

Roll-out of public EV charging infrastructure in the EU

Is the chicken and egg dilemma resolved?

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Executive Summary

Which comes first, electric cars or the recharging points? How to tackle this dilemma has been the subject of considerable debate. This report examines the importance and availability of public charging infrastructure and how to efficiently expand the existing network as the number of electric vehicles on the road increases.

Despite the considerable emphasis on the importance placed on public recharging to drive EV acceptance, the data shows that public chargers are only used for about 5% of charging events. Furthermore, as the market matures this share is expected to decline with a preference for more fast charging over slow kerbside sites. The visibility of public recharging may however be important in encouraging existing drivers of conventional cars to switch to electric options although public chargers are rarely used.

In western and northern Europe a basic minimum infrastructure is, or imminently will be, available to recharge the EVs. At present there are about 5 EVs on the road per public charging point (compared to the Commission recommendation of 10). With growth in both vehicle and charger numbers there should be about 220,000 chargers by 2020 and a ratio of 10:1. There will also be good coverage of fast chargers along the European motorway network with about 1,000 ultra-fast (150-350 kW) charging sites planned for 2020. These sites will allow drivers to replenish up to 400 km of driving range in only 15 minutes. Additional, 50 kW fast charging deployment will complement these sites with more than 2,500 sites existing today and nearly double this set to be operational by 2020. This translates into one recharging point every 34 km along the strategic TEN-T Core Network – more than sufficient to support the early market.

In Northern and Western Europe, where 3 in 4 new cars are sold and the chicken and egg dilemma has been resolved, the primary bottleneck in growing the market for electric cars is not the lack of recharging but the lack of cars to plug-in. The study estimates the initial need for public investment will gradually reduce and in the period 2020-2025 the cumulative cost of public charging is estimated at €12 billion, a small fraction of the €100 billion invested by the EU every year in transport infrastructures.

In Southern, Central and Eastern Europe the deployment of rechargers has been much more limited. The market for EVs is expected to lag behind those of the front runners by 5-10 years though investment will be available – the draft European Commission budget for 2020-7 has a commitment to spend at least 60% of the EU's cross-border infrastructure fund on schemes that help the fight against climate change. This includes €30bn for transport in the Connecting Europe Facility.

The limited number of charging points today has no significant effect on the current EU market as a whole and future support will be available. Targeting future investment appropriately will be essential and cities in particular should be able to access these monies. Support for grid upgrades should also be prioritized along with support for startup SMEs.

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1. Introduction

Resolving the chicken and egg dilemma of what comes first the electric vehicles (EVs) or recharging infrastructure has been a source of considerable debate between those engaged in achieving a shift to electromobility.

The limited availability of public recharging can undoubtedly be a psychological barrier to EV uptake for drivers of conventional vehicles. But cheap and convenient private charging is one of the many advantages of EV's avoiding the need to "fill up" and breath nauseous and toxic fumes on oily forecourts. Numerous studies have shown access to home recharging is the most important factor in encouraging consumers to purchase EVs¹ and it is clear the market has considerable growth potential just by focusing on citizens with access to a home charger.

This report examines the availability of recharging infrastructure for electric cars and whether it is sufficient for the niche market to grow in the next few years. Sales are expected to increase sharply to represent 5-7% of new car sales by 2021 in response to car CO2 regulation.² A study by the European Commissions Joint Research Centre (JRC)³ shows that early EV adopters are less reliant on the provision of public charging infrastructure. They indicated availability of public charging becomes more important only after the share of EVs in the vehicle fleet exceeds 5%, a level only likely to be reached around 2025 in leading markets. By this time the business case for investment will anyway be. The report therefore asks the question have we fixed the chicken and egg dilemma?

The first part of the report examines the availability of recharging infrastructure throughout the EU and shows the "egg" (infrastructure) has largely come first. The second part of the paper defines a roadmap for the next decade for the rollout of public charging infrastructure in the EU to evaluate whether roll out will be sufficient to support the anticipated higher sales.

Whilst there has been considerable focus on and investment in public recharging infrastructure evidence from studies shows that it is a very minor part of the way electric cars are charged and just 5% of vehicle charging happens at public charging locations including on-street city charging, car parks and fast charging along road corridors.⁴ 95% of EV charging happens home and at work. Evidence from Norway, the most developed EV market in Europe, shows that as the EV market matures, public urban charging is used less rather than more. A comparison of surveys from 2014 to today elaborated by IEA⁵ on evolution of charging habits indicates that relatively fewer people use publicly accessible slow chargers and that fast charging along corridors is the only charging type that has increased in use in Norway. This could be explained by improved coverage and power of fast charging networks and increasing driving ranges. As a consequence, in Norway, the share of drivers relying on public slow charging on a daily basis dropped from almost 10% in 2014 to just 2% in 2017 (about 15% of drives used it on a weekly basis).

