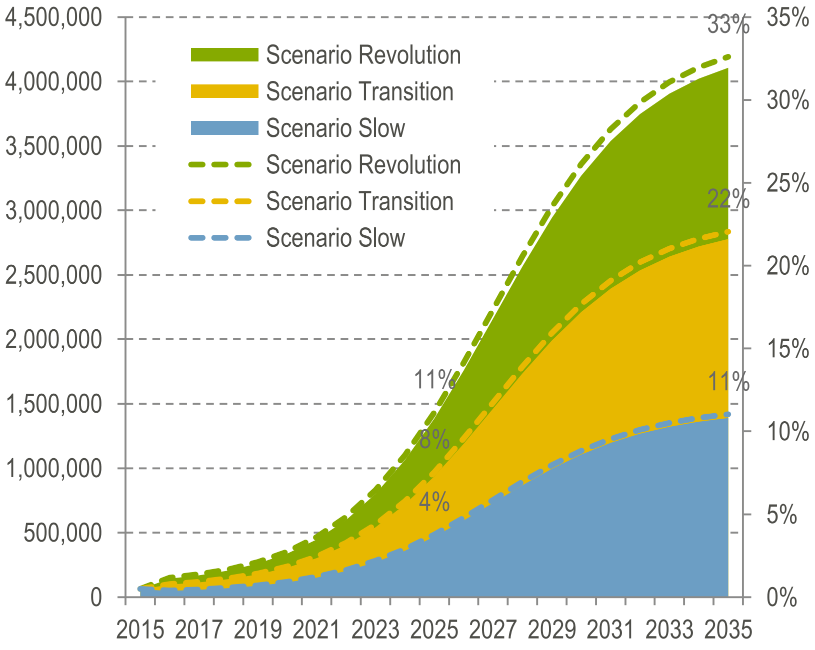


Figure 1: EV market uptake in a transition scenario (%) (theoretical approach S-curve vs exponential curve)
Source: EURELECTRIC smart charging and e-mobility survey

We can expect an uptake of fast growth starting in 2021, possibly because cars with higher battery capacity of more than 300 km would by then become available on the market at a cost-effective level of €/kWh. Figure 2 and Table 1 show related developments for the e-mobility market uptake under all three scenarios (slow, transition, revolution) in terms of both annual market shares and accumulated market shares.



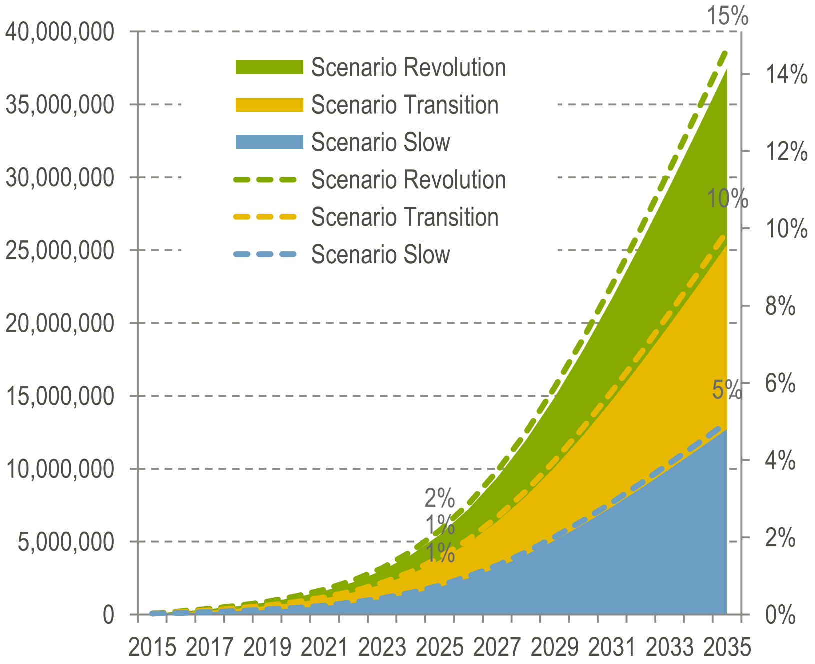


Figure 2: EV market uptake in the three scenarios. Upper graph: Annual Market Share (%) and Sales (Million). Lower graph: Accumulated Market Share (%) & Sales (Million); Source: EURELECTRIC smart charging and e-mobility survey

EV Mill - %	Slow	Transition	Revolution
2025	1.9M - 0.8%	3.7M - 1.5%	5.5M - 2.2%
2035	12.7M - 5%	25.4M - 10%	37.5M -15%
2050	37.1M - 15%	74.2M - 29%	109.7M - 43%

Table 1: Accumulated Sales (Million) and Market Share (%)
Source: EURELECTRIC smart charging and e-mobility survey

According to estimates a simultaneous development with an equal share of both plug-in hybrids (PHEVs) and fully battery electric vehicles (BEVs) could develop by 2035. In comparison to BEVs that only use an electric engine and a battery that can be charged from the grid, PHEVs also use an additional conventional fuel engine. Although PHEVs may have a smaller battery, they do not have the "range anxiety" and could drive more km per day on average than BEVs. Nevertheless, PHEVs and BEVs may have different impacts on the grid depending on the country, use case or the availability of recharging infrastructure.

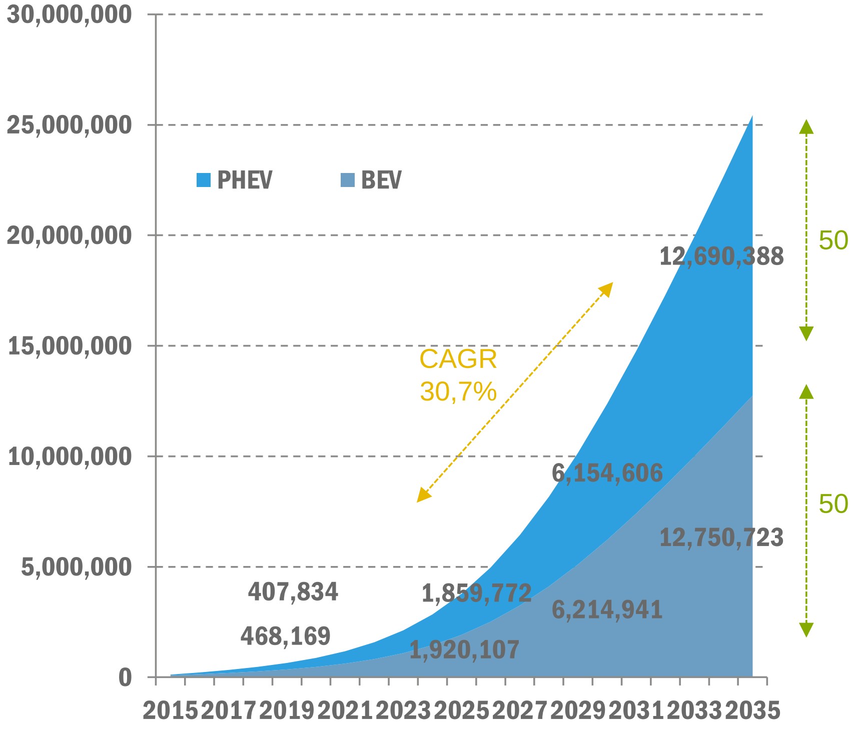


Figure 3: Share of accumulated PHEVs & BEVs by 2035 in a transition scenario (% and million); Source: EURELECTRIC smart charging and e-mobility survey

The major barriers for e-mobility are currently seen today in the:

- cost of battery, in terms of €/kWh, and therefore the cost of the electric car in general, of which the battery represents a significant part (normally not lower than 25%);
- limited electric storage capacity that influences the car's range; and
- lack of charging infrastructure, including smart charging business models availability

On the other hand it is evident that fuel costs are very competitive: despite the recent fall in the oil price, experts converge that the oil prices will remain volatile and rather increase than decrease in the future. In addition, an eventual spike in the price of oil could have even further negative consequences for customers. A higher share of electrification is therefore essential to reducing emissions, oil consumption and air pollution thereby leading to a more efficient and sustainable transport and power system.

We also witness promising trends on several of the barriers associated with e-mobility. As for the range, there is a positive trend in battery technology, which could see their capacity increase between 36 kWh and 43 kWh in 2025 in a slow or revolutionary scenario respectively. These figures mean that an average car will be able to provide a higher autonomy of more than 300 km, thereby overcoming range anxiety[3]. The battery of an average vehicle is also estimated to achieve an energy density of 287 Wh/kg in 2025.

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[3] Assumptions based on Nissan Leaf battery of 24kWh with a given manufacturing range of 200 km.

At the same time, the costs of batteries, a critical component of the overall cost of a car and range, are expected to experience a promising learning curve, with a significant decline in costs in the years to come. A battery pack of 39 KWh would see a reduction of 48%, reaching the value of 153 €/kWh in 2025 in the transition scenario. For comparison, estimates from McKinsey expect battery costs to drop to about 173 €/kWh by 2020[4], thereby falling between the EURELECTRIC transition and revolutionary scenario.

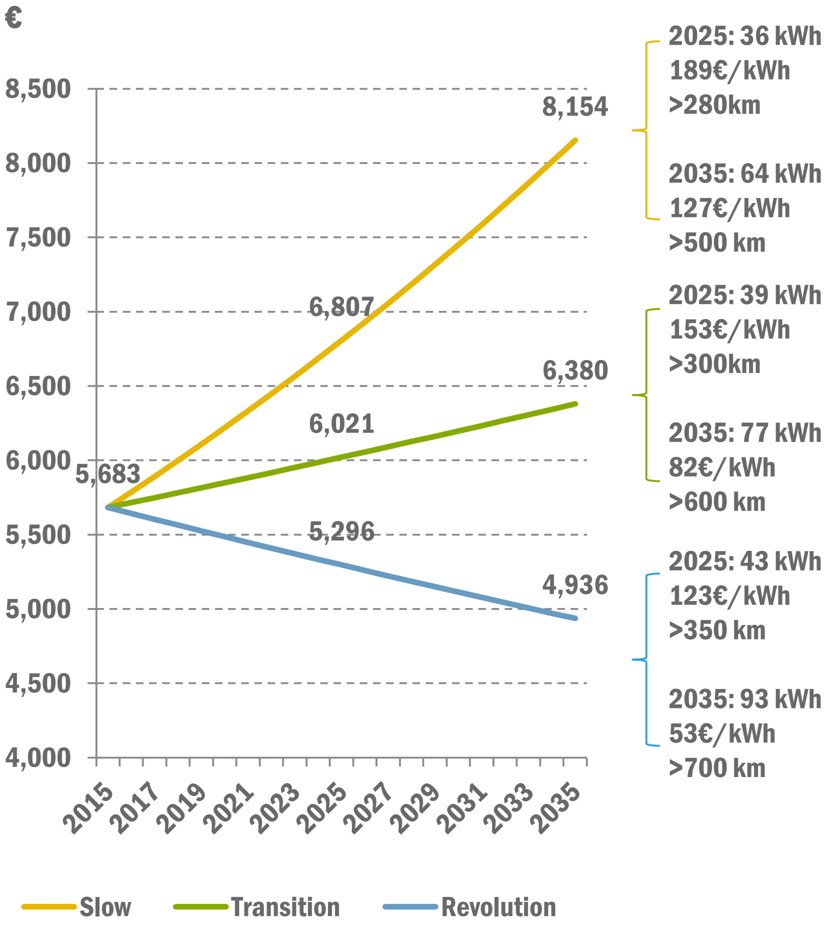

Figure 4: Development of battery costs (€) and capacity (kWh) in the three scenarios; Source: EURELECTRIC smart charging and e-mobility survey

Overall, lower battery prices will be a key driver for mass-market adoption, as well as mass-market adoption can trigger lower battery prices. Battery efficiency and the number of times they can recharge is also important. As an example, even if the battery can be recharged 5,000 times (80% state of charge), the total amount of km an average EV can drive over its lifetime is higher than current expectations of internal combustion engine (ICE) cars[5].

As for the argument that EVs are more expensive than ICE cars: it is important to remember that the cost structure is very different for both types of vehicles. Indeed the purchase price of an EV can be about 14% higher. But customers it is also important to raise customer’s awareness that the total cost over a car’s lifespan could be around 23% less expensive due to energy cost savings, but also lower maintenance costs. On our findings, the major saving is due to the energy cost which is three times lower as oil is substituted with electricity (see Chapter 3a)). Real price parity of EVs and ICEs is expected for 2020. If battery prices decrease the EV can either become more affordable or have an extended range, both of which can then have an even stronger impact on the total cost of ownership comparison of EVs to ICE cars.

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[4] https://handlemanpost.wordpress.com/2013/12/24/cost-projections-for-lithium-ion-batteries/. Convergence dollar/euro at 1 EUR = 1.15462 USD, January 2015

[5] Assuming a battery of 25 kWh and efficiency of 5 km/kWh

Regarding the last challenge, the electricity industry is actively engaging with other private and public stakeholders to promote the necessary charging solutions and infrastructure, as well as ensure customers can conveniently access the infrastructure. Member states are also expected to make significant progress in this area as they are required to prepare national plans by end-2016 with own targets for recharging stations as part of the EU's directive for the deployment of alternative fuels infrastructure.

As more governments encourage the adoption of EVs through buying bonuses, tax breaks and other measures, e-mobility is set to take off even more strongly. The recent German law offering free parking and permission to use bus lanes or the French government's proposal for additional measures to increase the buying bonus for electric vehicles (up to €10,000 for cars older than ten years) are just two examples of measures that can significantly boost EV uptake.

Electric vehicles loads and impact on the power system

A key factor to understand EVs interaction with the power system relates to when and how they are recharged. According to our survey, 90% of the charging is expected to occur at home, parking lots near home or at the office. As a result, the low-voltage distribution grids in residential or commercial areas are likely to be the first influenced by an increase in electric vehicles loads. Moreover, unlike other loads, electric vehicles are mobile and therefore are not always connected to the same place in the grid.

From a power system perspective, utilities are conscious of two elements with regard to the system's ability to introduce additional loads: the energy used at (kWh) and the capacity/power required (kW). Our analysis shows that **the additional electricity demand due to EV loads in terms of increase in total energy demand is feasible:** even a hypothetical 100% electrified fleet will add 802 TWh or a 24.3% increase in total electricity demand provided that those vehicles were charged outside peak hours**.** However, depending on their usage patterns, and thus the timing and the amount of charging power they draw from the grid, **EVs could have a significant impact on the peak demand (GW) of electricity at certain times and locations**.

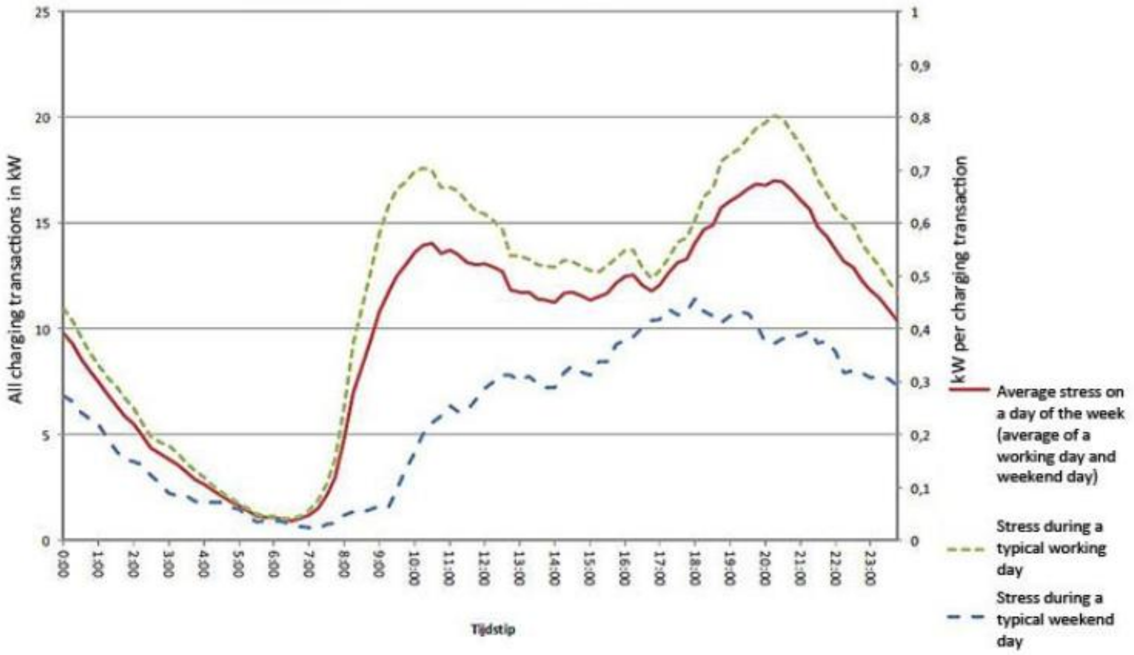

Figure 5: Stress on the electricity grid during the day due to EV charging on e-laad charging stations
Source: e-Laad foundation

The typical usage of an electric car shows that during the day the car is normally on the road, implying that the charging will be concentrated in the evening, when commuters arrive home from work (except if the cars charge when parked at the office). This means that the increased load will most typically coincide with the already existing evening peaks in residential areas. As parking for longer hours is largely related to commuter usage behaviour, there is also an additional risk that electric car usage could lead to late morning peaks when the drivers park their car at work, mainly in commercial or industrial areas.

Under these circumstances, uncoordinated charging could result in excessive peaks that occur for just a few hours a day, while the remaining part of the day is unaffected. This could have far-reaching consequences for all the stakeholders involved: distribution grids congestions due to power peaks and voltage drops, increased costs of electricity connection and use, expensive generation and grid reinforcements, as well as wider societal and environmental effects. Such situations could easily be overcome if the charging was actively managed to make better use of the available generation and grid capacity.

On the other hand, the fact that cars are parked for a long period of time during the night, and for several hours during the day means that electric vehicles can make use of the available storage potential and balancing power. Smart charging will make it possible to avoid most network reinforcements and associated costs, and tap the power and storage potential of electric vehicles according to the business model in place. The cars can also be scheduled to be charged when buildings producing more power that they consume i.e. at noon when there is enough solar power available.

In addition to the challenges and flexibility potential that electric vehicles may bring concerning grid impacts, electrification of transport presents the electricity industry with a significant opportunity. They can increase their revenues through increased sales of electricity by tapping into a new market and develop new business models for charging infrastructure and innovative smart charging products and services.

2. What is smart charging?

EURELECTRIC is aware of the on-going discussions to agree on a definition of smart charging, amongst others, the CEN-CENELEC Ad Hoc Group Smart Charging under Mandate 468.

This paper takes as definition for smart charging the one used by CEN-CENELEC[6]. Here it is described as “smart charging of an EV is when the charging cycle can be altered by external events, allowing for adaptive charging habits, providing the EV with the ability to integrate into the whole power system in a grid- and user-friendly way. Smart charging must facilitate the security (reliability) of supply and while meeting the mobility constraints and requirements of the user. To achieve those goals in a safe, secure, reliable, sustainable and efficient manner information needs to be exchanged between different stakeholders.”

The CEN-CENELEC paper also mentions that smart charging involves “the charging of an EV controlled by bidirectional communication between two or more actors to optimize all customer requirements, as well as grid management, and energy production including renewables with respect to system costs, limitations, reliability, security and safety”. Several actors can influence smart charging and can play different roles depending on the market model in each country. More details can be found in Annex 3.

In any case, smart charging is a process driven by both:

- **Price signals:** where flexible EV loads respond to time-of-use, dynamic hourly price of energy, price of maximum instantaneous power demand, etc.
- **Control signals**: according to grid and market situations (request for temporary demand power reduction, allowance for increase in the power, etc.)

The control mechanism can be enabled by the grid, by the charging point, or by the vehicle itself, while a communication system with the grid allows the charging process to take actual grid capabilities into account (intelligent algorithms can be distributed at all three levels) as well as customers preferences. Price or control signals can be communicated through an ICT infrastructure (e.g. intelligent metering system, communication between charging stations and back-end systems) in order to allow algorithms to take generation and grid constraints into consideration, as well as to enable the customers to benefit from price opportunities. Smart charging should respect customer's needs and charging requirements regarding vehicle availability as long as there are no critical limitations by the grid or the energy supply.