The availability of public recharging appears to have a psychological impact on the willingness of drivers to consider buying an EV, but once the decision has been made very little use is actually made of the available

¹ Bailey et al., 2015; Dunckley and Tal, 2016; Nicholas and Tal, 2017; Plotz and Funke, 2017; Skippon and Garwood, 2011

² https://www.transportenvironment.org/sites/te/files/publications/2018_04_CO2_emissions_cars_The_facts_report_final_0_0.pdf

³ The study has modelled the impact of different measures and their timing to help policy makers find the right balance in the transition to EVs. Harrison and Thiel, 2017: An exploratory policy analysis of electric vehicle sales competition and sensitivity to infrastructure in Europe. <https://www.sciencedirect.com/science/article/pii/S0040162516302104>

⁴ A review of consumer preferences of and interactions with electric vehicle charging infrastructure, Hardman et al., 2018

⁵ <https://webstore.iea.org/download/direct/1010?fileName=NordicEVO Outlook2018.pdf>

public infrastructure. In cities in which on-street parking is the norm public recharging infrastructure will be more important – but whether the extent to which in the future these cars will be privately owned rather than shared remains uncertain. Whilst this report focuses on public charging infrastructure roll-out its importance relative to private, including workplace recharging is minor.

2. Availability of EV charging infrastructure today

Analysis by the Platform for Electromobility⁶ of current and planned public charging infrastructure shows there is not lack of infrastructure today and if national charging infrastructure roll-out plans are met there will also be sufficient EV chargers until 2020⁷ to meet the anticipated surge in sales over the next few years. The analysis is based on Member States' submitted plans to implement the Alternative Fuels Infrastructure Directive. The Commission has recommended (based upon expert advice) there should be 1 public recharging point for every 10 EVs on the road. The analysis showed that in average there were about 5 EVs on the road per public charging point and by 2020, with the growth in both vehicles and recharging points the ratio will be around 10 EVs per public charging points in 2020 (assuming EU countries deliver on their plans) a total of about 220,000 chargers. The analysis also shows that there will be sufficient coverage along key EU strategic road network. Rather than the lack of infrastructure there is now solid evidence showing that it is the limited availability of electric vehicles, the minimal marketing⁸ of EVs and discouraging salespeople⁹ that are largely responsible for current low electric vehicles sales. Still, most national plans clearly focus on electromobility for the future of passenger car transportation whereas only several countries prioritize natural gas (Italy Hungary, Czech Republic)..

2.1 Slow charging

Slow (or “regular”) public chargers can be found in urban areas where they can be used with other charging options primarily to address the needs of EV owners that do not have access to private off-street parking and drivers making occasional trips into a city centre. There is no benchmark for the recommended supply of slow charging in cities since it can vary greatly from one city to another due to many local factors as availability of off-street parking, GDP, number of cars, etc. However, the map below shows that only 2 countries have a number of EVs per public slow charger significantly above 10 (Belgium and Sweden has values close to 20).

⁶ <https://www.transportenvironment.org/publications/how-eu-member-states-roll-out-electric-mobility-electric-charging-infrastructure-2020>

⁷ Based on the Commission's' guideline of 10 EVs per public charging point

⁸ <https://www.transportenvironment.org/publications/carmakers-still-failing-hit-their-own-goals-sales-electric-cars>

⁹ A study based on 82 car dealerships across Denmark, Finland, Iceland, Norway and Sweden found that dealers were dismissive of EVs, misinformed shoppers on vehicle specifications, omitted EVs from the sales conversation and strongly oriented customers towards petrol and diesel vehicle options. <https://electrek.co/2018/05/21/electric-car-adoption-deceptive-car-dealerships-new-study/>

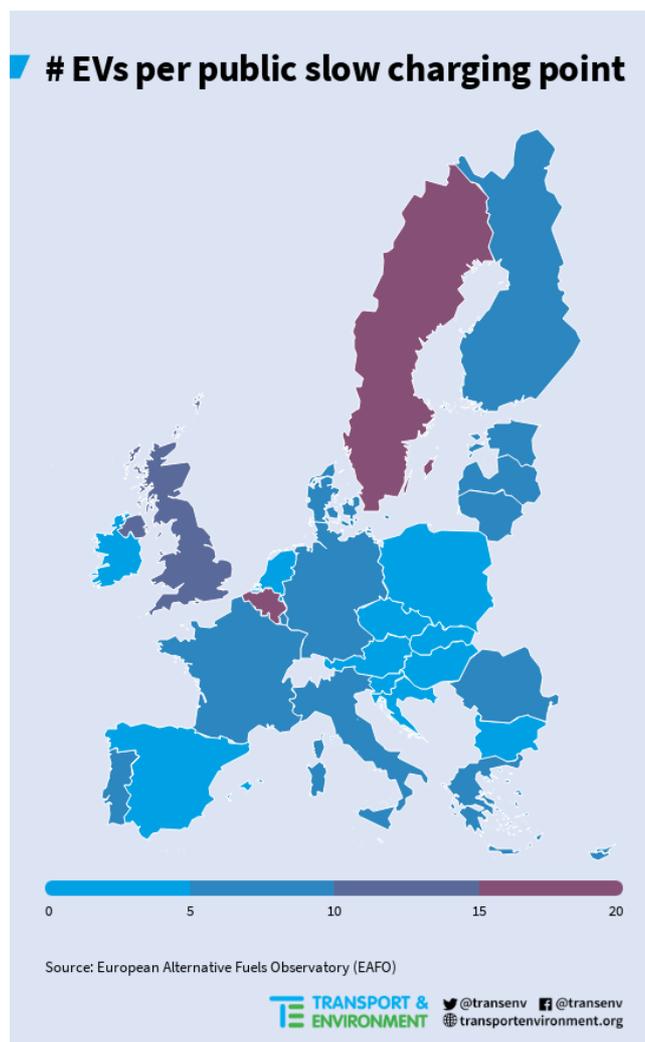


Figure 1 - The EU supply of slow charging

2.2 Fast charging

2.2.1 The current situation

Fast charging along corridors and highways is essential for drivers to complete journeys beyond the range of their vehicle. It also acts as a psychological safety net enabling drivers to travel longer distances and further from their usual charging location¹⁰.