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[6] WG Smart Charging Report – Smart Charging of electric vehicles in relation to smart grid, CEN-CENELEC e-Mobility Coordination Group, CEN-CENELEC-ETSI Smart Grid Coordination Group

3. Challenges and opportunities of smart charging: customers, power system, society

Smart charging can represent an opportunity for all the stakeholders involved:

- **Customers:** satisfaction, reduced energy costs and ecological value;
- **Power system**: optimising generation and grid capacity, cost efficiency by minimising network reinforcement costs, facilitating renewables integration;
- **Society:** reducing local and global CO2 emissions and related costs, in addition to increasing energy efficiency and social welfare

a) Maximising customer convenience while reducing costs

Studies show that EV users prefer to charge their cars in regular patterns, mostly at home or at work, which means that the residential low-voltage grids will likely be the primary charging point for EVs at least in the medium- term. As seen previously, EURELECTRIC's survey also shows that 90% of the charging is predicted to take place with normal and medium power in locations such as households and workplaces by 2035. This charging behaviour demonstrates the need for smart charging to change customer behaviour.

At the residential level, the EV has the potential to even double the power consumption of a household in some countries. Significant upgrades of the home grid might therefore be required (i.e. need to increase the level of connection and subscription power), which may come at an increased cost. In contrast, if the charging can be managed, customers can optimally use the moment when the charging process can be accommodated within the existing infrastructure. With mode 3 charging, customers are also able to manage the power level (the amperage).

In order to implement smart charging it is crucial to inform and empower customers about the active role they can play in avoiding the increase of the cost of electricity. Customers must be made aware that their cars might be charged with a delay or that the battery may not be fully charged at the start of a trip, but that neither necessarily has an impact on their mobility needs while it can improve the power system's economic and environmental performance. Customer acceptance will depend on actors[7] (be it electricity retailer, e-Mobility Service Provider, etc) respecting a set of customer-defined requirements. Customers can for instance set the car's departure time or the required battery capacity reserve. The charging station then determines the current battery status and calculates the energy necessary to reach the desired state.

In addition, customers could more easily accept a smart charging service if it is economically convenient. Indeed, smart charging could lead to significant cost savings if customers use cheaper electricity at "off-peak" time. This is possible when time-varying prices are applied (i.e. time-of-use or dynamic prices) that can incentivise drivers to charge at more favourable times for power system operation (e.g. overnight). Customers may take the price signal into account or they may decide not to and pay a higher price as a result. New charging models with premium prices that penalise peak usage are also being considered.

Figure 6 shows that cost savings between 24% and 41% are possible when the charging is deferred to off-peak periods. The reduction is due to the significant price gap between on-peak and off-peak hours. To reduce such peaks, it is important that price signals are established that will encourage customers to curb their consumption at peak times, as well as that customers are informed about these opportunities. The roll-out of smart meters alone will have no or limited impact on peak demand, but should be accompanied by time-varying prices to provide the appropriate price signals to customers.

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[7] See Annex 3 for a description of actors involved in smart charging

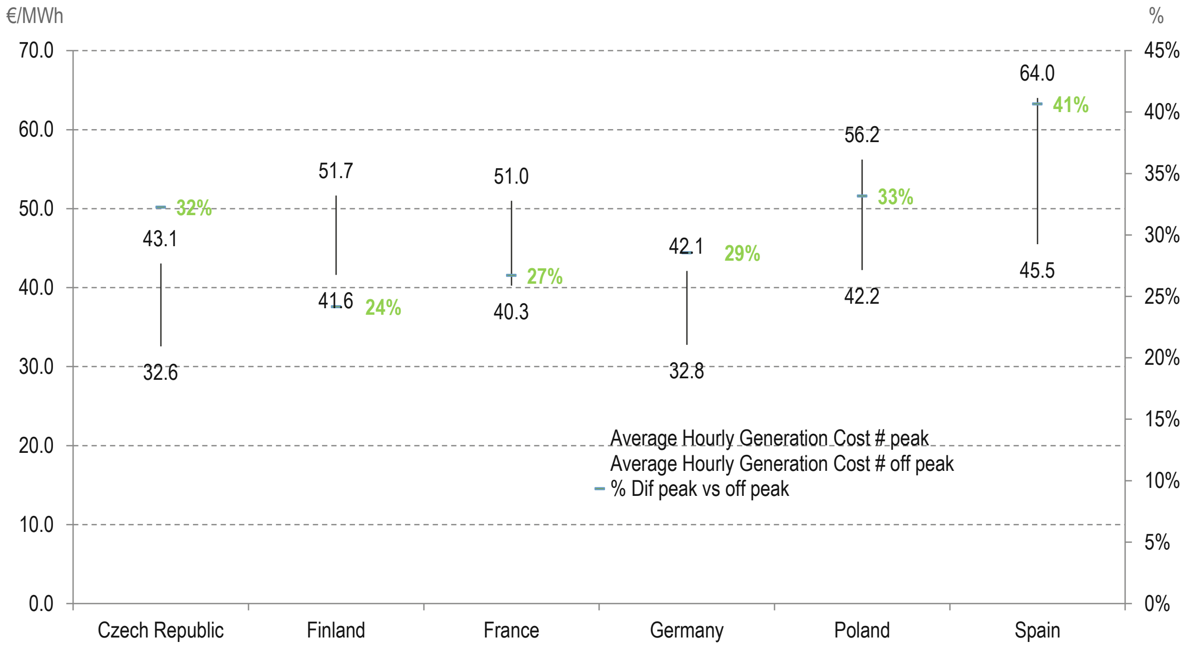

Figure 6: % of discount for EV demand response based on on-peak and off-peak prices (€/MWh) in six EU countries; Sources: Platts, EURELECTRIC smart charging and e-mobility survey

Customers could access the reward or cost savings through a smart charging option via their supplier or via their e-mobility contract with their e-Mobility Service Provider (eMSP). In case of private charging, the smart charging option can be planned automatically by the household's IT system. Usually in case of public and semi-public locations, customers can be rewarded the benefit via their contract with their eMSP/supplier that includes a smart charging service. In any smart charging strategy the customer should always be in control, either directly or indirectly through automated systems. Customers should be able to override any automatic load control signal if they need an immediate battery charging.

Active demand response is already happening today for other types of electricity loads. In some countries, customers already have a system that manages their home appliances' energy consumption. For these customers, the coupling of the smart charging system with their energy management system will help to optimise energy consumption for their whole household.

Example of demand response in France: boilers and electrical heating systems

Today in France it is possible to control sanitary boilers (i.e. water is heated during the night and stored for daily use) and heating systems in response to price signals from the energy retailer. The price signals are sent by the DSO, on behalf of the retailer, from the primary substation directly to the meter located at the customers' premises via a PLC communication link. In case of grid emergency, the DSO uses the same process to send load-shedding/shifting orders to customers. Customers can always override the systems if needed, at the cost of higher electricity prices.

In addition, so-called energy boxes are being developed by energy suppliers or ESCOs. These energy boxes are able to manage and optimize the energy consumption of the in-home electrical devices, depending on criteria that can be selected by the customer (energy prices, time-of-day, etc.).

The Grid for Vehicle[8] project carried out a survey on customers' willingness to delay charging to off-peak times (10 p.m. – 6 a.m.). Overall, the respondents answered positively but concerns about not being able to use their car were the most frequent reason for not being interested. Faced with the option of having their battery partially recharged immediately in order to have a price incentive, the choices to charge 40 km (2€), 80 km (2.5€) or 120 km (3€, full range) were almost equally preferred by respondents, with a slight tendency for a full battery immediately. The interest in participating in V2G was significantly lower than the interest in delayed charging. The low level of benefits expected as a result of participation was given as the prime reason (45% of respondents). Offers to choose between 20€ and 60€ showed that a higher benefit is naturally more attractive for people and stimulates participation.

The EURELECTRIC survey results also show that only 5% of EVs connected to grid at peak time could be able to provide V2G services by 2035. Results show that customer acceptance of discharging schemes are mainly related to range anxiety issues and price incentives. Customers would need a 30% reserve capacity left in the battery when unloading once a day is considered, and demand response with price incentive discounts of 20% to 30%. The fact that EVs are parked for about 90% of their lifetime could nevertheless provide a good opportunity for their battery to be used as power supply feeding electricity back into the grid. Effects on the battery usage due to charging/discharging, metering and regulatory issues as well as economic viability represent additional issues to be considered in order to fully exploit this technology in the future.

In addition, customers are more likely to accept an alteration or interruption in the charge with normal power recharging (even up to 22 kW) as the charging process is likely to coincide with the parking. High-power DC charging is likely to be more associated with en-route charging when a customer has stopped at a motorway service station to recharge on a longer journey. As they would like to continue the journey after a relatively short recharging stop, the charging time may prove more critical for an interruption, despite the financial benefit involved. It is however estimated that few fast public charging points will be necessary because most cars will spend most of their time parked at home or at work.

Lower total cost of ownership

The total cost of ownership (TCO) can represent an important factor in assessing the benefits of smart charging for EV customers. In addition to fixed costs (i.e. capital costs), the TCO also includes other key parameters of a car's running costs such as energy and maintenance costs, which are comparatively lower than for an ICE car.

EV owners will be able to save on their energy bill and benefit from a lower total cost of ownership. Our findings show that today's TCO including subsidies is already more attractive for EVs as a result of energy cost savings derived from the substitution of oil with electricity. **Over a ten-year lifetime of a car, customers can benefit from a cost reduction of up to 23% when the conventional fuel car is replaced by a comparable electric car and when smart charging is used**. This figure also includes the future scenario when the EVs will have reached capital cost competitiveness with ICE cars.

EV owners could reduce three times their energy bill due to the EV consumption. With smart charging, the bill will decrease by another 30% (Figure 7). Therefore, in addition to the reduction in the energy bill realised by EV customers over a vehicle's lifetime, smart charging has an additional potential to reduce energy costs due to cheaper electricity tariffs at off-peak hours. Also, as it can be seen in the figure below, the purchasing price of an average EV in 2014 was 14% higher than the average conventional fuel car. But this higher capital cost is largely offset by the energy cost savings.

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[8] http://www.g4v.eu/

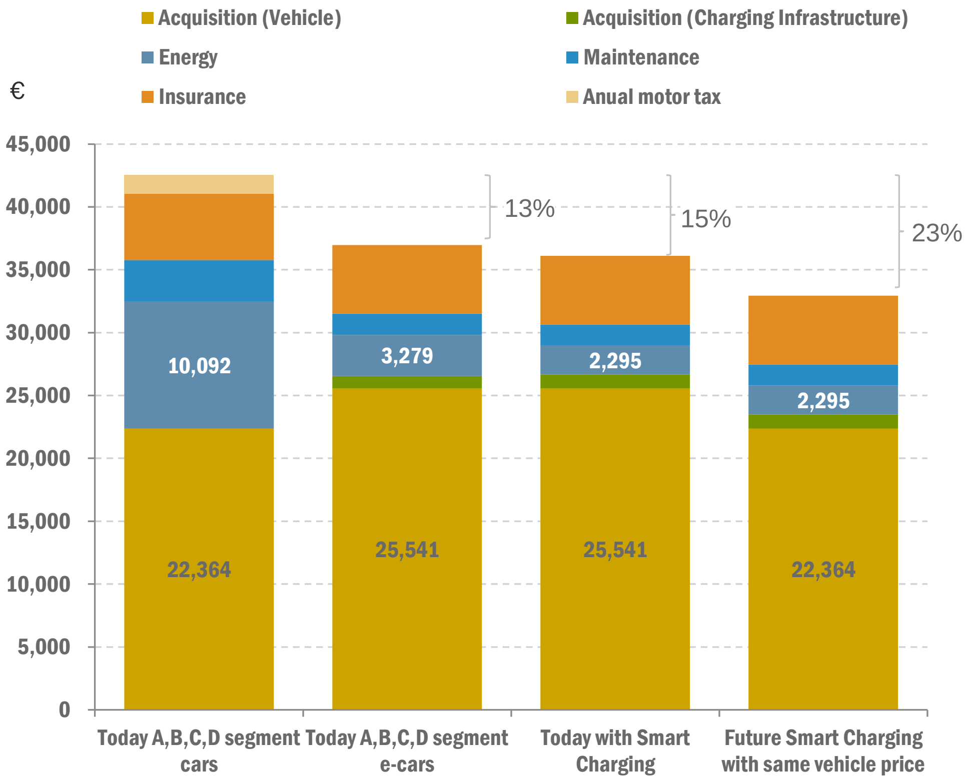

Figure 7: Estimated Total Cost of Ownership[9] EV (e-cars) vs. ICE (10 years, in €); Source: EURELECTRIC smart charging and e-mobility survey

Period (years)	A,B,C,D segment EV-cars	Today with Smart Charging	Smart Charging & same vehicle price
5	-6%	-7%	-16%
10	-13%	-15%	-23%

Table 2: Total Cost Ownership (savings EV vs ICE); Source: EURELECTRIC smart charging and e-mobility survey

As explained above, the major contributor to recovering the difference from the higher capital cost are the lower energy costs which account for about 70% in terms of total cost savings opportunities in a vehicle's lifetime. To realise smart charging, additional infrastructure such as ICT devices or smart metering might need to be installed which is also more than offset by the savings incurred. Moreover, EVs with higher battery capacity and greater range (C, D) can achieve greater savings than smaller vehicles (A,B) because the cost of the battery represents a significant weight in the total price of a vehicle.

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[9] Assumptions: e-cars (battery electric vehicles), A segment: mini (e-) or ICE- cars, B segment: small e- or ICE- cars; C segment: medium e- or ICE- cars; D segment: large e- or ICE- cars; E-segment: executive e- or ICE- cars; Lifetime: 10 years, mileage 15,000 km, average consumption: 20 kWh/100km; electricity cost 0.14 €/kWh, ; price of oil: 1.41 €/l; discount factor: 7% (ICE – internal combustion engine)

b) Power system benefits for generation and the grids

Enable grid management for a flexible system

EVs represent a new mobile, power-dense and variable type of electricity load that will mostly be connected to the distribution grids at the low voltage level. As EVs were not considered at the initial stage of network planning, they could cause serious network congestion and assets overloads. Smart charging will therefore need to take into account network constraints in order to avoid overloading the grid.

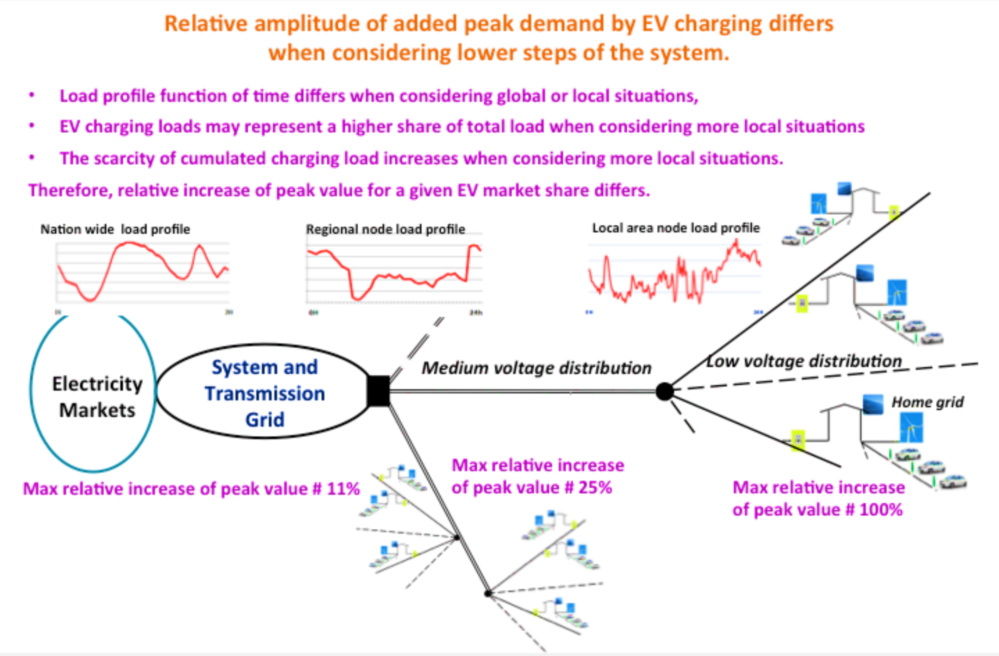
Today's distribution networks are designed to meet peak demand. However, with increasing penetration of EV loads and DER, the traditional approach of "fit and forget" may no longer be cost-effective. In many cases, peaks occur often for only a few hours a year and the utilisation rate of network assets declines. The major risk therefore is when the demand caused by EV loading exceeds the capacity of a network i.e. charging coincides with already existing peaks. Moreover, peaks need to be considered at the different scales of the power system: from the global where the balancing between supply and demand takes place (generally the transmission level) to the local (house, building, city, etc).

How to understand peak demand

When analysing the impact of EVs, it is important to clarify how peak demand is considered in the power system in order to design effective smart charging solutions. Peak demand needs to be considered at the following levels:

- **Wholesale markets** level where contractual demand meets contractual offers. Peak times where high demand and low availability create high energy prices.
- **TSO grid level** where a high demand for auxiliary services with low availability of offers creates high balancing prices for system services (frequency control and reserve power)
- **DSO grid level** where electricity is transmitted to end users. Peak demand can cause physical capacity constraints (overload of lines, transformers, voltage drops)

EV load profiles and their relative increases in the "peak" may appear to be very different, in time and value, depending on the place considered in the power system - be it at the electricity market level, transmission level or at the distribution level. EV charging concentration on the same grid could create potential extreme local demand. These peaks are independent from one another: a peak load in a local grid does not necessarily affect other parts in the rest of the power system.



Relative amplitude of added peak demand by EV charging differs when considering lower steps of the system.

- Load profile function of time differs when considering global or local situations,
- EV charging loads may represent a higher share of total load when considering more local situations
- The scarcity of cumulated charging load increases when considering more local situations.

Therefore, relative increase of peak value for a given EV market share differs.

Figure 8: Peak demand of electric vehicles in the power system. Source: ERDF

Although it depends greatly on the location on the grid and the individual grid itself, the increased load from EVs could expose the grid to a dramatic increase in peak demand at certain times and locations. This can lead to major network overloads such as voltage drop or thermal overstress which could result in grid assets ageing or eventually can cause service interruption. In that case, heavy investments could be required to upgrade the electricity cables connecting households to transformers and the transformers themselves. Investments in the upstream grid could also be needed. These investments may burden therefore the electric mobility technology adoption at national and international scale.

In assessing the ability to introduce EV loads on peak demand, we use as reference the IEA methodology of estimating peak load and the potential of smart grids to reduce it[10]. Peak demand serves as an important key design metric for grid operators and planners to assess current and future infrastructure needs and which helps to define the generation, transmission and distribution capacity of an electricity system. As the distribution system was designed to deliver the maximum load at any point in time, the gap between off-peak times and peak means an underutilisation of capacity and investments.