Today there are around 2,550 rapid charging sites installed on European main roads¹¹ with a total of about 5,000 CCS chargers.¹² This is equivalent, in average, to one site (equipped with 2 CCS chargers) placed every 60 km in average on EU motorways¹³ for every direction on the highway¹⁴. Figure 2 show the

¹⁰ Neaimeh et al., 2017

¹¹ Element Energy's analysis of the OpenChargeMap.org (OCM) database, June 2017 found in Fuelling Europe's Future II. Discounting charge points found at Nissan car dealerships, and Tesla's supercharger network sites (this reduces the number of sites by ca. 15%).

¹² CCS Charge Map Europe, July 2018, <http://ccs-map.eu/stats/>

¹³ Total EU motorways: 76,500km (Eurostat, 2016)

¹⁴ In practice this is two sites every 60 km but EV drivers would only access one site, depending on their direction of travel (e.g. most gas stations on motorways)

current situation of the rollout of fast charging infrastructure in the EU¹⁵:

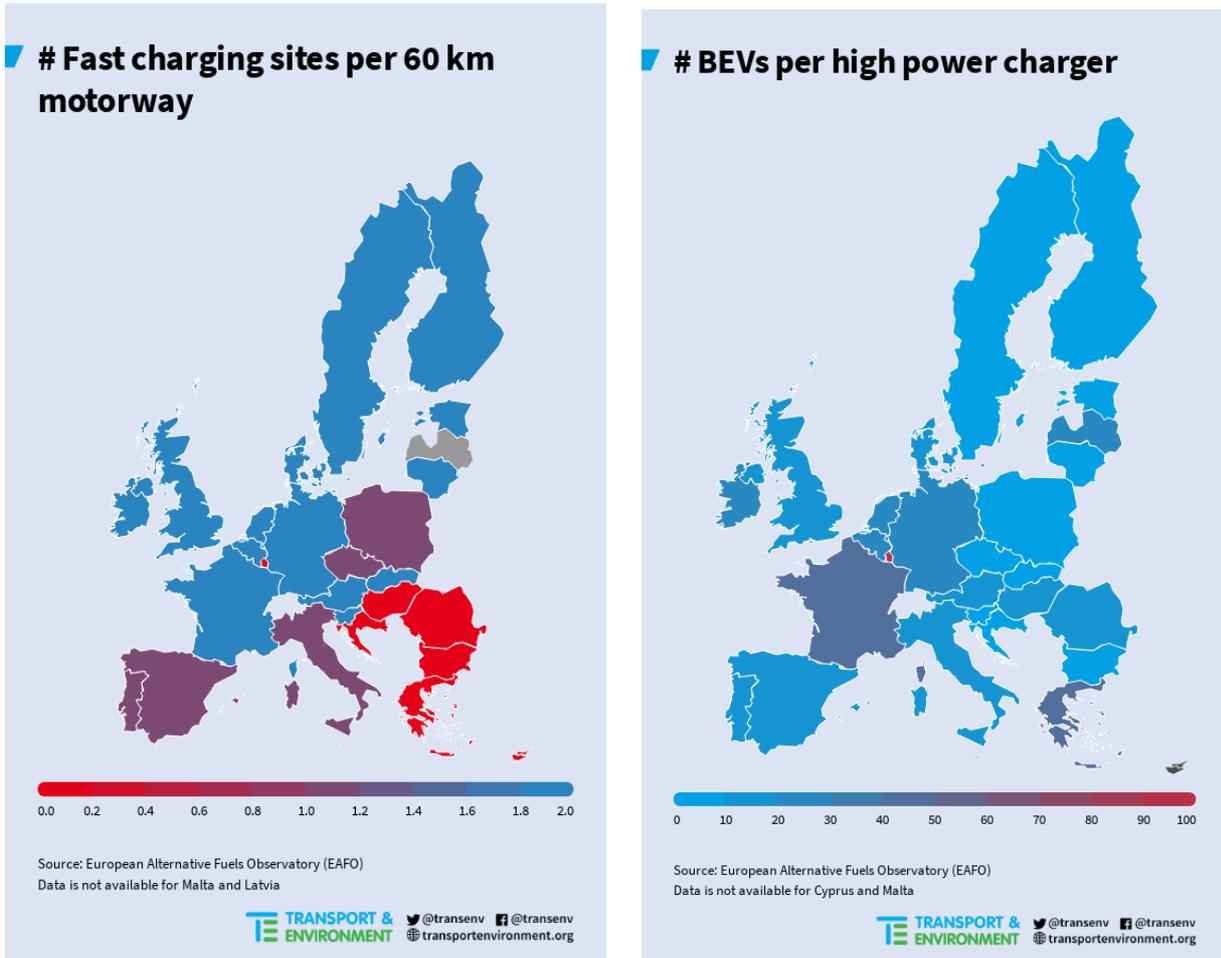


Figure 2 - The existing EU fast charging network

The map on the left illustrates that most countries already have a good coverage of fast charging sites. For comparison the European Commission's guideline is one fast charging site every 60 km on the TEN-T Core Network¹⁶ by 2025, whereas here this same coverage is, in most parts, already achieved in average on EU motorways (which are almost twice as long as the TEN-T Core network). Indeed 11 countries -representing 56% of EU's BEVs- already have more than 2 fast charging sites per km of motorway.