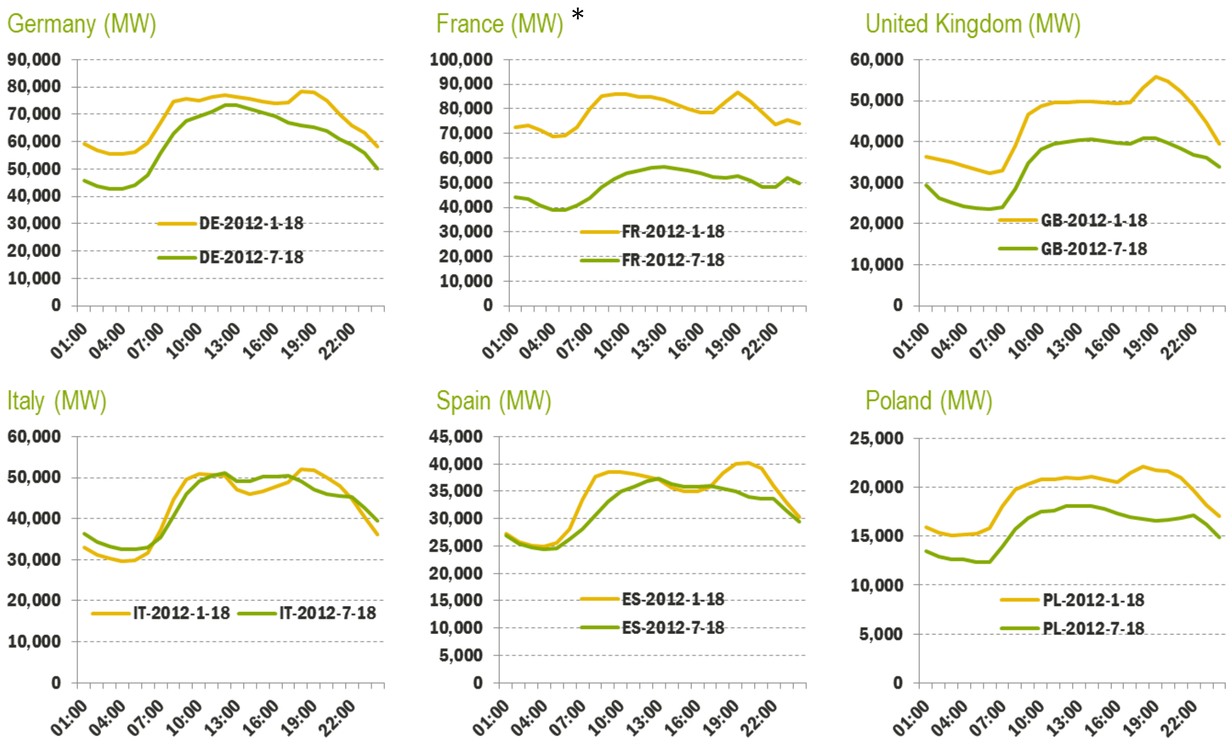


Figure 9: Load curves of six largest EU countries (hourly load values every 3rd Wednesday (MW) summer and winter (DB: 02.09.2014); Source: ENTSO-E (*gap between winter and summer is justified by the high proportion of electric heating in France)

If we define the peak load as the maximum load of a power system, we could then also assess the average load by dividing the annual generation demand by the total hours of a year. To illustrate, Figure 10 shows the peak load and the average load of the six largest EU countries based on current load curves, as well as for the EU-28.

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[10] IEA Impact of Smart Grids Technologies to 2050

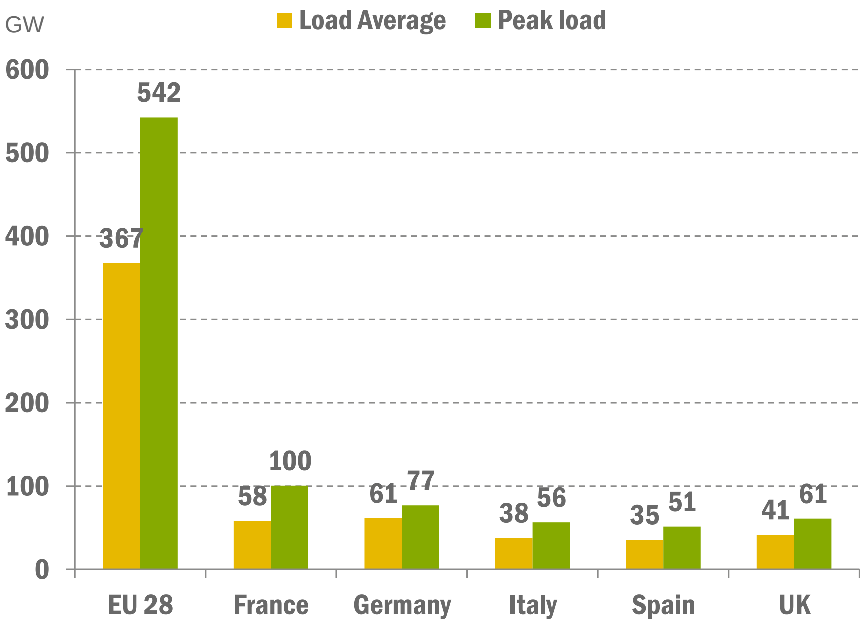

Figure 10: Peak load of six largest EU countries and EU-28 (GW) (reference case); Source: EURELECTRIC smart charging and e-mobility survey

Further, we consider that the evolution of the peak will depend on the coefficient of the peak load (CPL) or on its utilisation factor (UF)[11]. The CPL is defined as the ratio of peak load to average load and is an indication of the flatness of the load curve. The UF is used in the planning stage of infrastructure. Its values depend on the degree of interconnection of each electricity system. Values close to 1 show an optimised system. In the example below, countries such as Italy or Spain display values that could imply additional costs due to lower support from other systems (i.e. interconnection). They show behaviour of "isolated" systems which can indicate strong potential to optimise the grid asset utilisation.

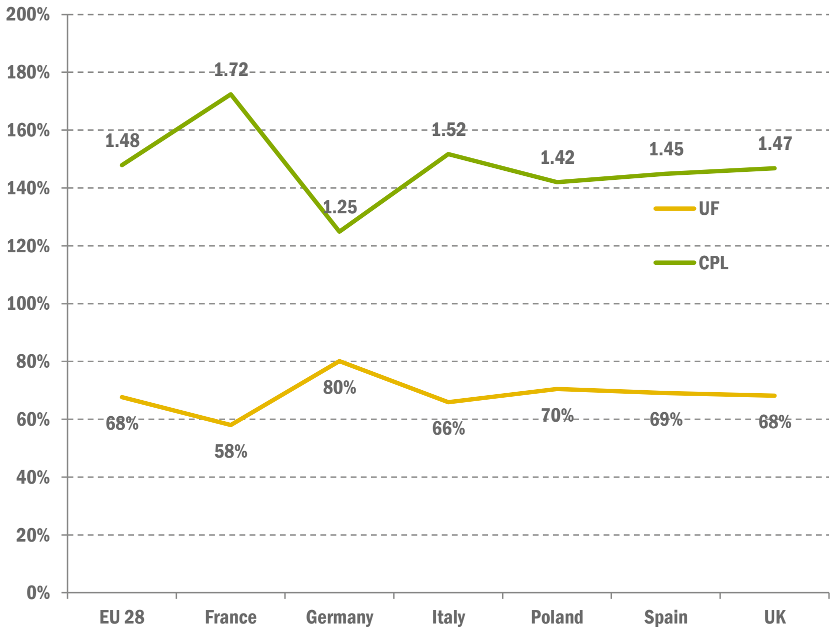

Figure 11: Coefficient peak load (CPL) and utilisation factor (UF) of six largest EU countries and EU-28 (%)[12]; Source: EURELECTRIC smart charging and e-mobility survey

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[11] CPL = peak load PL (GW)/load average LA (GW). The values go from 1.25 to 1.72 (1.48 average at European level). These values are correlated with the reversed Utilisation Factor (UF) (68% average). UF = 1/CPL.

[12] Based on ENTSO-E SWD (2013) 438.

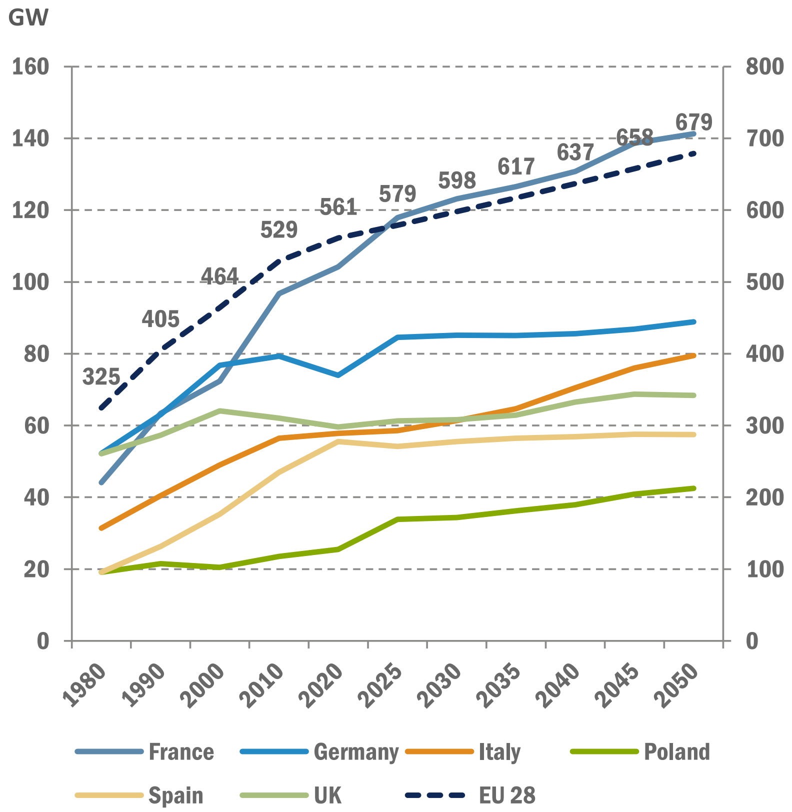

Figure 12: Evolution of Peak Load for EU-28 and six EU countries (GW). Source: EURELECTRIC smart charging and e-mobility survey

Based on the European Commission's trends to 2050 reference scenario, we estimate the evolution of the European peak load[13]. The estimates also include assumptions from the EURELECTRIC survey. Three major uncertainties are considered: EV market uptake, evolution of storage technology and policy support for smart charging. In assessing the peak load projection up to 2050, estimates for the evolution of the CPL and the load average are also taken into account in the process for the six countries considered. Figure 12 shows the evolution of the peak demand towards 2050 - no electrification of transport is considered.

Impact of 100% electric vehicles on peak demand

The increasing demand from electric vehicles could pose a serious challenge for the network as EV loads have the potential to exacerbate the peaking of the load curve. This can happen at the same time with increased electrification from other applications, such as heating and cooling that could also contribute to increasing demand at peak hours. The electricity generation in the EU-28 is estimated to reach 3,806 TWh by 2035, and the European peak demand 617 GW.

Assuming the hypothetical scenario of 100% car electrification, EV loads would add 92 GW to the load average and 130 GW to the peak load by 2035. In case the charging is uncontrolled, the additional demand from EVs could raise the peak demand by 21.1% by 2035 according to the expected growth in the co-efficient peak load by that year (Figure 13). This assumes that the load is uniformly spread across the peaking of the load curve. However, we can also expect that in some cases the peak load could be much higher. Figure 14 thus also assesses a scenario where the peak load at the European level could increase further to 30%, assuming a case when the co-efficient peak load doubles.

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[13] EU Energy, Transport and GHG Emissions Trends to 2050

100% EVs	Unit	EU 28
What is the Load Factor (2035)		
LA (Load Average)	GW	434
PL (Peak load) EURELECTRIC	GW	617
PL-LA	GW	183
% Reserve (PL-LA)/LA	**%**	**42,0%**
CPL (GW) = PL (GW)/LA (GW)	#	1,42
Utilisation factor (UF = 1 / CPL)	%	70,4%
What is the Impact in Load Average & Peak Load (2035)		
LA (Load Average) 100% EV	GW	92
New LA (Load Average)	GW	526
PL (Peak load) 100% EV assuming CPL = 2	GW	183
New total PL (Peak Load)	GW	800
Dumb charging (increase electricity Peak)	%	**29.7%**
PL (Peak load) 100% EV assuming CPL current	GW	130
New total PL (Peak load)	GW	747
Dumb charging (increase electricity Peak)	**%**	**21.1%**
PL (Peak load) 100% EV assuming CPL=0	GW	0
New total PL (Peak load)	GW	617
Smart Charging (increase electricity Peak)	**%**	**0,0%**
CPL (GW) = PL (GW)/LA (GW) (with EVs)	#	1,17
New Utilisation Factor (with EVs)	%	85%
Dif CPL (%.)	%	-17,4%
Dif Utilisation Factor (p.b.)	%	14,8%

Figure 13: Impact of 100% EVs on peak load by 2035; Source: EURELECTRIC smart charging and e-mobility survey

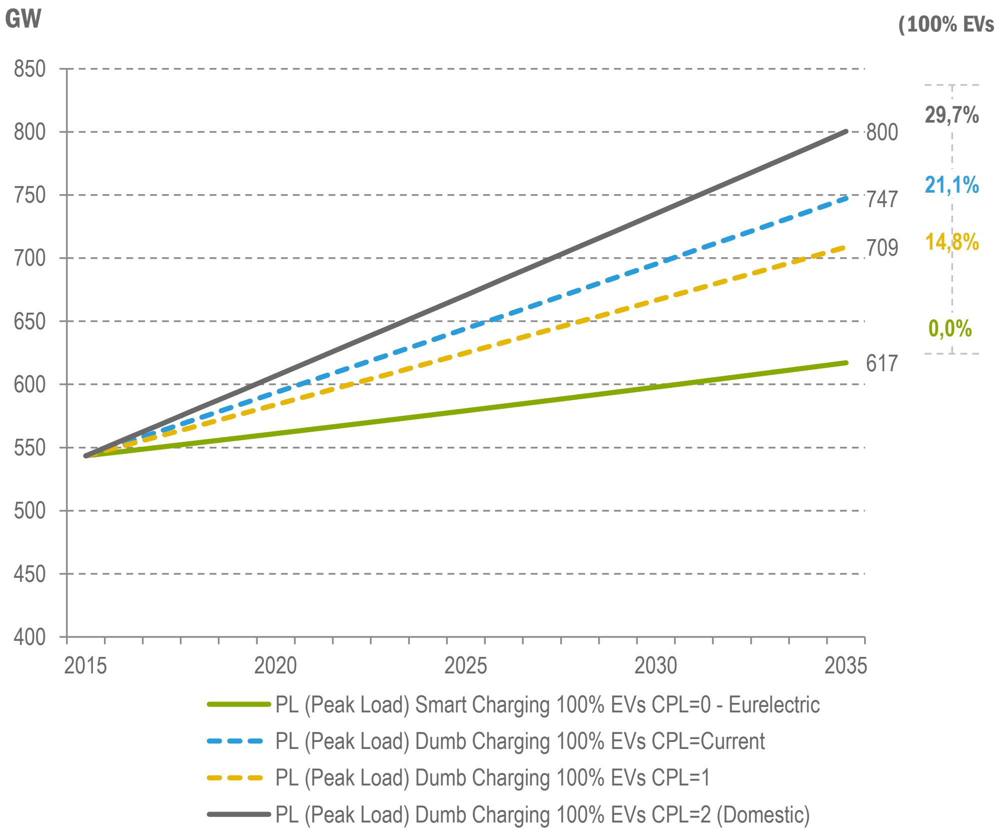

Figure 14: European Peak Load (GW) evolution in case of 100% EVs by 2035 and potential of smart charging to reduce the peak load between 15% - 30%; Source: EURELECTRIC smart charging and e-mobility survey

But if the charging is coordinated to make better use of the available grid capacity at off-peak hours, **smart charging has a potential to reduce the peak load to zero.** At the same time, the utilisation factor will improve by 14.8%. Thus smart charging has a strong potential to optimise the grid asset utilisation, thereby decoupling electricity capacity growth from peak load growth – and generating a whole new value chain from this decoupling.

Using the same rationale, we can analyse the increase in the peak load and the potential for smart charging for the three e-mobility scenarios (slow, transition, revolutionary). Depending on the degree of EV penetration in each scenario, EVs can increase the peak demand by 1.1 % to 3.1%, which could be reduced with smart charging. This means an improvement in the utilisation factor from 0.8% to 2.2%.

10% EVs	Unit	EU 28
What is the Impact in Load Average & Peak Load (2035)		
LA (Load Average) 100% EV	GW	9
New LA (Load Average)	GW	444
PL (Peak load) 100% EV assuming CPL=2	GW	19
New total PL (Peak load)	GW	636
Dumb Charging (increase electricity Peak)	**%**	**3,0%**
PL (Peak load) 100% EV assuming CPL=0	GW	13
New total PL (Peak load)	GW	630
Dumb Charging (increase electricity Peak)	**%**	**2.2%**
PL (Peak load) 100% EV assuming CPL=0	GW	0
New total PL (Peak load)	GW	617
Smart Charging (increase electricity Peak)	**%**	**0,0%**
CPL (GW) = PL (GW)/LA (GW) (with EVs)	#	1,39
New Utilisation Factor (with EVs)	%	72%
Dif CPL (%.)	%	-2,1%
Dif Utilisation Factor (p.b.)	%	1,5%

Figure 15: Impact of 10% EV on Peak Demand by 2035; Source: EURELECTRIC smart charging and e-mobility survey

%	**Slow**	**Transition**	**Revolution**
Peak Demand (CPL = 2 Domestic)	1.6%	3.0%	4.4%
Peak Demand	1.1%	2.2%	3.1%
Utilisation Factor	0.8%	1.5%	2.2%

Table 3: Main impacts by scenario (%); Source: EURELECTRIC smart charging and e-mobility survey

While price signals may provide an effective method to customers to lower their load at peak times, they may not always reflect network conditions, especially if they are heavily loaded. Price signals in the wholesale electricity markets do not always match price signals in network tariffs reflecting local grid congestions on the DSO network. We can have a situation where grid fees will increase due to the increased load, while the prices on the wholesale prices decrease. To prevent network overload and congestion at the local level, the DSO may want to make use of different flexibility measures to solve areas in addition to price signals. The DSO may adopt future flexibility solutions such as flexible network tariffs that could incentivise smart charging (i.e. capacity, time-varying), contract-based based smart charging (i.e. via eMSP including flexibility services for the DSO) or other services. Smart charging solutions will therefore require new innovative solutions and services, as well as an adequate regulatory framework that allows for flexibility for both network operators and market participants.

Electricity retailers and third party providers are best placed to provide the service to the customers. They can offer simple and integrated services with smart charging based on both price signals and control signals that would help to take into account network constraints (overload risk, coordination between different loads to avoid peak demand). The DSO would need to constantly monitor the state of the grid and, in case of congestion, send control signals to the retailer or the third party provider (e-Mobility Service Provider). An intelligent connection will be necessary to combine wholesale price signals and grid signals.

To manage the operation of distribution systems, tariffs could be accompanied by a "traffic light scheme" to influence smart charging. Under normal conditions "green light", the grid would operate following the market procedures, without any restrictions for network customers. In alter/insecure states "yellow light", the DSO could use market-based procedures to incentivise grid users to adapt production and/or consumption to the grid situation. In well-defined emergency conditions "red light", the DSO should be able to undertake direct load management or emergency interruption of supply after the contracted options have been exhausted. In any case, the DSO still have to compensate the customers that are subject to such "imposed actions", either based on compensation rules agreed with their NRAs or based on contractual arrangement.

Ensure a cost-effective solution by avoiding unnecessary grid investments

Therefore by optimising the grid utilisation (i.e. by making sure the demand does not exceed grid capacity), smart charging can also help to avoid grid reinforcements costs.

At "home grid" level[14] (being a house, a multi-dwelling or business building, a plant etc.), a dedicated line from the low-voltage (LV) source has generally to be installed to connect the additional charging point(s). The addition of EV charging on top of other existing loads in the building may require a reinforcement of the connection line to the DSO grid, and the subscription of a higher maximum rated power at the delivery point. Overall, simplistic charging regulation (e.g. time-varying) or more elaborated regulation (e.g. maximum power control of each charging point through an energy management system) has to be chosen in relation with the economy of investment and operation.

Moreover, for fleet garages, it has to be considered that some charging points may be designed for accelerated or high power charging. The higher is the charging power requirement, the more is the need for smart charging proved. However, high power recharging of more than 22 kW (usually > 43 kW) may be less acceptable for customers for load management purposes due it short duration. In any case, high-power recharging is likely to be a premium-priced service (peak demand pricing) for the EV driver.

For single homes, the economy at stake generally requests simplified smart charging such as time regulation (i.e. overnight charging). For buildings with EV fleets, a computation on a ten-year period, taking into account 20 electric vehicles, lead to a total cost of 30 k€, from which 22 k€ can be avoided by smart charging, to be compared to the cost of an energy management system deployment and operation at the building in order to prove smart charging cost-effectiveness.

At DSO grid level, investment costs for the DSO result from the reinforcement of grid lines and transformers, plus its share of the cost of home grids connections according to the regulation (e.g. in France ~50% of the total cost of connection of a customer). The size of the reinforcements result from statistical calculations that take into account a forecast of customer behaviour, and particularly their implementation of smart charging.