The coverage of fast charging sites is not uniform. 10 Member States have less than 1 fast charging site per 60 km of motorway but only about 8% of today's EVs on the road. The lack of coverage in Hungary, Romania, Bulgaria and Greece is notable and needs to be addressed to enable EVs to be used EU-wide.

The right map shows the number of BEVs per fast charger in each country. The huge majority of Member States have a low number of BEVs per high power charger (blue coloring). A lack of fast charging infrastructure for the number of BEVs currently on the roads would indicate number above 100 BEVs per fast charger. Today, only one country (Luxembourg) has more than 50 BEVs per fast charger (154).

¹⁵ Based on EAFO data: 17,000 high power chargers in the EU, July 2018. This corresponds, to the 2,550 sites equipped with two tri-standard connectors (CCS, CHAdeMO, AC Type 2).

¹⁶ The total length of the EU28 TEN-T Core network is 34,401 km, TEN-T Comprehensive network is 136,706 km. The comprehensive network ensure accessibility to all European regions (including peripheral and outermost regions) and the core network is distinguished by its strategic importance for major European and global transport flows: https://ec.europa.eu/transport/themes/infrastructure/ten-t-guidelines/maps_fr

Coverage of fast charging infrastructure in Europe is progressing well and has already reached today a sufficient minimum level for long distance travels in Western and Northern countries but not yet in Central and Eastern Europe.

2.2.2 Planned developments of fast charging networks

Ultra-fast charging enables EVs to replenish for up to 400 km of range in only 15 minutes with powers ranging from 150 kW to 350 kW. Recent announcement for deployment of ultra-fast charging networks (e.g. Ionity, Ultra-e, Mega-e) are that there will be more than a 1,000 such sites within the next few years (see annex for the detail on planned networks). Sites are initially planned to 150 kW, with upgrades to 350 kW once new vehicle models capable of receiving such power are available and charging standards (CHAdeMO and CCS) are updated to support higher powers. The planned sites are equivalent in average to one ultra-fast charging station every 34 km on the TEN-T Core Network (for comparison Tesla has just hit 400 Supercharger sites in Europe¹⁷). Projects like NEXT-E and Central European Ultra Charging ensure Central and Eastern Europe will also be well covered by ultra-fast charging infrastructure.

Automakers are also involved in installing fast-charging infrastructure (e.g. FastCharge Consortium by BMW and Porsche want to improve charge rate to 450 kW). Such investment from car makers in charging networks increases the value of their EVs. Being able to recharge cars within the recommended driving break time (10/15 minutes every 2 hours) is expected to be a game changer for market uptake as it should help to address drivers remaining range anxiety.

Assuming those chargers are located in stations along the TEN-T Comprehensive network, there would be an average of one high power charging station every 58 km in average on the TEN-T Comprehensive network in 2020¹⁸ or a total of 4,800 stations. This is ahead of the Commission's recommendation which covers only the TEN-T Core network and has set 2025 as the target year. The Commission concluded that the coverage "largely seems to be progressing well" and almost all countries will have a coverage that "seems sufficient" by 2025. In conclusion, **the EU motorways are likely to be very well covered with fast charging stations by the early 2020's.**

3. Solving the chicken and the egg dilemma

The previous section has shown that availability of charging infrastructure (the "egg") is currently ahead of EV deployment and will stay so in the next couple years. Furthermore, the planned fast charging network will be sufficiently dense to enable more recent EVs (with longer ranges) can be used for trips throughout much of Western & Northern Europe by 2020 and throughout Europe a few years later. Access to city centre charging points will also be within the Commissions proposed 10:1 vehicle to charging point ratio indicating sufficient initial coverage. It is however clear that recharging is not being rolled out uniformly EU wide – a point carmakers have been keen to highlight. This section therefore examines whether homogenous roll-out is needed or a phased approach is more practical and cost effective?

3.1 Leaders and followers: waves of roll out of EV infrastructure

The rational approach to recharging infrastructure roll-out is for this to develop beyond the necessary minimum as the number of EVs on the road increases. Since EV sales are focused in Western and Northern

¹⁷ Announcement from June 2018. Network is sufficient for drivers to move freely between the Northern top of Norway, the Southern tip of Spain, the UK and Hungary or Poland

<https://www.driving.co.uk/news/now-400-tesla-supercharger-stations-across-europe/>

¹⁸ Sites are direction-specific, i.e. each site can only be accessed by drivers going in one direction on the motorway.

European markets (as all new car sales are) it can be expected that the deployment of charging infrastructure will also happen first in these countries. Accordingly, it is expected that **Germany, France and the UK will be leading the transition as the biggest new car markets.**

Recently the European Automobile Manufacturers Association (ACEA) claimed¹⁹ that the provision and geographical distribution of current public charging infrastructure is “putting consumers off buying electric cars” because 76% of all charging points are located in 4 countries (Netherlands, Germany, France, and UK). This misleading claim ignores that use of EVs, like the uptake of any other new technology, will not happen homogeneously over the continent. Rather in Europe it is likely to occur in several steps or waves, due to differences in GDP per capita of the Member State, the renewal rate of national vehicle markets and geographic location. The four top selling EV markets in the EU represent 76% of public charging infrastructure but also concentrate 75% of the EVs, showing that both EV rollout and infrastructure deployment is happening in parallel. Since these countries represent such a large share of EU’s GDP and car sales, it is natural for these countries to be the starting point of new technology adoption²⁰.

Mapping the number of public chargers in each Member State should always be put into perspective with the size of the car market and the EV market, rather than the correlating the number of infrastructure and the area of the country (see EV charging infrastructure versus area per country, same ACEA study).

ACEA points out that six countries have low number of public charging points (Cyprus, Greece, Latvia, Bulgaria, Malta, and Romania). The five EU countries with less than 100 public charging points account for 0.26% of public charging points but only 0.17% of EVs and represent about 1% of new car registrations.²¹ As such these countries cannot be expected to progress sales at the same rate as more wealthy countries.

To better understand the expected EV and infrastructure rollout, we’ve identified groups of Member States where **e-mobility uptake will happen in successive “waves”** based on factors explained above:

- **Front-runners** are most Western and Nordic countries: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden and the UK
- **Followers:** Italy, Portugal and Spain
- **Slow starters** composed of EU13 and Greece: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Slovenia.

The Front-runners group is composed of the EU’s 11 most wealthy countries (per capita), these Member States are identified as market leaders. The region amounts for about 80% of EVs and public charging infrastructure in 2020 and represents about 70% of the Union’s GDP and sales of cars. As technology becomes more affordable, e-mobility will spread to the South and East. The uptake in other countries will likely happen in two “waves”, through which the two other regions will catch up with the leading region thanks to stronger growth rates. Eventually the share of EVs and public infrastructure will stabilise around a ratio of 70-20-10 (i.e. same as share of GDP or car sales). Already in 2017, 91% of the registered EVs were sold in the Front-runners group (1.9% market share) while 8% were registered in the followers group (0.5% market share) and 2% in the Slow Starter group (0.3% market share).

¹⁹ <https://www.acea.be/press-releases/article/electric-cars-unrealistic-co2-targets-proposed-by-eu-parliament-ignore-lack>

full study: https://www.acea.be/uploads/publications/Study_ECV_barriers.pdf#page=8

²⁰ These four countries represent 56% of car sales and of the EU GDP.

²¹ According to updated data from EAFO, Lithuania has less public charging points than Romania and they both have more than 100.

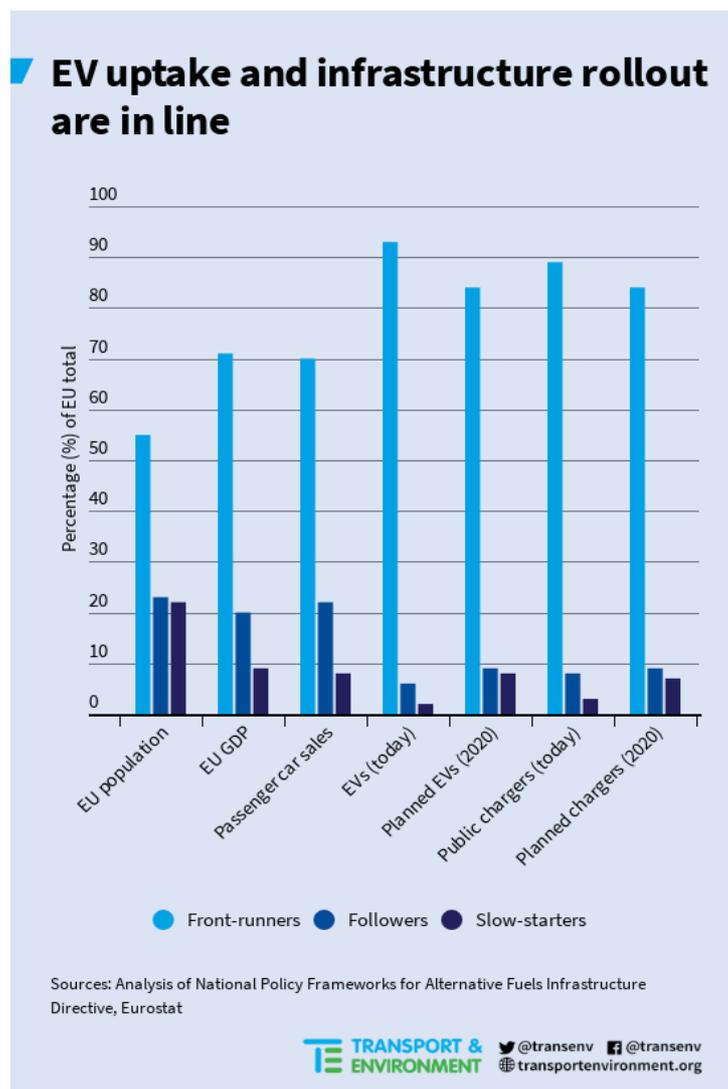


Figure 3 - Comparison of planned EVs and chargers per zone

Based on current trends, the Front-runners’ group is expected to be selling 5-7% EVs by the early 2020’s in order to comply with car CO2 regulations. Representing around 1 million sales per year this level of uptake is expected to be sufficient to kick start business interest in deploying recharging points without subsidies. The Follower countries are expected to reach a similar proportion of sales around 5 years later, 2025; and the Slow-starters by 2030s.