Considering low-voltage grids, calculation made in France by ERDF lead to the following costs assessment without smart charging, and resulting costs savings due to smart charging (costs are assessed per unit equal to 1 MEV = 1 million EV globally travelling):

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[14] See Annex 3 for a description of different levels of smart charging in private locations

Total LV grid reinforcement cost per million EV for:	Cost without smart charging	Cost reduction due to smart charging
EV charging in single houses	200 M€	200 M€ (almost total cost avoided)
Multiple EV charging in multi-dwelling or business buildings	650 M€	450 M€
Public charging spots in the streets and parking lots	240 M€	120 M€

Table 4: Reinforcement costs (Million €) for low-voltage grids and cost reduction with smart charging; Source: ERDF

Considering the main substations and medium-voltage lines, their reinforcement without smart charging would request 80 M€ per million of travelling EVs, to be added to the LV grid costs. Smart charging could reduce most of this cost, and consequently related upstream costs at the TSO level.

The total of these costs will be borne by the DSO, but will be passed on to the customers later due to the tariff system. Therefore, the following question is raised: will the existing costs signals and system regulations naturally push home grid operators to adopt smart charging inducing cost-efficiency at DSO grid level? We have reason to think that it will not be the case, and that more effective signals and incentives have to be designed in order to achieve best global economy of grids. They will have to be combined with those related to wholesale power demand and production balancing.

A benefit resulting from avoiding reinforcement costs at a system level would be that they could be used to be redistributed as a business opportunity across the smart charging value chain, with e-mobility service providers and charging station operators possibly providing ancillary services to the DSO.

Optimising the efficient use of generation capacity

Any additional demand triggered by EVs could also require additional efforts with regard to electricity generation optimisation. In the long-term, the use of flexible EV demand will not only result in more efficient grid usage, but could also avoid unnecessary investment in generation capacity, resulting in longer asset lifetime.

In case of uncontrolled charging, it is likely that the availability of generation to meet peak demand could lead to a decrease in efficiency – where increased peaks can put greater strain and result in reduced efficiency of the thermal units providing electricity, as well as potential increase in the cost of electricity generation. With smart charging, charging energy requirements are more evenly spread throughout the system, enabling a more optimal use of the available generating capacity. Therefore, it reduces the need for expensive peaking plants which are usually more expensive to run and more carbon-intensive.

One major issue for the power system is by how much and to which extent the grid and the generation capacity can cope with an increased electrification of transport. A large share of electric vehicles connected to the grid will naturally be followed by an increase in the total electricity demand in the respective grid. The results of our findings suggest that there is enough generating capacity to accommodate 100% electric cars by using the existing grid infrastructure – but only if those cars were charged outside the peak periods.

Even if all the European car fleet on the roads today was electric there would be about 249 million batteries drawing power from the grid with a corresponding 802 TWh as additional demand. This translates into a 24.3% increase in electricity demand, and respectively about 17% increase in the load factor[15] in the power system. In 2035, the same hypothetical share would add a lower 21.1% to total electricity demand as the electricity generation is estimated to increase by that time. Assuming a 10% EV growth in Europe by 2035 as in our transition scenario, e-mobility will account for just 2.2% of total electricity demand in 2035.

However, whereas the increase in terms of energy used is feasible, even at very high penetration levels, they can lead to excessive increases in peak demand (see previous section).

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[15] Load Factor equals: total electricity energy used (=existing + passenger cars) / Max demand * hours per year (8760

100% EVs	**Unit**	**EU 28**
What is the total electricity energy used? 100% EVs		
Total numbers of Cars in the EU (2015)	Mill	249
Average annual distance per car	km	15,000
Electricity consumption if all were electric	kWh/km	0.20
Losses	%	7
Total Electricity consumption if 100% were electric	**TWh**	**802**
What is the maximum demand today?		
100% Passenger Car electrification	TWh	802
Gross Electricity Generation	TWh	3,295.5
Percentage of increased electricity consumed 100% EVs (today)	**%**	**24.3%**
What is the maximum demand in 2035?		
100% Passenger Car electrification	TWh	802
Gross Electricity Generation (2035)	TWh	3,806.1
Percentage of increased electricity consumed 100% EVs (2035)	**%**	**21.1%**
10% EVs		
What is the total electricity energy used? 10% EVs		
Total numbers of Cars in the Relevant Area (2035)	Mill cars	25
Total Electricity consumption if 10% were electric	TWh	82
Gross Electricity Generation (2035)	TWh	3,806.1
Percentage of increased electricity consumed 10% EVs (2035)	**%**	**2.2%**

Figure 16: Impact of 100% EV on electricity demand & impact of 10% EVs on electricity demand in the transition scenario; EURELECTRIC smart charging and e-mobility survey

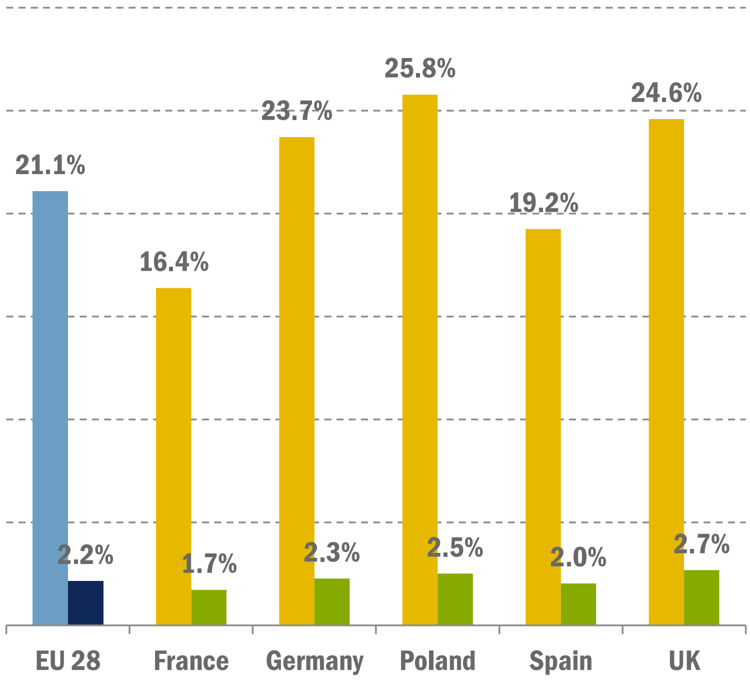

Figure 17: Percentage of increased electricity consumed due to EVs in 2035 (%); Source: EURELECTRIC smart charging and e-mobility

Facilitating renewables and making efficient use of available capacity

Since electricity demand varies widely and supply of generation cannot yet be stored economically on a large scale, the traditional power system has been designed so that supply always meets demand. When high demand occurs, most of the power plants are working flat out while at times of low demand many are left idle. The growing shares of unpredictable, variable RES challenge the traditional way. Given their volatility, wind and solar power can create excess energy output, causing significant peaks in the power system. Several options could be used to stabilise and reduce fluctuations: use of flexible back-up generation such as hydro or gas combined cycle units, large storage systems or demand response.

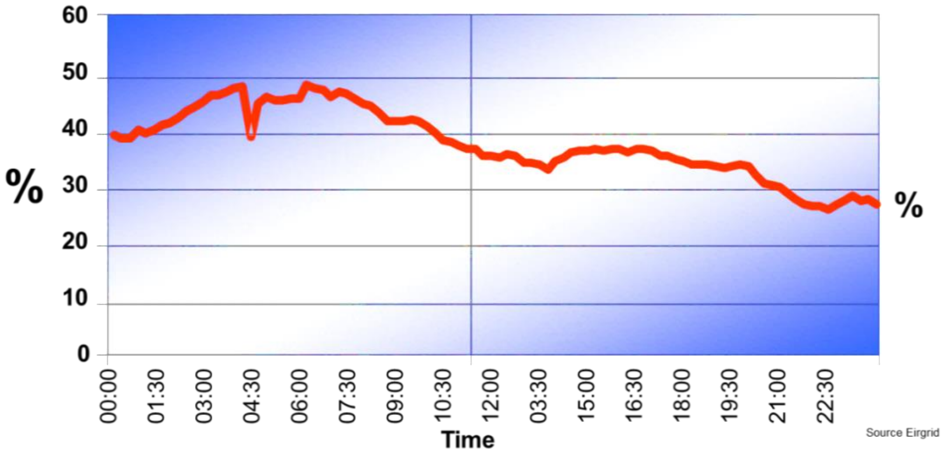

Figure 18: Ireland - Wind Generation as % of System Demand Monday 5/04/2010; Source: Eirgrid, Ireland

Electric vehicles with rechargeable batteries and thereby inherent storage capacity represent yet another form of demand that could contribute to system flexibility. With smart charging, EVs have the potential to shift their loads into periods of lower demand or store electricity for later use. This coordinated charging could therefore allow to integrate RES in a cost-effective way benefiting both the customers and the generators. The customers will be able to benefit from more attractive prices due to the abundance of renewable energy i.e. such as wind power at night or solar during the day. The generators will also benefit as they will have the opportunity to sell their production at any time.

EU-project GridTech has analysed EV smart charging integration of RES as illustrated below.

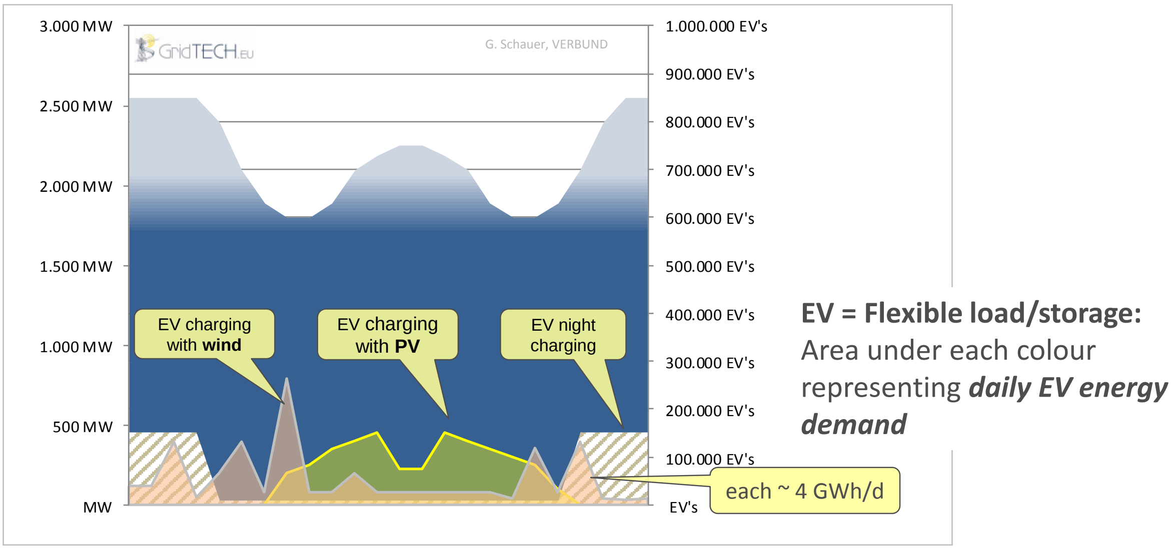

Figure 19: EV smart charging supports RES integration (MW); Source: GridTech EU project

Self-consumption of electricity with solar power and electric vehicles

Smart charging can also help to maximise self-consumption from solar systems installed on customers' houses combined with available storage and recharging infrastructure. This use case can be very interesting for utilities, as it can be deployed as a new end-customer service combining energy efficiency, household DER financing and EV charging costs minimisation.

Controlling the charging (and discharging) process at a smart home may help to both avoid peaks and maximise the energy supplied by solar panels – making it possible to recover the upfront investment for local assets (charging stations, solar panels, storage). A local stationary battery can store the excess power when it becomes available and release when it is needed but it is not produced[16]. The EV charging taking place at night means an increased availability of storage in the residential area, thereby contributing to flattening the demand curve. The remaining supply could be filled with electricity from the grid.

Despite concerns over potential costs, a model developed by UBS bank suggests that it can make economic sense. Each technology will help to speed up each other's adoption, reducing costs over time: lower battery costs will boost EVs sales, which in turn would bring further economies of scale to stationary batteries[17].

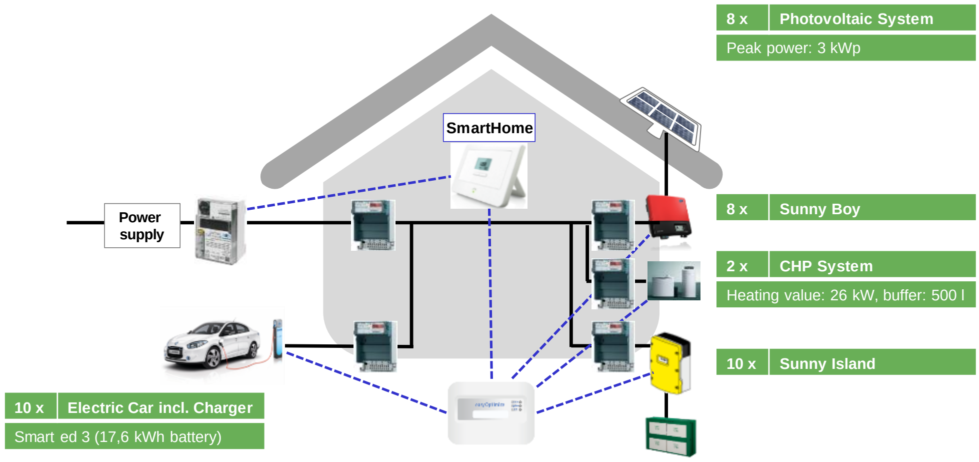

Figure 20: Smart Home concept; Source: Smart-E, RWE

c) Sustainability gains for society at large

In the face of the EU's climate and energy ambitions, both the electricity and the transport sector will need to become smarter and more sustainable. Today, mobility and power systems are only loosely linked. Tomorrow, they will be widely integrated. Smart charging will be an essential part of the transition towards a low-carbon economy and smarter electricity system.

EVs represent electricity-consuming technologies that can increase the total demand of electricity, and related peaks – but this issue could be solved if charging is optimised in an intelligent way. Smart charging will thus help enable a faster uptake of e-mobility, leading to important societal benefits as system efficiency and cost savings are realised for the customers. Moreover, EVs also hold great potential in increasing energy efficiency, improving air quality and reducing emissions. They also result in lower noise levels, particularly in urban driving conditions.

Road transport is responsible for about a fifth of the EU's total CO2 emissions and it is the only major sector with rising emissions. Moreover, it is nearly 94% dependent on oil. While efficiency improvements of ICE vehicles have been made over the past years, significant shares of transport electrification will be key to further meet emissions targets in this sector and reduce its dependence on oil.

The EU has put in place legislation[18] to reduce CO2 emissions from cars and vans, including targets for 2015 and 2020. Whereas the target for 2015 of 130 g CO2/km has already been achieved, the regulation requires further reductions from a current average of 126 g CO2/km to 95 g CO2/km by 2021. Emissions targets encouraged manufacturers to diversify their fleets with lower emissions cars as it can be seen below.

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[16] UBS report "Will solar, batteries and electric cars re-shape the electricity system?"

[18] Regulation (EC) 443/2009 (CO2 from cars), Regulation (EU) 510/2011 (CO2 from vans)

Range Fuel	type	g CO2/km
BMW i3, Citroën C-Zero, Ford Focus, Kia Soul, Mercedes S, MIA, Mitsubishi i, Nissan LEAF, Peugeot Ion, Renault Fluence, Zoe, smart fortwo, Tesla, VW Golf e-Up!	EV	0
BMW i3 (Range Extender)	PHEV	13
Vauxhall Ampera	PHEV	27
Chevrolet Volt	PHEV	27
Golf GTI	PHEV	35
Audi e-tron	PHEV	37
Mitsubishi Outlander	PHEV	44
Volvo V60	PHEV	48
Toyota Prius Plug-in	PHEV	49
Porsche Panamera	PHEV	71
Toyota Yaris	HEV	75
Peugeot 308, Lexus CT200h, VW Polo	D	82
Renault Clio	D	83
Toyota Auris, Citroen DS5	HEV	84
Hyundai i20, Skoda Octavia, Peugeot 3008, Ford Fiesta,	D	85

PHEV: plug-in hybrid EV and range extender; HEV: hybrid EV and D: diésel

Figure 21: Top lowest CO2 emitting car models g CO2/km in 2015: Source: EURELECTRIC smart charging and e-mobility survey

Concept	Unit	2012	2013
Passenger car density	#/1000 inhab	483	487
New registration Cars vs 100 inhabitants	#/100 inhab	2.4	2.4
Average of CO2 of new cars (DE,IT,FR,UK,ES)	gCO2/km	131.6	125.6

Table 5: Main transport data; Source: ACEA pocketbook

We can therefore see that from a so-called “tank-to-wheel” analysis (Figure 21) the least emitting cars are pure EVs with zero-tailpipe emissions (an electric motor has no waste gases or exhaust fumes), followed by PHEVs with emissions below 50 g CO2, and some hybrid and conventional fuel cars. Yet the average CO2 emissions of new cars in 2013 are exceeding 95 g CO2/km (Table 5).

However, electric cars not only have zero-tailpipe emissions, but they can also result in major CO2 emissions savings even when emissions from the power generation process are included. As an indication, **with a carbon intensity of the power sector of 330 g CO_2/kWh in 2010, a typical battery electric car would result in CO2 emissions of around 66 g CO_2/km**[19]. This compares favourably to the 2013 average CO2 emissions of new cars of 126 g CO_2/km[20].

E-mobility’s effectiveness in reducing large-scale CO2 emissions will rely on the decarbonisation pace of the power sector. Indeed, electric cars will contribute to even further emissions cuts as the European electricity sector will reduce in carbon intensity over the coming years. **By 2035, the average electric vehicle could deliver emissions of about 28g CO2/km[21], which means they could be almost five times less carbon**

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[19] Calculation: 1) EV: CO2/ km =[CO2 g/ kWh (for the relevant area electricity)] X 2) [kWh/ km (for the particular EV)]. Assumptions: 1) estimated carbon intensity of the power sector of 330 gCO2/kWh in 2010; European Commission Trends to 2050; 2) average consumption of a typical BEV assumed at 20 kWh/100km

[20] ACEA pocketbook http://www.acea.be/publications/article/acea-pocket-guide

[21] Estimated power sector carbon intensity of around 140 gCO2/kWh in 2035, European Commission Trends to 2050

intensive than today's average conventional car[22]. Given the European electricity sector's commitment for decarbonisation by 2050, coupled with an increasing deployment of RES, electric vehicles could become nearly zero-carbon in terms of CO2 emissions by that time. In 2013, renewables represented 27% of the electricity produced in the EU-28, and more than half of the electricity generated was low-carbon[23].

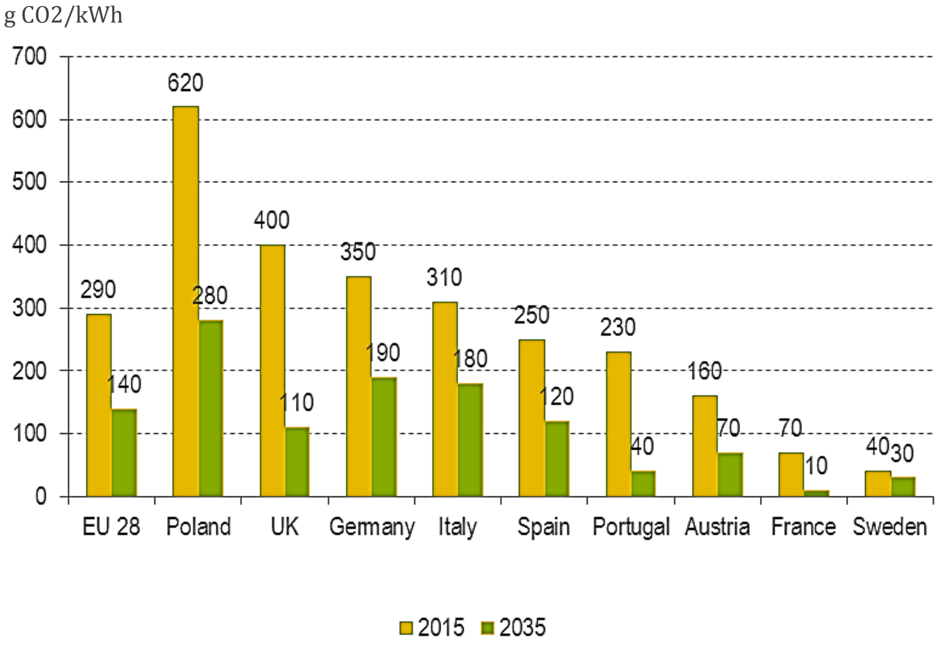

Figure 22: Estimation of the carbon intensity of the electricity sector (g CO2/kWh) for EU-28 and other EU countries in 2015 and 2035 based on the EC Trends to 2050

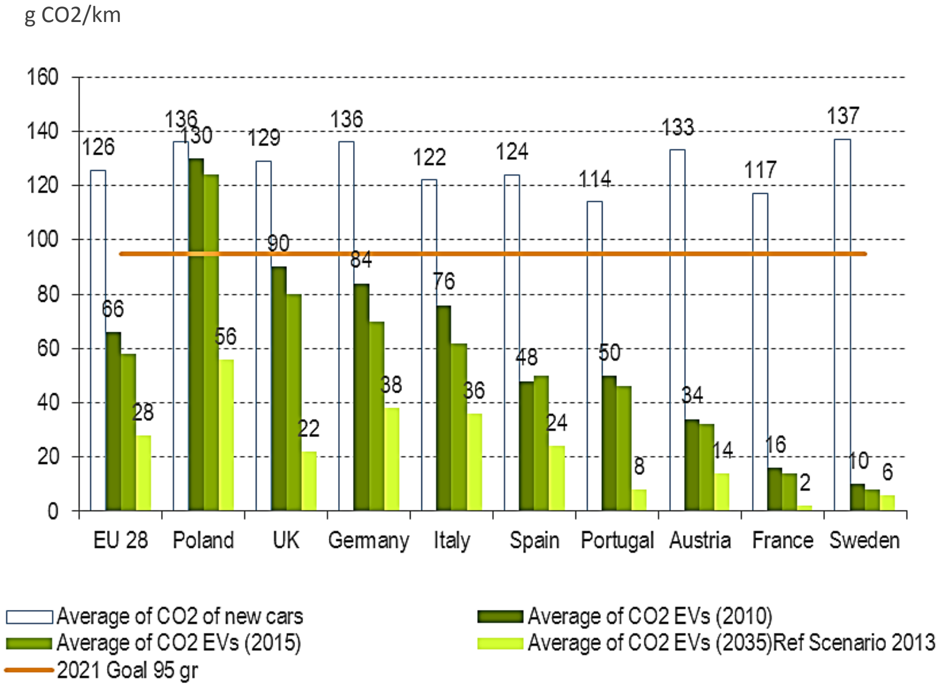

Figure 23: Average CO2 emissions (g CO2/km) of EVs (2010, 2015 and 2035) vs average CO2 emissions of new cars (2013) for EU-28 and other EU countries; Source: EURELECTRIC smart charging and e-mobility survey

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[22] Annex 2 provides graphs with more information on the CO2 emissions of cars for all EU-28

[23] EURELECTRIC Power Statistics 2015

Lastly, the power sector is covered by the EU's Emissions Trading Scheme (ETS) which means that the total CO2 emissions of power stations will not increase, even when more electricity is delivered for electric cars.

Electricity is therefore an extremely effective way of solving the EU's transport emissions challenge. In particular, "smart charging" will add an additional benefit by achieving emissions close to zero due to optimised charging. If cars are coordinated to charge at times of lower electricity consumption, they can optimise the use of existing capacity and use less emitting power plants running outside peak hours which would be needed to meet what are otherwise infrequent spikes in electricity demand, maximising their integration in the electricity system. Moreover, with smart charging the time of charge can be coordinated to coincide with available renewable capacity such as wind at night, or solar at noon, bringing further benefits in terms of emissions reductions.

The following figures show total emissions and savings due to emissions avoided in Mt CO2 (million tons of CO2) when combustion fuel cars are replaced with EVs according to their estimated shares in the three scenarios analysed in this paper (slow, transition, revolution). The indices are based on the rates of emissions of vehicles that are currently registered and future emission levels as seen above.

Mt CO2	Slow	Transition	Revolution
New cars			
2025 oil cars	4	7	10
2035 oil cars	24	48	71
2050 oil cars	70	140	207
Average EVs 2015			
2025 EVs	1	3	4
2035 EVs	9	18	26
2050 EVs	26	52	77
Average EVs 2035			
2025 EVs	1	2	3
2035 EVs	6	12	18
2050 EVs	18	35	52
Smart Charging (2035)			
2025 EVs smart charging	0	1	1
2035 EVs smart charging	3	5	8
2050 EVs smart charging	8	16	23

Figure 24: Total Million tons of CO2 emissions savings (Mt CO2) in the three scenarios; Source: EURELECTRIC smart charging and e-mobility scenario

Our model shows that smart charging has the potential to achieve almost decarbonisation of electric transport due to the use of less emitting technologies as explained above. In the transition scenario, replacing the same share of conventional fuel cars with EVs would cut CO2 emissions by 36 Mt of CO2 in 2035. **With smart charging, these reductions could be further increased by 19% which would translate into overall CO2 emissions avoided of 43 Mt CO2 in 2035.** In 2050, the transition scenario could reach significant CO2 emissions savings of 105 Mt CO2, and respectively 124 Mt CO2 with smart charging.

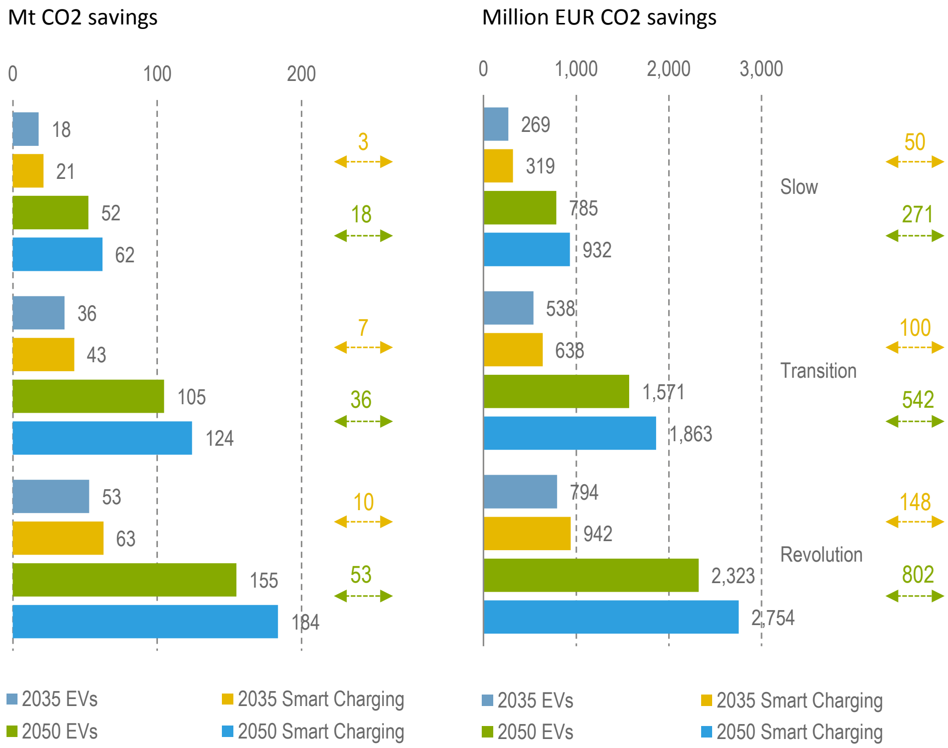

Figure 25: Total Million tons of CO2 emissions (Mt CO2) savings (left) and Million EUR CO2 savings (right) in the three scenarios in 2035 and 2050

Assuming a price of 15€ per tonne of CO2 in 2050 we could estimate that the savings achieved due to replacing conventional cars with EVs in terms of economic benefits would reach 1,571 million EUR per year. With smart charging, these economic benefits would be even higher, achieving **1,863 million EUR per year in terms of avoided costs on CO2.**

Additionally, the EV potential in terms of reducing energy consumption is also significant. EVs can be three times more energy efficient than conventional fuel cars. To illustrate, already today, assuming a hypothetical scenario of 100% car electrification, **the potential energy efficiency of electric cars could achieve a net reduction of 137 Mtoe (million tons of oil equivalent) per year** in the EU[24].

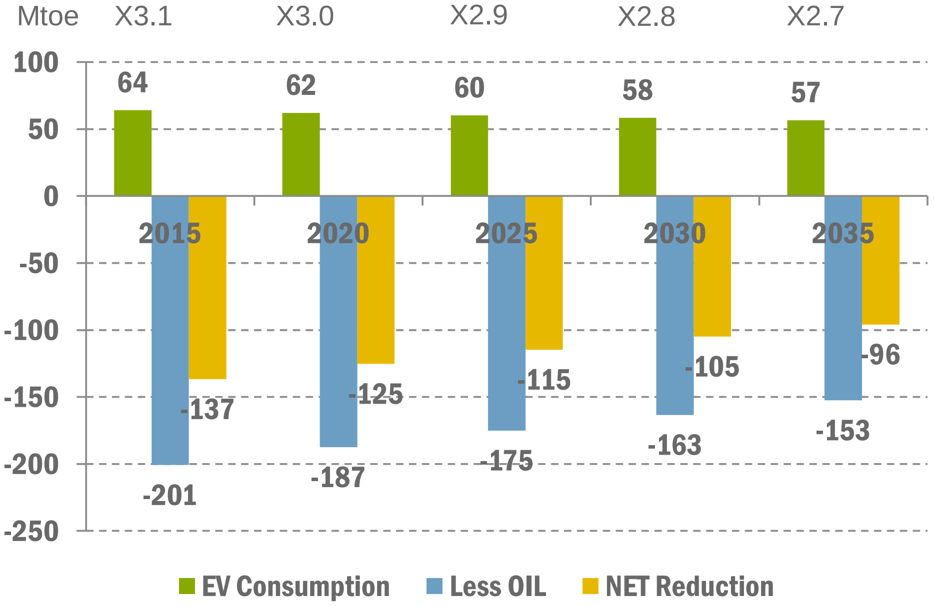

Figure 26: Energy efficiency potential of 100% car electrification (Mtoe); Source: EURELECTRIC smart charging and e-mobility survey

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[24] Assumptions: average mileage of 15,000 km per car/year, an electric car consumption (3,000 kWh BEV and 1,100 kWh PHEV), oil import price around 0.55 €/litre

In the EURELECTRIC transition scenario, a share of 10% EVs would achieve a net reduction of 9.5 Mtoe per year in 2035, with a reduction on oil imports of 12,500 million EUR and accumulated savings of around 72,000 million EUR in the next 20 years. In the revolution scenario, the energy savings would be 20.5 Mtoe, with a resulting reduction in oil imports of 26,700 million EUR and accumulated savings of around 153,000 million EUR.

Finally, as the cost of grid reinforcements would be otherwise spread across all electricity grid customers through network tariffs if no smart charging strategy were used, the fact that these could be avoided represents an additional economic advantage for customers and society. To sum up, smart charging has the potential to reduce CO2 emissions and costs while increasing system efficiency and social welfare.

4. Smart charging strategies: examples from the industry

In short, while growing shares of EVs could provide flexibility as mobile loads and storage resources that can integrate renewables, this potential can be tapped only if vehicles are charged in a smart way. Otherwise, on the contrary, their charging could even have a detrimental effect on the power system.

The simplest form of charging electric vehicles is when the charging process is not controlled by an external factor i.e. drivers are allowed to recharge as and when they wish. This approach requires no changes to the market design or operation of the distribution system but can dramatically increase the peak load in a given area, causing overloads and grid congestions. Existing strategies with prices signals which may require little change in network design i.e time-of-use or dynamic tariffs could be used to influence customer behaviour. Customers are therefore expected to react in an active way to price signals and that they shift their electricity usage to the lower tariff period. The interaction with the customer is done by using unidirectional communication signals to the meter or the load.

Considering the most common case of charging vehicles at home, when prices are low at night or when there is cheap surplus renewable capacity available (i.e sun during the day, wind during the night), this can be done be using simple control mechanisms. One way would be to connect the cars all the time when parked at home so that most frequently the charging takes place, it will require only part of the total battery capacity. Another strategy would be to have a controlled charging station so that the charging will start only at best price hours thereby carrying a financial benefit for the customer.

A simple timer-based mechanism such as clock system (which may be provided within the EV) can fulfil the control mechanism. This solution can be effective in an early phase with a low electric vehicles penetration in the power system. However, as the electric vehicle market grows, EURELECTRIC stresses that this solution can have a major drawback for the electricity grids: synchronisation of all charging sessions can lead to excessive peaks of power demand at some other point in time (e.g. grid congestions and new peaks could happen even during the night due to simultaneous charging as EV loads tend to charge at the beginning of the low tariff period).

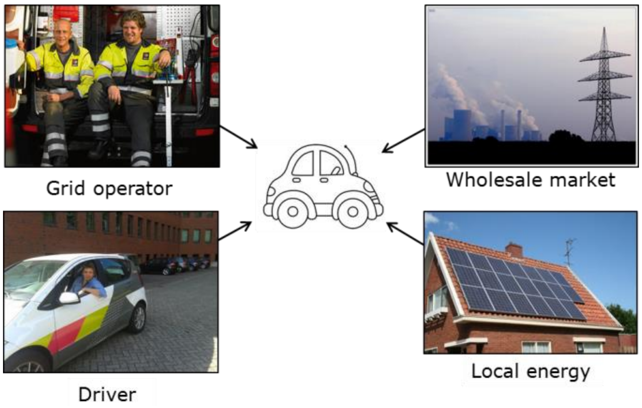
Therefore, more advanced control mechanisms should be considered, taking into account control signals from the DSO, with an energy management system (EMS) within the house or in the charging station to coordinate the charging process with other uses so as to minimize peak demand. If smart metering is implemented within the house, the EMS may use the signals and data from it. Smart meters may also help to optimise the extent to which EV loads would be discouraged to be used simultaneously when time-varying prices are applied. In addition, advanced controlled charging will require an intelligent bi-directional communication to exchange information between the electric vehicles and the charging stations.

More advanced features of charge management strategies can be achieved with the possibility of providing advanced grid-supporting flexibility with the use of bi-directional power flow mechanisms (V2G). An example of an interim Vehicle-to-Home technology was initiated by Nissan in Japan (see example 3).

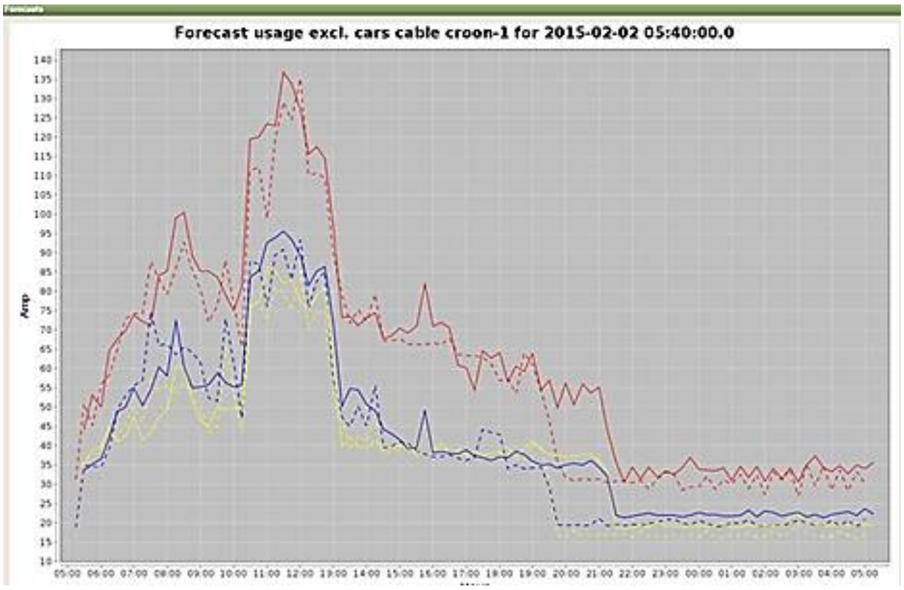
Examples of smart charging from industry and pilot projects

1) Smart charging at Enexis – an example from the Netherlands

Smart charging is nothing more than tuning the power with which to charge an electric vehicle. It is the motivation behind this process that makes smart charging interesting. There are basically four different actors that can influence the tuning of the charging power:



1. The grid operator, who does not want to overload its cables and transformers;
2. All actors in the wholesale market that want predictability of consumption and flexibility to balancing supply and demand;
3. The drivers, who want a full (enough) battery when they need it;
4. The owners of local renewables that want to use the locally produced energy to locally charge EVs.



Enexis carries out pilots on all these four levels in order to come to a holistic smart charging approach. The example below shows how smart charging can be realised from a grid operator's point of view.

In the head office of Enexis, the power consumption is not constant. The graph shows the building's power consumption without the 16 electric vehicles available. The peak in consumption is caused by the canteen during lunch time. The purpose of smart charging in this case is to charge the vehicles in such a way that they take less energy during lunch time, in order to avoid overloading the fuses of the building.

Calculations show that without smart charging - assuming a worst case scenario when all charging points are using maximum capacity during lunch time, about 18 charge points could be installed. But with smart charging - taking into account the non-constant available capacity, a much higher number of about 300 charge points could be installed.

The system that was built for this is shown below:

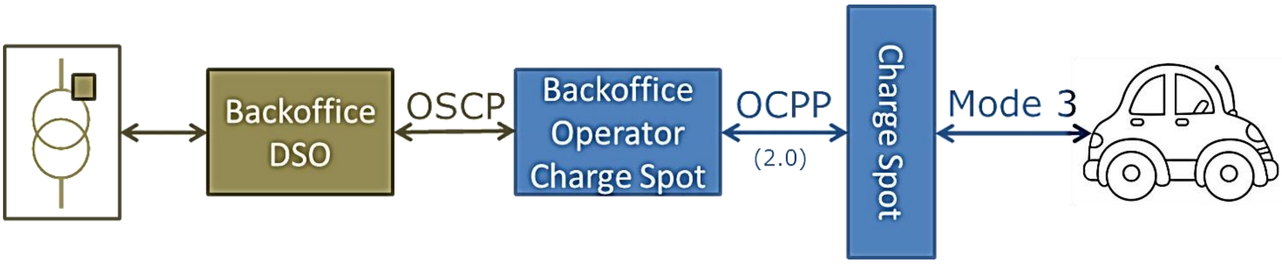


Figure 27: Smart charging value chain; Source: Enexis

The back-office of the DSO contains an algorithm that is able to predict the power consumption for each phase 24 hours in advance. This is also why there is a difference between the dashed and the solid line in the second figure above: the solid line shows the prediction whereas the dashed line shows the actual measurements. Using predictions instead of real time measurements is important for three reasons:

1. If there are technical problems, there are 24 hours available to fix the problems before the system crashes.
2. If you decide to postpone charging because energy prices will be lower in a few hours, it is vital that you know if there is sufficient capacity in a few hours.
3. It allows for better planning of charging schemes (you can give certain cars higher priority).

The DSO produces a forecast of the available capacity over time (which is a mirrored version of the graph in the second figure above) and sends this to a back-office that is able to control the charge spots. This could be an e-Mobility Service Provider, a Charging Station Operator, or in more general terms: an aggregator. The protocol used to communicate about this information is the Open Smart Charging Protocol (OSCP). OSCP was recently adopted by the Open Charge Alliance as a new standard. The two most important messages within OSCP are: 1) information about available capacity for flexible loads; and 2) the possibility to return capacity or ask for extra capacity.

The protocol has a wider range of application that goes beyond electric vehicles only. More complex cases with for instance several operators on the same site are worked out but not described here.

Given the available capacity over time, the aggregator can decide how to charge the EVs. There are many ways to do this (contract based, priority based, based on user-interaction, fair division, etc.). It is important to notice that the grid operator in this scenario does not decide how the individual EVs can be charged. In Enexis' view, this is up to a commercial party which has a client relation with the electric vehicle driver. The grid operator merely gives information about the available band-with.

Charging in this way at Enexis' premises is very profitable. If charging points were installed at all 150 parking spots available in the basements and smart charging was not used, the increase in hardware costs and grid operator fees would be about €13,000 per month. But if smart charging was applied, there would be no need to increase the building's capacity at all.

This is very important since it means that, already within the current market situation, there is a big financial benefit for smart charging in private locations. If, in the next years, we can roll out smart charging in this way, it could be the ideal stepping stone to also enabling uptake of smart charging in the public domain - which is a bit more complicated to regulation.