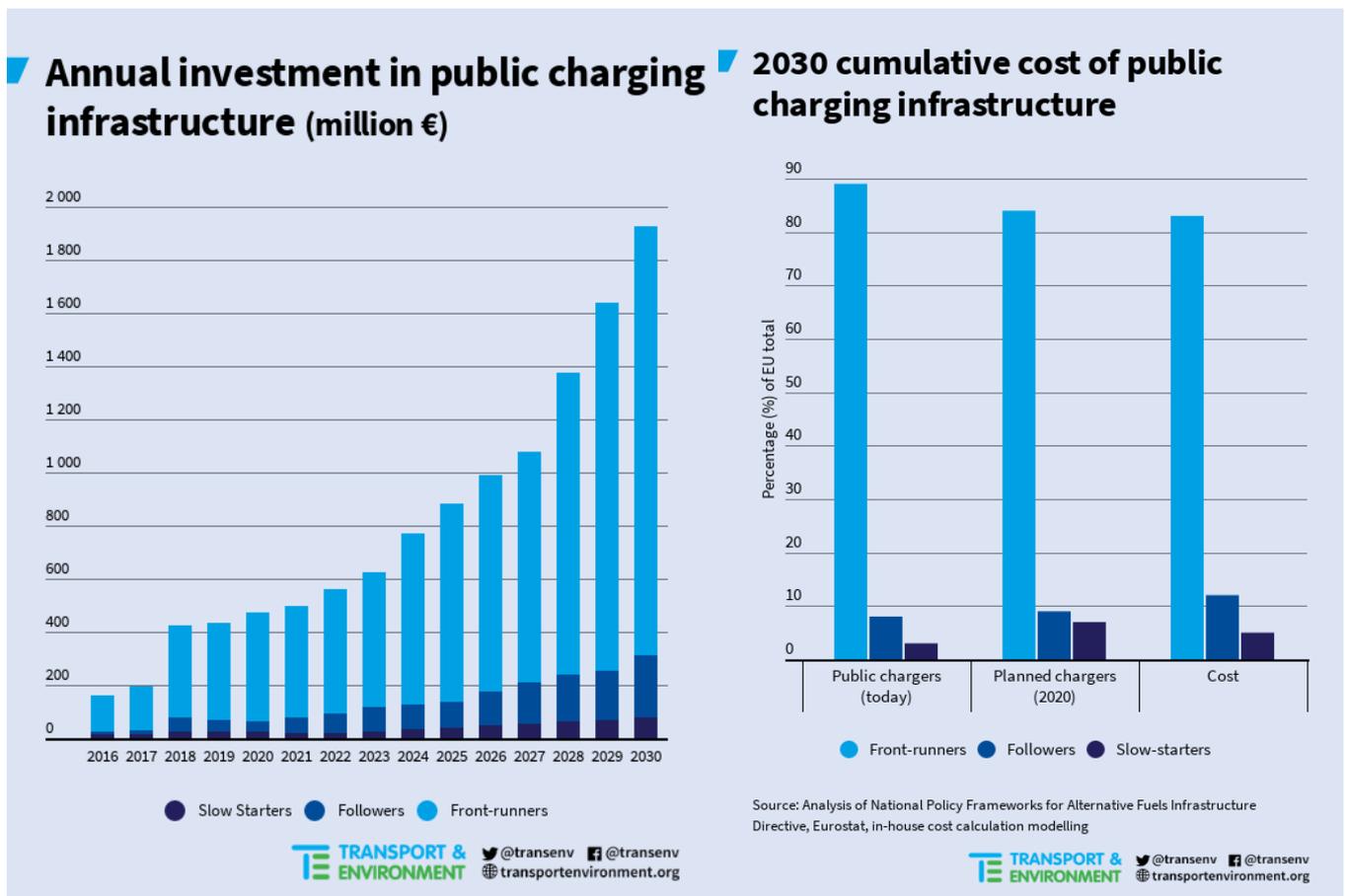
The vehicle market in Member States from the slow starters’ region is heavily dependent on importation of second hand cars from Western European countries like Germany. However, early indications are that EVs are likely to be attractive second hand purchases due to their low running and maintenance costs. It is therefore expected that initially the first generation EVs in the front-runners group will largely remain within the country in which they are sold. There are unlikely to be large flows of second hand imports of EVs into the countries of the slow starters group until the early 2030s. This would suggest there is little need to develop a comprehensive network of recharging points until the end of the 2020’s.

A heterogeneous EV market uptake does not represent a market barrier as long as in each market, the number of public infrastructures increases in line with the number of vehicles sold and cross-border infrastructure networks are fully covered along the TEN-T network. Moreover, gradually diffusion of technologies is natural and the economics for technology diffusion and adoption are clear; poorer countries

catch up with richer countries through technological diffusion by the adoption of advanced technologies produced in high-income countries²².

3.2 Costs of EV infrastructure build up

Based upon assumptions and findings from the Fuelling Europe’s Future (FEF) II by Cambridge Econometrics, the total cumulative costs for public charging infrastructures is estimated to be €12 billion with about €20 billion investment needed for private charging by 2030 (62% of all infrastructure costs). A breakdown of costs for the three zones identified previously was also analysed:²³



The charts illustrate very different investment in each of the three regions with about 83% of the cumulative costs in the front-runners’ group, 12% for Followers and 5% for Slow-starters.²⁴ The total cumulative cost of 12€ billion for the public deployment of infrastructure across the EU should be put into perspective with the 100€ billion invested every year in transport infrastructures (less than 2% of annual investment until 2030)²⁵.

²² Microeconomics of Technology Adoption: http://www.econ.yale.edu/growth_pdf/cdp984.pdf

The Economics of Technology Diffusion: Implications for Climate Policy in Developing Countries <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.474.6305&rep=rep1&type=pdf>
<https://ourworldindata.org/technology-adoption>

²³ The study FEF II assumes that the share of new EV sales are the same for all Member states, however as seen previously this is very unlikely to happen. As a consequence the technological deployment scenario of FEF II was used but an earlier or delayed uptake for each region was implemented.

²⁴ The scenario considered assumes an average EV market share of 13% in 2025 and 30% in 2030 and that the front-runner region is approximately 5 years ahead of the Central Eastern Europe zone.

²⁵ <https://www.eea.europa.eu/data-and-maps/indicators/infrastructure-investments/assessment-3>

In the early phase, investments in charging infrastructure are paid by a mixture of public sector financing and private investors (e.g. European Commission's funds and blend calls as CEF or Horizon 2020, OEM joint investments, DSOs, etc..) and utilization of chargers is not (yet) high enough for private companies alone to be profitable. Later, as the share of EVs in the total fleet increases and the market matures, charge point operators and other charging services have viable business. Public funding will not be necessary anymore and infrastructure is rolled-out to answer the growing demand from cars (demand-driven). Competition among charge point operators to retain good market share pushes private companies to invest in charging infrastructure before any financial benefit can be made (they aim at securing good locations). According to the study FEF II, investment in infrastructure deployment will be entirely private in 2025.²⁶

Already today, there are some examples of public infrastructure deployed without any public money:

- Flanders (Belgium): 2,500 public charging stations will be installed and paid by Allego²⁷ at their own costs by 2020 with a least one in each municipality and it is a “*self-sustaining business case*” according to the Minister of Energy²⁸.
- Netherlands: Nuon-Heijmans will install 2,480 points in the provinces of Noord-Brabant and Limburg in the south of Netherlands without financial contribution from the government subsidy²⁹.
- EV Point, a Flemish charge point operator, explains that they don't see a need for subsidies for electric car charging³⁰: “*as soon as more electric cars drive, the charging stations will also become economically viable*”.

The Dutch fast charging point operator Fastned has claimed that with 50,000-100,000 BEVs (compatible with CCS or CHAdeMO) on the roads in Netherlands they would be profitable, this represents about 0.6-1.3% of the vehicle fleet. In Norway fast charging is commercial with as few as 115 000 BEVs, around 3% of the car fleet.³¹ We assume that above 2% of the vehicle fleet³² then fast charging along motorways will be profitable and not require subsidy. The rate of phase out of public subsidy depends on several factors including car density, ratio of households with off-street parking, etc... and cannot be interpreted the same way everywhere but according to our market modeling based on FEF II data, this 2% share would be reached in the Front-runners' group around 2024/5³³, 2028 for Followers and 2030/32 for Slow starters. This EV share of the fleet marks the point at which market maturity is reached. The business case for slow urban charging is less clear but there is evidence private operators will step in to encourage use of shops and other facilities.

In brief, we estimate that **the need for public subsidy will gradually phase-out in the 2020-2025 period in the Front-runners' group**. Then, thanks to technological acceptance and spread and economies of scale we expect a similar development in the other countries.

²⁶ “*after 2025, installation in parkings/retail/shopping will be undertaken by the land management business that operates them to attract higher rents and more customer and, rapid charging will be funded purely by private investments as the number of EVs on the road will make the business model viable*”

²⁷ Allego shows in an infographic that investment in charge points is not necessary http://www.allego.nl/wp-content/uploads/sites/2/2015/02/Open-markt-model-Allego_DEF.pdf

²⁸

Private individuals can also request additional public charging station (about 1,000 additional chargers) <http://www.tommelein.com/publieke-netwerk-van-laadpalen-voor-elektrische-wagens-van-start/>

²⁹ <https://www.heijmans.nl/nl/nieuws/nuon-heijmans-plaatst-2500-laadpunten-brabant-en-limburg/>

³⁰ <https://www.hln.be/regio/wetteren/-2-500-laadpalen-tegen-2020-zonder-subsidie~aba08062/>

³¹ Charging infrastructure experiences in Norway - the world's most advanced EV market, Lorentzen et al., 2017

³² Nearly all BEVs in the future will be compatible with regular CCS or CHAdeMO standards as Tesla cars already have CHAdeMO adaptors at some stations and the next Renault Zoé will be able to charge in DC.