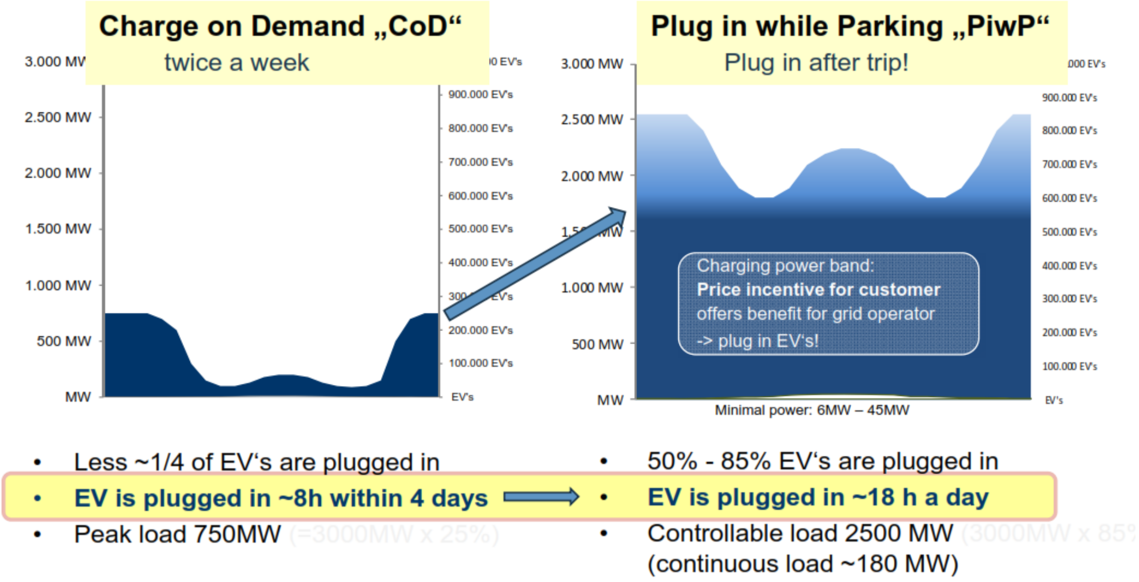
2) Electric vehicles as storage device and balancing capacity – an example from the GridTech EU project

One interesting aspect of smart charging is that EVs with intelligent, controlled charging could be used as storage capacity similar to existing ones. In addition, EV could have future potential to provide balancing services to the grid as well. This is currently being demonstrated in the GridTech EU-funded project, which is EEGI (European Electricity Grid Initiative) core labelled[25].

The potential of EVs to offer storage capacity to the grid system operator varies largely depending on the time when they are plugged into the grid. The highest EV charging capacity - and thereby potential controllable load for the grid operator is usually available when vehicles are stationary or parked – at night, or to a lower extent, at noon during working days. By contrast, the potential EV charging power is lowest in the early morning or evening rush hours when the cars are usually in use, on the roads. With high RES penetration, wind power could for instance be used at night to meet EV demand, or surplus solar power during the day at noon time. An intelligent business model could help to overcome low charging power.

"Plug-in while Parking" concept business model

The project has also analysed different business models that could attract customers into using smart charging services for grid operations. EVs offer today driving ranges of 150 km or 200 km which can easily cover customers' daily trips of normally less than 50 km for several days. Thus, there is no need for daily recharging and leads to a situation that cars were plugged in on demand. From a grid point of view therefore, the cars will be plugged into the grid only for a few hours within three or four days. DSOs and suppliers should offer incentives to encourage customers to connect their car to the grid whenever the car is standing. This will lead to a situation where less power will be needed to fully recharge the battery for a new trip. Such a "Plug in while Parking" (see figure below) business model concept will offer the grid operator a controllable power tool for supporting grid load flow and power management. The real situation will of course be in between these two scenarios: "Charge on Demand" and "Plug in while Parking".



Charge on Demand „CoD"
twice a week

Plug in while Parking „PiwP"
Plug in after trip!

Charging power band:
Price incentive for customer
offers benefit for grid operator
-> plug in EV's!

- Less ~1/4 of EV's are plugged in
- **EV is plugged in ~8h within 4 days**
- Peak load 750MW (=3000MW x 25%)

- 50% - 85% EV's are plugged in
- **EV is plugged in ~18 h a day**
- Controllable load 2500 MW (3000MW x 85%
  (continuous load ~180 MW)

Figure 28: Influence of Business Models in Grid Tech simulations; Source: GridTech, Verbund

With future technology developments on the generation and the demand side, electric vehicles will be able to influence the electricity system and offer benefits to the distribution grids. Technologies such as e.g. inverters for wind and PV power will be able to monitor grid voltage and frequency, and to deliver active and reactive power control in order to stabilise the grid. Smart charging of EVs can offer high flexibility

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[25] GridTech project co-funded by the EU's Intelligent Energy Europe Programme http://www.gridtech.eu

regarding daily charging power i.e. when considering a scenario similar to the "Plug in while Parking" model. The high installed EV charging load can help to integrate RES (PV, wind) which will make a good fit with EV technology with ability for smart charging functions as described in Chapter 4b) (Figure 19).

EV potential to support balancing power

With the help of ICT technologies, in the future electric vehicles could provide significant value for power grid balancing. The picture below shows the theoretical, but in the future feasible EV potential to contribute to balancing power. The balancing can be enabled mainly by load control. V2G technology represents a future opportunity to be explored further with regards to flexibility opportunities.

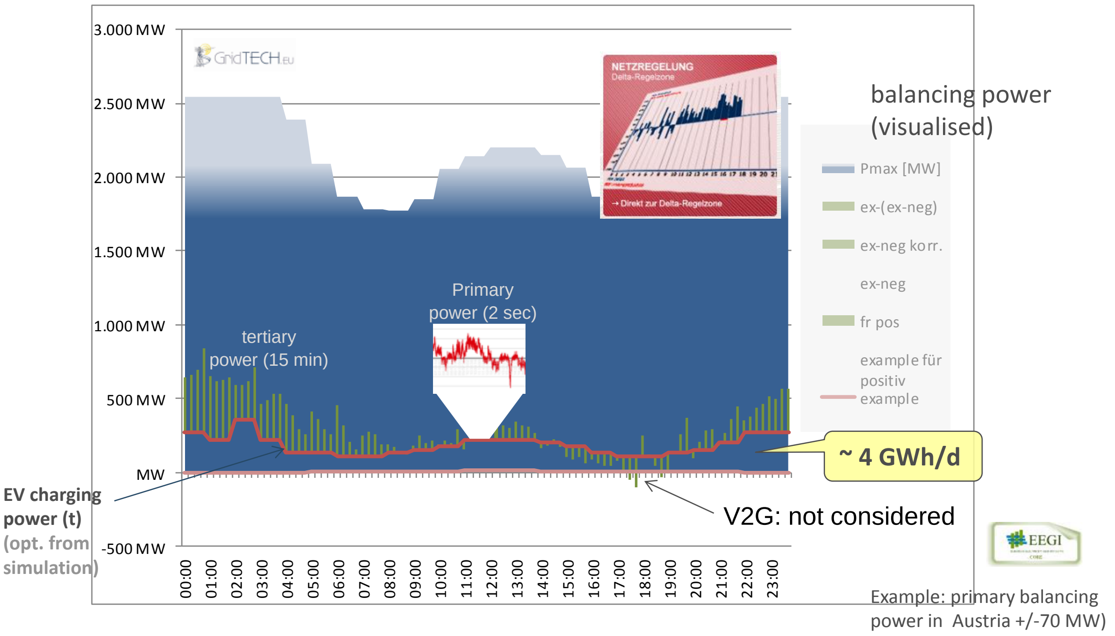

Figure 29: Electric vehicles as balancing tool; Source: Verbund for GridTech project

To fully achieve smart charging potential in the future there are still efforts necessary in ICT implementation, information on car battery status to service providers and regulatory framework.

3) Case of Vehicle-to-Home – example from Nissan

In September 2012, Nissan and Nichicon have introduced their world-first mass-produced bi-directional V-2-H system, a combination of EV and EVPS (Electric Vehicle Power Supply system), into Japanese market. The protocol for its bi-directional power flow was organized based on CHAdeMO, and has subsequently been published in April 2014 as "DC-V-2-H guideline" by EVPOSSA/CHAdeMO, implementing the interoperability among different players from the automobile and electrical equipment industry.

The V-2-H system contains the following four technologies:

1. Insulated bi-directional power convertor for charging and discharging of/from EV,
2. Extended communication and control protocol/sequence which avoids confliction with existing CHAdeMO quick chargers and allows intelligent operation of bi-directional system,
3. Interlocking system in hardware and software to meet the "grid connection code" which is regionally specific,
4. Power management function.

In Nichicon EVPS, named "EV Power Station", a separate junction box equipped with detectors, disconnectors and other miscellaneous devices is supplied for the third point where the properties of utility and homeowner are divided, to meet Japanese grid connection code described in 3. The EVPS is rated as follows:

Power input: Single phase 3 wire system, 100/200V AC 50/60Hz; Charging electricity: less than 6kW, Output power: 6kVA and under, (max. 30A and under at single phase)

The system is solving the above "remaining-challenges" described in 1, 2 and 4 in the main-body of EVPS, meeting the regionally specific condition of the home installation side. On the car side, Nissan LEAF simply requires the software upgrade to become bi-directional, but no modification to the hardware. The impact on battery life of bi-directional operation is no more than that of normal AC charge and drive. The load condition of home is theoretically less challenging than that of on-board electric motor. The local grid connection codes are met by adding the junction box as mentioned above. The system is introduced in residential application in Japan so that the homeowners can take advantage of Time of Use electricity rates by its peak cut/shift function financially, while at the same time being insured from emergency/blackout by its back up function. But the challenge in marketing exists: the system design and the business model could be completely different depending on the global market areas and its applications.

5. The way forward: Recommendations and Actions

1. Set up supportive policies for e-mobility and smart charging

Electricity is a key solution to making transport more sustainable. Yet evolving towards low-carbon mobility requires that electric vehicles be charged in a smart way that optimally integrates electricity use and mobility needs. Smart charging helps to avoid unnecessary power system constraints while creating opportunities for all stakeholders involved.

European policymakers and member states (MS) must encourage and develop policies in support of smart charging. Policy should avoid prescribing and overregulating markets that could hamper investments or the creation of innovative tools and services. In this regard, EU and national regulators should adjust the current regulation to be more reflective of demand response needs.

EURELECTRIC suggests that policymakers focus on the following actions to support e-mobility:

Set ambitious national targets for recharging points by 2020, and supportive measures for e-mobility in the national policy frameworks prepared by MS as part of the directive on the deployment of alternative fuels infrastructure[26]. Member states should fully integrate measures to implement smart charging functionalities in preparation of their national plans for the deployment of the charging infrastructure.

Lead by example with public procurement: set a 30% target for local, national and regional public authorities, incentivising them to increase the share of electric vehicles in their vehicle fleets.

Provide strong incentives and lighten administration: introduce and maintain exemptions from vehicle registration, purchase or circulation taxes, encourage local use of electric vehicles (free or reduced parking, preferential access, car-sharing schemes). Cities should be encouraged to grant permission to deploy charging infrastructure and allocate parking spots to electric vehicles.

Inform and thus empower customers: Set up awareness-raising campaigns and disseminate public information on the value and convenience of EVs and smart charging to change customers' behaviour.

Expand electrification in transport: A clean alternative to today's urban public transport, electric buses are becoming commercially available. In the long-term also consider the partial or full electrification of heavy-

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[26] Directive 2014/94/EU

duty vehicles and long-haul bus and coach fleets. Use EU islands as test-beds for e-mobility and smart charging.

Think beyond 2020: the 24 October 2014 Council[27] conclusions clearly recognised the importance of reducing GHG emissions beyond 2020 and the risks related to fossil fuel dependency in the transport sector. The European Council also invited the Commission to develop instruments for RES and electric transportation in particular, also after 2020. These encouraging signals are a step in the right direction. They should be further supported by concrete policy measures, including those outlined in the European Commission's Energy Union strategy.

Smart charging will be a key enabler in paving the way for mass-market EV deployment. Similarly, a wider uptake of e-mobility will contribute to more system flexibility. If EVs are charged in a smart, coordinated way, we see no reason to doubt that the electric vehicles will become a competitive transport technology.

2. Incentivise innovative smart charging through smart regulation

The regulatory framework must incentivise retailers and distribution system operators (DSOs) to invest and use smart charging solutions, allowing DSOs to manage their grids more intelligently and retailers to offer innovative smart charging services to customers. Smart charging will help to make the system more flexible and minimise investments in distribution grids. By doing this, it will also pay off for the customers. Yet at the moment, there is little incentive to invest in new innovative solutions.

In many countries today, DSOs are obliged to design their networks to meet peak demand. Yet with growing shares of EVs and more DERs connected to the distribution grid, other solutions may be more effective. Regulation focusing on long-term investments should allow network solutions beyond the traditional approach of 'investing in copper'. It must be adapted to reward DSOs for adopting the most sustainable solution, be it conventional investment or innovative smart charging solutions.

Customers will be more willing to participate in smart charging if there is an economic benefit involved. EURELECTRIC believes that tariffs encouraging customers to shift their peak hour consumption should gain importance. This may take the form of two-part network tariffs with power (kW) and energy (kWh) components, a network tariff with peak-price differentiation, or other solutions that would encourage participation in smart charging while providing adequate revenues for the DSOs. Proper coordination between retailers and DSOs is also needed to ensure that adequate price signals are sent to customers.

3. Support the customer: smart customers use smart charging

The success of smart charging and e-mobility will primarily depend on customers' mobility needs and behaviour. As the electric cars differ from conventional cars in terms of charging needs, the lack of familiarity with the recharging process including smart charging (range anxiety) could have adverse impacts. Yet smart charging can enable customers to play a more active role in the way they use energy and their vehicles, and thus change user behaviour. In exchange for their freedom to charge as they wish, customers can benefit from reduced energy costs and advanced services when using electricity at times of lower demand, which also results in a lower total cost of ownership for the car owner. By optimising the electricity used, such customer behaviour can bring important environmental and societal benefits.

EURELECTRIC encourages customers to charge predominantly with normal power, which mostly takes place in locations where the car is parked for a significant period of time (home, parking lots near home wherever customers do not have access to recharging facilities on private property, and office buildings,

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[27] http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf

especially for fleets). This will suit a lot of customers' needs, as many daily trips fall within today's battery capacity. Moreover, future developments in battery capacity will allow for even bigger ranges (300 km).

If customers are encouraged to charge their vehicles regularly while parked – and a majority of cars are stationary about 90% of their lifetime - not much power is needed to fully recharge the battery. Normal power recharging goes hand in hand with smart charging as it can provide flexibility support to grid operators such as load management and storage. By contrast, due to its lower duration, high power (above 22 kW) is less relevant for such flexibility services. We recommend that high power recharging does not become the dominant way of EV charging as customers would then probably not accept load management.

It is therefore crucial that customers are well-informed and incentivised to become more engaged and participate in smart charging schemes. The active participation of customers will only become possible if they are offered more attractive prices such as off-peak electricity tariffs. It is also equally important that customers are equipped with the necessary information and tools that will allow them to do so. Both retail prices and grid tariffs must incentivise smart charging and overall demand response. Regulation should work towards reducing the current uncertainty on how to encourage the power sector to deliver competitive and innovative products and services to customers.

4. Develop innovative smart charging technologies and services

Smart charging devices and services relate to interfaces between the electricity grid, the charging infrastructure and the electric vehicle. Smart charging offers significant possibilities for wide-range market model and technology innovation, creating opportunities for all electricity industry (generators, DSOs, TSOs, retailers) and e-mobility stakeholders involved (ICT, manufacturing, etc.).

DSOs and commercial parties need to develop and use innovative tools that can help to better monitor system operations, avoiding unnecessary grid upgrades. Mechanisms such as energy management systems, including optimal algorithms for loads and EV charging, back-end systems, automated meter reading, or smart meters with uses for grid operation are crucial to paving the way for smart charging. E-mobility will be part of the future smart grid and smart home concepts.

Retailers and third-party e-mobility service providers will be able to provide customers with innovative products and services for smart charging (smart phone applications, etc). Contracts between e-mobility customers and service providers should also be clearly defined. DSOs can liaise with customers where necessary to agree on load management measures in cases where distribution system service reliability is at stake.

At the same time, other e-mobility market parties such as charging station equipment manufacturers and operators (i.e. in markets where the DSO is not involved in the charge service operation), ICT providers for data clearing or any other services, car manufacturers and others will be able to benefit from developing smart charging services and products. Standardised and interoperable communication between the grid, the charging infrastructure and the vehicle will be essential in any case.

More specifically, EURELECTRIC recommends that, due to its potential for smart charging, normal AC charging with Mode 3 should remain the preferred charging method in all types of locations.

5. Prioritise demonstration and commercialisation of smart charging

There is a chicken and egg situation between e-mobility roll-out and smart charging: one cannot be successful without the other. EVs today are on the brink of wider commercialisation. Incentives for e-mobility roll-out are needed to make the most of learning curves and lead to broad market uptake. At the same time, smart charging needs to be demonstrated and deployed on a large scale. This will help to test and develop solutions that can be deployed, enabling real-world validation of RD&D findings.

Private actors usually lack a business case to undertake large-scale demonstration projects, making public support a necessity. The EU's focus to put greater emphasis on demonstrations in the EU's Horizon 2020, as well as transport-related initiatives such as the Green Vehicle Initiative are a welcome start and should be pursued. The FP7 Green eMotion project in which EURELECTRIC was a partner was a very successful example of such private-public partnerships. We expect that the new European Fund for Strategic Investments set up under the Commission President Juncker investment initiative will also enable greater investments in smart grids projects which can contribute to bolstering economic growth and jobs creation.

Further pilot projects are needed to test and develop innovative smart charging strategies and products to encourage customer acceptance. Efforts are also needed to demonstrate V2G technologies with regards to the battery's lifetime and usage, control and communication technology as well as regulatory requirements. Given the current lack of smart charging business models availability, further development for successful commercialisation are also needed. Moreover, shifting the focus towards the customers experience will represent an added-value for the acceptance of the technology.

6. Ensure EU-wide interoperability, common standards and efficient exchange of information

As electric vehicles will become more and more integrated into the smarter power system of the future, they will need to be able to communicate with that system in a smart, easy and efficient way. Common standards and interoperability between electric vehicles, the recharging infrastructure and the grid are a key precondition for smart charging to materialise.

Standardisation not only on the technical side, but also on the ICT side are critical to ensuring that electric vehicles can be charged and can communicate with the electricity grid anywhere in Europe. Nonetheless, standardisation on its own does not necessarily lead to interoperable EU-wide solutions for recharging electric vehicles. Interoperability is therefore equally important in order to avoid a multiplication of standards, and ensure compatibility and efficient communication.

According to standardisation body CEN-CENELEC, interoperability in the context of smart charging "describes the integration of tasks and refers to the *exchange of information* between *two or more devices from the same actor, or different actors, and the use of information for correct cooperation* (...) Two or more systems (devices or components) are interoperable if they are able to perform cooperatively a specific function by using information which is exchanged.[28]"

Smart charging thus requires intelligent bi-directional communication to allow for an efficient flow of information between all stakeholders involved. In this regard, it needs to take into account information regarding grid constraints, for instance maximum power demand, available capacity or the share of RES available. Grid operators also need to know to which extent they can optimise the charging and reduce grid impacts. Information such as the state of charge or the battery status is important in this regard. Moreover, retailers and e-mobility service providers need to give customers clear access to information so that they become aware of time-varying prices. Battery usage and other vehicle aspects (thermal management, etc.) are also other important items to be considered.

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[28] CEN/CENELEC "Working Group Smart Charging" – "Report – Smart charging of electric vehicles in relation to smart grid", final draft 2015

Finally, interoperability of data exchange is also key for "roaming" customers – a term derived from mobile phone communication - who want to charge their vehicle outside the area of their home operator. This can be done either via identification with an RFID card or via direct payment at the charging station - or by using any other form of payment or billing.

Paving the way for an interoperable e-mobility system: the Green eMotion project

Progress on interoperability has been achieved in the FP7 Green eMotion project (2011 – 2015), which gathered over 40 partners to demonstrate a seamless and cost-efficient e-mobility system. One of the key aspects of the Green eMotion demonstration regions was to prove the interoperability of the European charging network from a user's perspective. To achieve this, Green eMotion developed a complete roaming solution possible via an ICT marketplace, allowing drivers to use their own RFID card and/or smartphone app to charge in other demonstration regions. At a dedicated Rally to Brussels event this solution proved its viability with different partners driving to Brussels and an on-site roaming demo. As for identification, RFID proved to have many obstacles for interoperability, whereas the smartphone app worked flawlessly. About 10 Green eMotion demo regions in Europe used the B-2-B marketplace for roaming services, linking their ICT system via a standard open interface.

7. Create win-win industry synergies between electricity, automotive and manufacturing sectors

Smart charging is inherently linked to wider e-mobility developments regarding automotive and battery technology as well as other industries. The electricity industry should engage more with such e-mobility stakeholders to building awareness and developing best practices with a focus on customer opportunities.

From an electricity industry perspective, choices on the battery design will play a crucial role, with the expected battery capacity and its interaction with the grid being of particular importance. Currently a typical 24 kWh battery charging at a 3-3.7 kW single-phase connection point takes between roughly 6 to 8 hours to fully charge. This could easily be met by charging during night-time period. Larger battery capacity will increase the range but could also require faster charging power rates at the charging station. Although it depends significantly on the individual grid, significant capacity increases will generally have adverse impacts in countries where single phase supply is the default connection for residential customers. Industry would need to work together and develop optimal smart charging solutions for both the car and the power system.

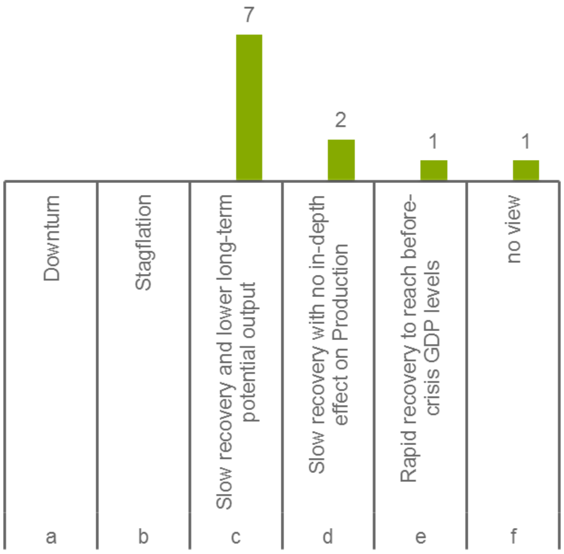
Shedding light on best practice example: Vattenfall cooperates with Renault

Renault and Vattenfall have recently teamed up in Sweden to offer customers a free wall box and home installation with every new Zoe electric car purchased. With Vattenfall's 22 kW wall box, the car can be fully charged in one hour at home. Renault pays Vattenfall for each wall box and installation, which is free of charge for the customer. Approximately 50 Zoe owners have received a Vattenfall wall box so far. Vattenfall is also equipping all Renault dealers in Sweden with wall boxes, with over 100 having been installed so far. As part of its commercial partnerships with other car manufacturers, Vattenfall cooperates with BMW in Germany in setting up second-life battery storage.

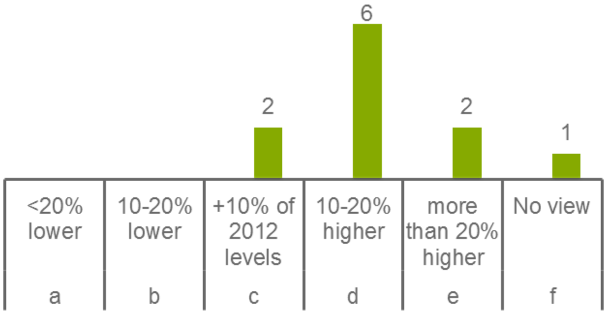
ANNEX 1 – EURELECTRIC Smart Charging and e-Mobility Survey

(courtesy of Endesa)

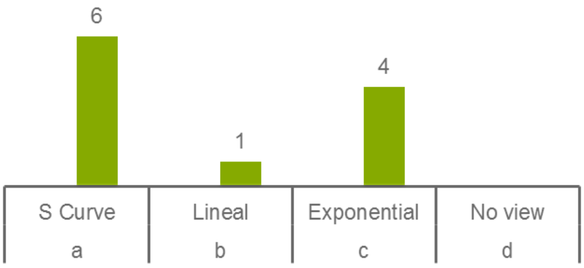
Q1- What will be the economic & financial growth (GDP) profile in the next decade?



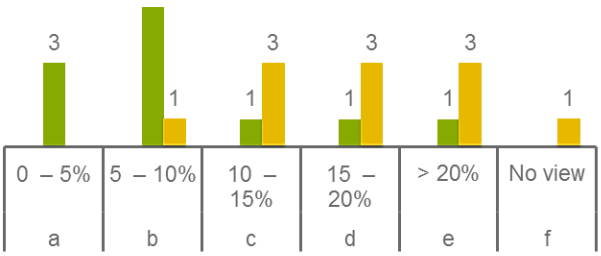
Q2-What will be the annual level of total electricity consumption in 2035 in Europe compared to 2012?

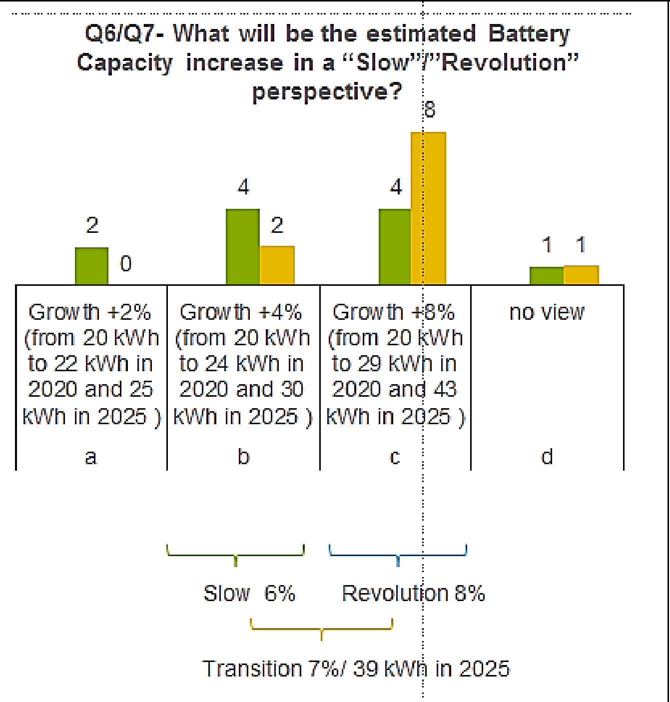


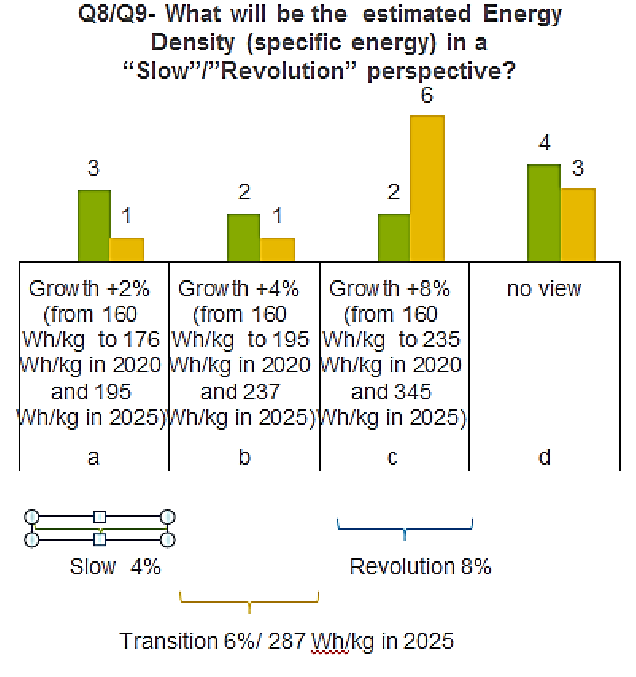
Q3-Which form of EV market growth?

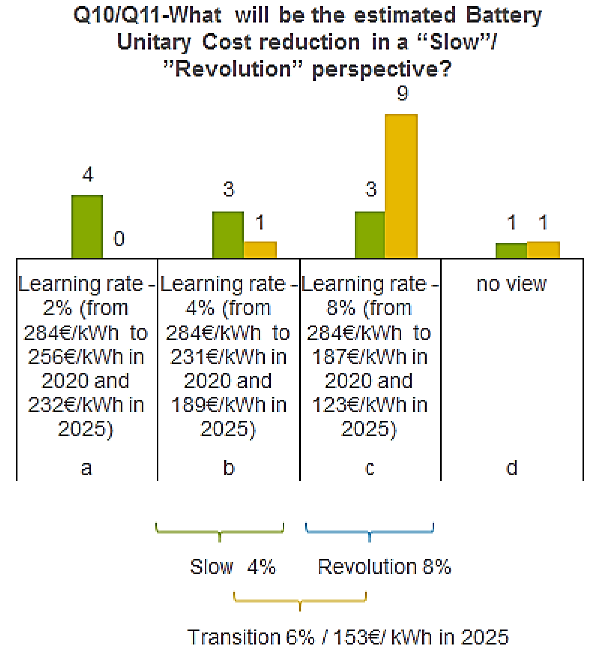


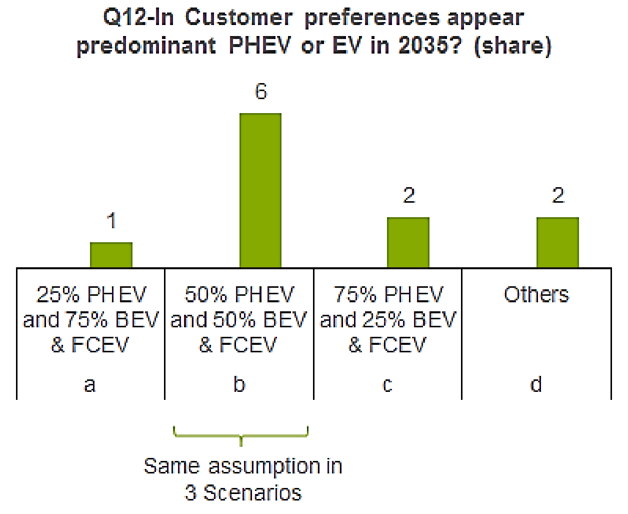
Q4/Q5- What will be, in 2035, the "Slow"/"Revolution" market share of EVs (accumulated) in the total vehicles fleet of the EU?

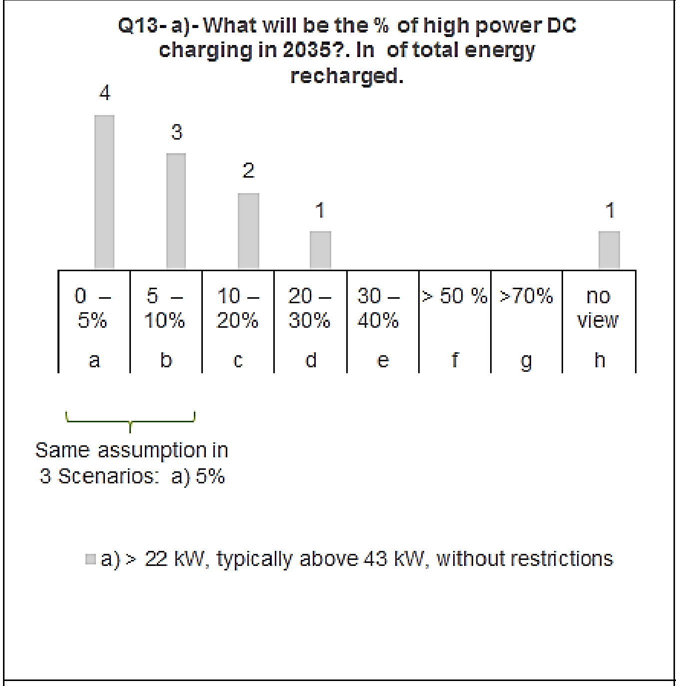


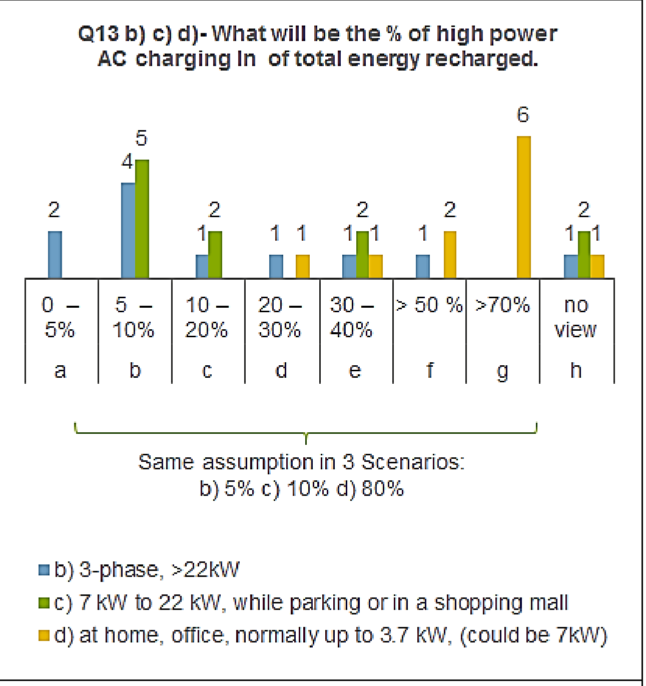

Q6/Q7- What will be the estimated Battery Capacity increase in a "Slow"/"Revolution" perspective?
2
0
4
2
4
8
1
1
Growth +2% (from 20 kWh to 22 kWh in 2020 and 25 kWh in 2025)
a
Growth +4% (from 20 kWh to 24 kWh in 2020 and 30 kWh in 2025)
b
Growth +8% (from 20 kWh to 29 kWh in 2020 and 43 kWh in 2025)
c
no view
d
Slow 6%
Revolution 8%
Transition 7%/ 39 kWh in 2025

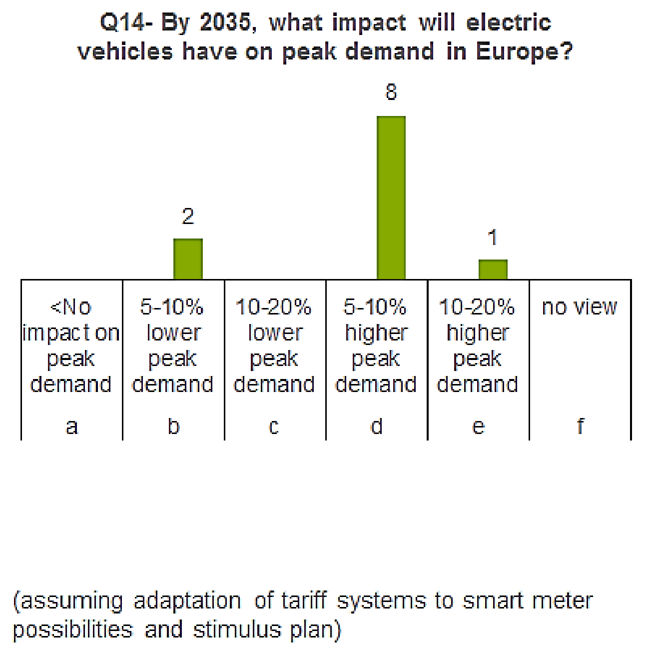

Q8/Q9- What will be the estimated Energy Density (specific energy) in a "Slow"/"Revolution" perspective?
3
1
2
1
2
6
4
3
Growth +2% (from 160 Wh/kg to 176 Wh/kg in 2020 and 195 Wh/kg in 2025)
a
Growth +4% (from 160 Wh/kg to 195 Wh/kg in 2020 and 237 Wh/kg in 2025)
b
Growth +8% (from 160 Wh/kg to 235 Wh/kg in 2020 and 345 Wh/kg in 2025)
c
no view
d
Slow 4%
Revolution 8%
Transition 6%/ 287 Wh/kg in 2025

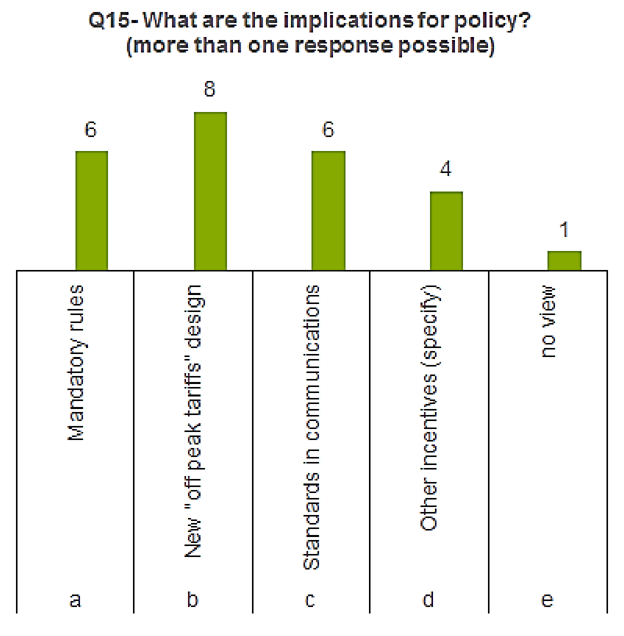

Q10/Q11-What will be the estimated Battery Unitary Cost reduction in a "Slow"/ "Revolution" perspective?
4
0
3
1
3
9
1
1
Learning rate - 2% (from 284€/kWh to 256€/kWh in 2020 and 232€/kWh in 2025)
a
Learning rate - 4% (from 284€/kWh to 231€/kWh in 2020 and 189€/kWh in 2025)
b
Learning rate - 8% (from 284€/kWh to 187€/kWh in 2020 and 123€/kWh in 2025)
c
no view
d
Slow 4%
Revolution 8%
Transition 6% / 153€/ kWh in 2025

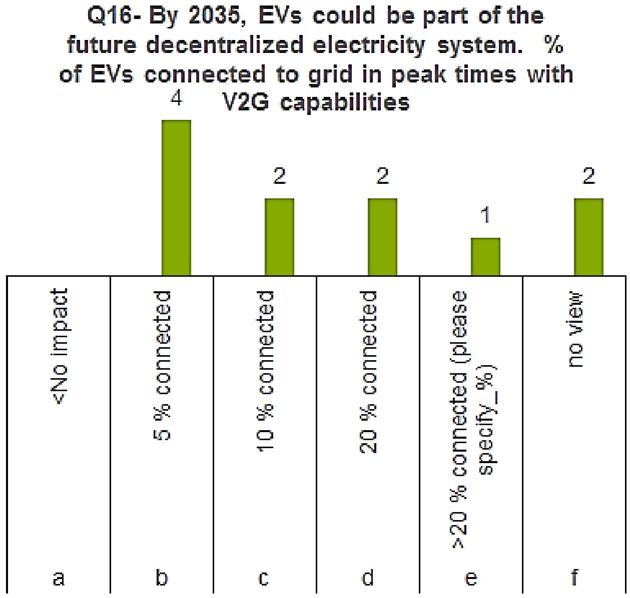

Q12-In Customer preferences appear predominant PHEV or EV in 2035? (share)
1
6
2
2
25% PHEV and 75% BEV & FCEV
a
50% PHEV and 50% BEV & FCEV
b
75% PHEV and 25% BEV & FCEV
c
Others
d
Same assumption in 3 Scenarios


Q13- a)- What will be the % of high power DC charging in 2035?. In of total energy recharged.

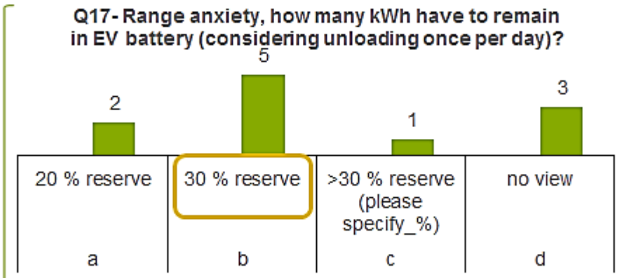

Q13 b) c) d)- What will be the % of high power AC charging In of total energy recharged.

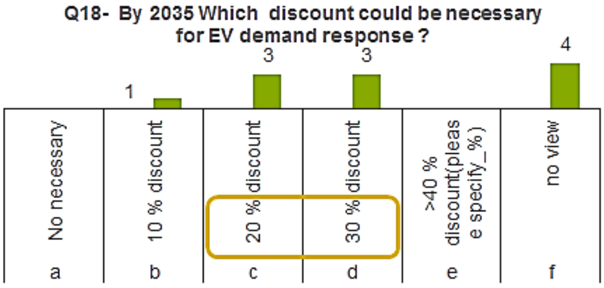

Q14- By 2035, what impact will electric vehicles have on peak demand in Europe?


Q15- What are the implications for policy? (more than one response possible)

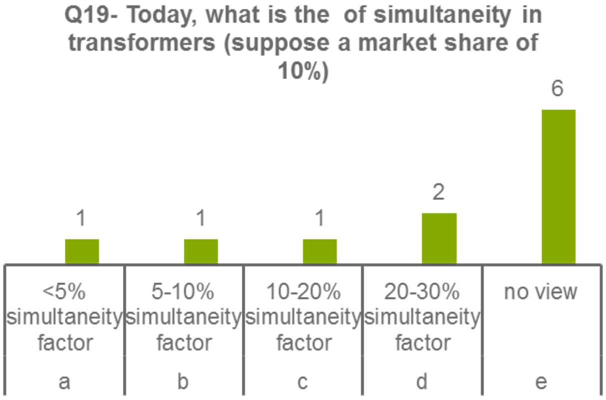


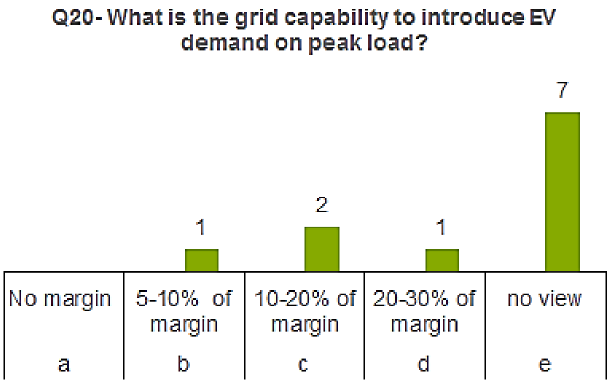
Same assumption in 3 Scenarios: 5%





Customer need a 30% of capacity, and demand response need discounts, 20%-30%.





ANNEX 2 – CO2 emissions of cars

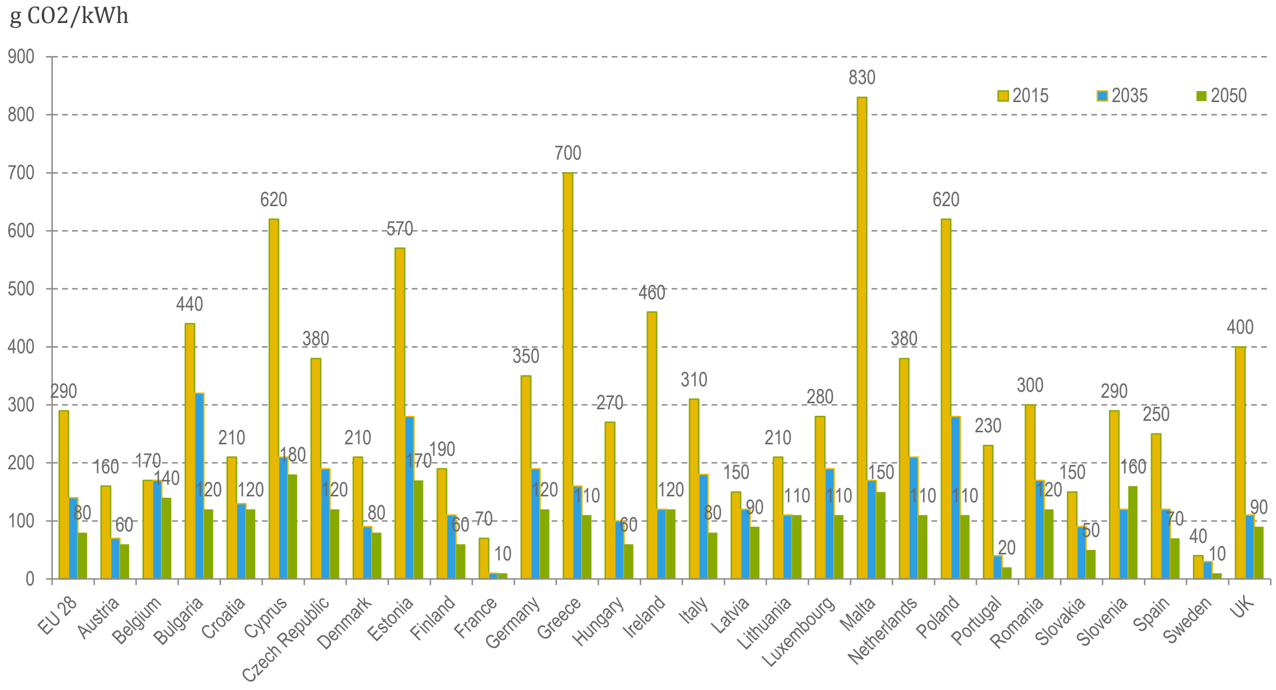


Figure 30: Estimation of the carbon intensity of the electricity sector (g CO2/kWh) for the EU-28 and all individual countries in 2015, 2035, 2050 based on the EC scenarios

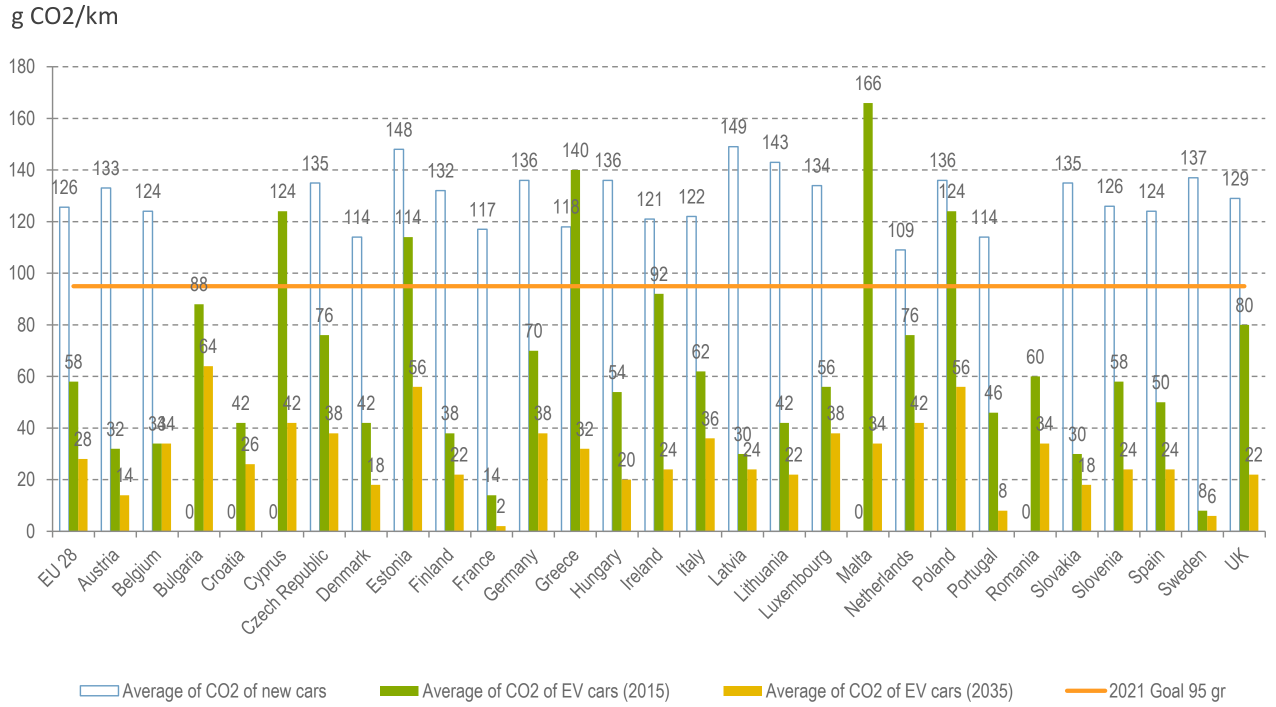


Figure 31: Average CO2 emissions of EVs (g CO2/km) in 2015 and 2035 vs average CO2 emissions of new cars (2013) for the EU-28 and all individual EU countries

ANNEX 3 – Actors involved in smart charging at different locations

EURELECTRIC has described e-mobility actor roles and responsibilities in a previous paper[29] which sets out a general architecture for deploying public charging infrastructure. This role model also applies to private charging services and added-value services within the electric mobility market, including smart charging.

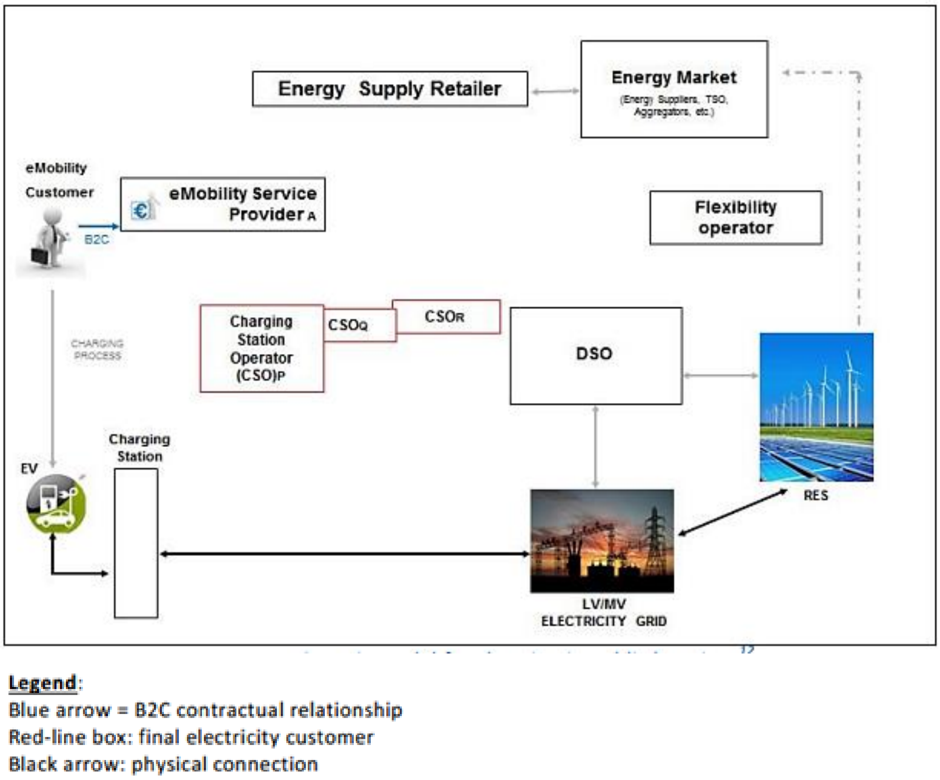


Figure 32: EURELECTRIC generic market model for e-mobility

In general, the following actors could be considered key in implementing and offering smart charging services:

- **E-Mobility customers** whose satisfaction with e-mobility will depend on the ease of use and whose willingness to access smart charging services will depend on the contractual benefits received, as accessing scheduled charging is putting constraints and reducing customers degrees of freedom.
- **Charging Station Operators (CSO)** have to fulfil their contractual commitments and business economy while considering charging requests of other market parties, including eMSP, which could be unbundled from CSOs in multi-vendor market scenarios, regulated as well as unregulated.
- **E-Mobility Service Provider (eMSP)** requests charging access following requests by their e-mobility customers. The charging requests might be executed either on a charging infrastructure owned by a third party, the CSO, or owned by the eMSP itself, in the case when this is also playing the role of CSO.
- **Energy supply retailers** and the **flexibility operator** are seeking to develop smart charging, as a measure to support their power plants portfolio strategy, particularly at the local level, and as a possible revenue stream coming from ancillary services sold to the DSO.
- **Distribution system operators (DSO)** have to maintain voltage levels within regulated margins and to balance fluctuating power requests and injections from decentralised renewable generation - to which purposes the mobile, power-dense and fluctuant load curve of EVs suits perfectly as a measure to counter peak DER unbalancing sources. Further, in some cases, DSOs are seeking support from eMSP and energy vendors in the delivery of smart charging services through their customers to ease the cost of technology adoption and delay/avoid grid reinforcements.

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[29] "Deploying publicly accessible charging infrastructure for electric vehicles: how to organise the market?, A EURELECTRIC concept paper, July 2013

According to the market model and national regulatory framework, different patterns of the above-depicted roles may be involved in smart charging, particularly depending on the ownership and the management of the charging stations deployed in public premises (e.g. be it a CSO as generally unbundled market actor or a DSO, in case of multi-vendor regulated market model).

For private charging, (charging stations within houses, multi-dwelling premises and fleet garages), the role of the CSO is generally under the control of the building owner/manager. The latter is generally in charge of the building's installation and operation of electrical equipment within the building premise, and can take the role of CSO - as the charging station becomes thus part of the building's equipment. The available charging station(s) may be exclusively used by occupants but can also be partly open to visitors.

Four levels of action could be considered for smart charging in these types of situations.

Home grid: to which the charging spot(s) are connected, under the responsibility of the operator of that particular grid: house inhabitant, CSO, building manager. Smart charging can particularly be used to maximise self-consumption of DERs such as photovoltaic systems, also through storage.

DSO grid (LV and MV) to which the home grid is connected via a delivery point, where the maximum power capacity is defined based on the contract signed with the home operator. This is also the point where the metering operator (who may be generally the DSO) allows for billing energy by a supplier. In this case smart charging may be used to keep under control the maximum power capacity contracted with the DSO or to provide ancillary service to the DSO.

TSO grid where balancing takes place and where system services are contracted. In case a large-scale EV rollout is performed in the next decade, reasonably large amounts of GWh could be eventually aggregated and potentially serve as a significant resource for primary capacity mechanisms.

Power market where energy prices are settled according to timely balance between demand and supply. A flexibility operator may be the actor organizing smart charging on this level, and possibly other. The aggregator might trade with the DSO for carrying out the service.

The smart charging drivers will come from these levels through signals: either tariff signals (hourly price of energy, price of maximum instantaneous power demand, etc) or control signals according to the grid and market situation (request for temporary demand power reduction, allowance for increase, etc.). The home grid operators receiving these signals from an external actor involved in the process, depending on the specific use case, will control the charging process to minimize their total cost of operation. Another option, without connection to an external actor, is to apply technical signals via arbitration between the different electricity uses within the home grid.

Usually for **public or semi-public charging,** when an eMSP is responsible for providing e-mobility services, contract-based smart charging is possible, which may include more advanced flexibility and aggregation services including V2G schemes in a direct relationship with the customer. A negotiation between the eMSP and the CSO, according to their contractual relationship, can set the EV charge profile constraints and possibilities. The eMSP can control the charging speed with direct control signals and could also provide emergency services to the DSO. Typically the service could be traded with the DSO in order to support the DSO granting EVs hosting capacity without investing in electrical wires. In case of a multi-vendor regulated market model, the CSO typically is the DSO and the roles relationship is simplified. Variations of this model are currently considered in some countries i.e. Netherlands, Finland, France, Italy etc. The Netherlands example is described in Chapter 5 of this paper.

The following paragraphs detail how the different actors and their smart charging interactions can be considered for **private charging** at households or at offices.

Single home with garage

This situation is straight forward because the e-mobility customer buys electricity from an electricity supplier for his household purposes, including EV charging needs. In theory, customers take on the roles of:

- Charging Station Operator: customers use their own wall-box to charge their vehicle. This may performed through an asset management front-end (e.g. smartphone application), controlling the charging processes with a behaviour-based model.

- Private Network Operator: customers have the connection to the network via their home/domestic connection. They have to settle their maximum power demand with the DSO, according to the contractual scope of its connection to the grid. To minimize the charging cost, the customer will adapt the charging process according to electricity prices from the retailer (especially hourly price), and to minimize its maximum power demand in response to price or control signals from the DSO. This may be performed through an asset management front-end, which embeds smart charging techniques.

If the e-Mobility customers have a contract with an eMSP that covers charging at home, including electricity supply, then the organisation could require a specific metering for charging electricity and data transmission and processing depending on the market model and country specific regulation. Moreover, the eMSP may be involved in the charging management through remote communication with the Energy Management System or the charging station.

Multi-dwelling residential building

The principles for charging management in this case may be similar to the above situation for single homes, but the organisation will be different as e-mobility customers may not be the Charging Station Operator. The situation might actually be complicated by the fact that in most cases the building manager/owner, who controls the distribution of electricity in the premises i.e. is the Private Network Operator, can install charging stations in the parking lots, and may delegate their operation to a subcontractor playing the role of the CSO. An Energy Management System may be provided by the building manager or the CSO, according to both situations:

- The charging stations are connected to a network also delivering electricity to other common uses within the premises (light, lift etc.); then the Energy Management System is under the responsibility of the building manager.
- The charging stations are connected to a specific network with a separate connection to DSO grid; then the Energy Management System is under the responsibility of the Charging Station Operator.

Secondary meters may be installed with the charging stations for managing the costs and determine the charging price to be paid by the e-mobility customers. There again, electricity consumption cost may be included in a global charging service cost, or may be roamed according to a specific electricity supplier chosen by the e-mobility customer or by its e-mobility service provider.

Company fleet building

This situation describes electric vehicles fleets that could charge for instance at office buildings – and it is probably the use closest to full commercialisation amongst the whole set of smart charging use cases.

A fleet manager can play the role of an e-Mobility Service Provider with regard to the operational needs of the company, managed by a crew manager acting as a “combined” e-mobility customer, requesting availability of mobility means to the fleet manager for each crew according to the company’s mission to fulfil. Each member of the crew may set preferences with the help of an asset management software. Again, the private network operator may be the company itself, if it owns/manages the building or if it has procured charging assets and assets management system with smart charging functionalities. If the premises are rented, the building manager and private network operator are under the control of the building owner. Power signalling managed by the assets management system can be based on the maximization of local DER/ storage usage but also on the minimization of contractual power.

Charging control and electricity management then follow the same previous principles in an organisation between these different roles.

To ensure fleet drivers satisfaction while ensuring global system efficiency, smart charging functionalities in the fleet asset management system will require sufficient knowledge of the state of charge of the battery, the final desired state of charge and the time of departure of each fleet driver. Similar requirements have been considered by Enel in Italy in carrying out a smart charging pilot project within the activities of PlanGridEV FP7 project. Other data required relates to situations such as e.g. the influence on electricity consumption per kilometer according to weather conditions, load to carry by the vehicle, unevenness of road trip. The optimisation trade-off within the fleet asset management system aims at ensuring availability of transportation means for company crews at optimal cost.

ANNEX 4 – Abbreviations

BEV – Battery Electric Vehicle

CPL – Coefficient Peak Load

CSO – Charging Station Operator

DER – Distributed Energy Sources

DSO – Distribution System Operator

EMS – energy management system

eMSP – E-mobility Service Provider

ESCOs – Energy Service Companies

EV – Electric Vehicle

HEV – Hybrid Electric Vehicle

ICE – Internal Combustion Engine

IEA – International Energy Agency

LV – Low-Voltage Lines

MV – Medium-Voltage Lines

OSCP – Open Smart Charging Protocol

PHEV – Plug-in Hybrid Electric Vehicle

PL – Peak Load

PLC - Power-line Communication

RES – Renewable Energy Sources

RFID – Radio – frequency identification card

TSO – Transmission System Operator

TCO – Total Cost of Ownership

UF – Utilisation Factor

V2G – Vehicle-to-Grid

V2H – Vehicle-to-Home

Units

CO2 – carbon dioxide

kWh – kilowatt-hour

km – kilometre

Mt – million tons

Mtoe – million tons of oil equivalent

EURELECTRIC pursues in all its activities the application of the following sustainable development values:

Economic Development

- Growth, added-value, efficiency

Environmental Leadership

- Commitment, innovation, pro-activeness

Social Responsibility

- Transparency, ethics, accountability

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