³³ Western leading countries have different characteristics in terms of passenger car transport activity and density of motorway for example but the transport activity per km of motorway, per km of TEN-T Core network or per passenger car of countries like Germany and France was relatively similar to those of Netherlands.

4. Recharging in Cities

Cities are both the destination for many long trips and location of most off-street parking and will therefore be the location of most public recharging infrastructure. However, as the range of EVs improves to reach real-world ranges of 400 km, the average urban driver only needs to typically charge once a week, far less than at present.³⁴ Charging solutions in cities will be composed of a mix of slow, fast and ultra-fast chargers.

Slow/regular chargers are the solution with the most limited grid impact since powers are lower and demand can easily be directed to off-peak hours since the car is usually parked at these times. In cities slow charger may be found at:

1. On-street charging for drivers that leave their car during the day or the night parked in the street;
2. 'Park & Ride' chargers in parking lots with public transport connections that allow commuters to enter the city center without their car.

In densely populated areas, a demand-driven approach using slow rechargers, as piloted in Amsterdam, ensures chargers are appropriately located and used from day one and also addresses the issue of uncertain usage forecasting that makes constructing a robust business case difficult. 50 kW fast chargers typically charge an EV in about one hour. They are therefore most suited for facilities and amenities where people typically stay 30 minutes to 2 hours. For example, these locations would be parking lots of stores, supermarket or commercial zone. There is a strong incentive for owners of such properties to install chargers to encourage customers to their facilities.

Ultra-fast charging sites near cities are ideal for tackling range anxiety and recharging for those users without off-street parking or access to a slow charging site. They are particularly appropriate for shared electric cars enabling these to be operative most of the time. Studies have shown how the provision of fast charging infrastructure is a strong driver for EV uptake. For example a first study has shown that providing charging solutions above 50 kW close to urban areas increases the annual EV kilometers traveled³⁵ by about 25% (even in cases where it was used for less than 5% of total charging events). A second study³⁶ has shown that fast charging is a stronger driver than standard charging and confirms that access to fast chargers increases daily electric distance travelled.

There are indications users prefer to use ultra-fast chargers for both inter- and intra-urban travel.³⁷ A network of fast chargers may therefore prove to be more popular and cheaper than installing a large number of slow chargers in cities. Fast chargers do however incur greater impact on the electricity grid and less readily balance renewables and cannot be so smart. The optimum balance of slow and fast charging in urban areas may therefore depend to some extent on the capacity of the local electricity grid to accommodate fast charging and possibly differential charges.

In China, there are several examples of charging hubs serving many types of vehicles. For example, the Qian Hai charging station can charge 60 vehicles simultaneously (maximum capacity of 3 200 kW) and is used by taxis (50%), vans (30%), passenger cars (10%) and buses (10%). The project Mega-e, also aims to bring multimodal charging hubs including ultra-fast chargers to metropolitan areas. Providing a mixture of services can potentially help to balance demand throughout the day and night but may require considerable space to park vehicles before and after charging overnight.

³⁴ 40-50 km per day in average in the EU

³⁵

https://www.energy.gov/sites/prod/files/2017/10/f38/XFC%20Technology%20Gap%20Assessment%20Report_FINAL_10202017.pdf

³⁶ Neaimeh et al., 2017, based on data from 90,000 fast charge events in the UK and US

³⁷ Blythe et al., 2015

Costs for a network of fast chargers may be less than for slow charge systems if grid reinforcement is not required. For example; for a city of 1 million inhabitants (e.g. Brussels or Cologne); where a high proportion of drivers do not have access to off-street charging according to the ICCT's benchmark,³⁸ there would be 85,000 BEVs in a 'high electric vehicle market'³⁹ scenario. If half of these would not have access to off-street parking⁴⁰ they would require around 300 public fast chargers;⁴¹ or between 8,500 and 17,000 standard L2 chargers.⁴² Based on the costs used by Cambridge Econometrics in FEF II study⁴³, the total cost to supply infrastructure to this city would be around €45.8M with fast chargers and between €54.4M and €108.8M with standard L2 chargers. Approximately half in the fast charging case. For consistency between the two scenarios, this case study excludes PHEVs (that would not be using fast chargers as much), any high-utilization vehicles (taxis, on-demand transportation, etc...) and any major grid upgrades at city level. In conclusion, implementing fast charging hubs in urban area seems like a cheaper solution than providing extensive coverage of regular L2 charging infrastructure on the streets.

According to ICCT, in the case were drivers do not rely exclusively on public fast charging, a city of 1 million inhabitants would actually only need about one fast charger for 700 BEVs, which would cost €18.5M.

Access to a higher voltage power supply is essential but not usually an issue as a medium voltage grid exists in many places within urban areas to serve industrial or commercial buildings and metro/train/tram grid infrastructure. The charging hubs have thus to be strategically placed at these locations to eliminate high costs of extending the high voltage power source to the desired place. Based upon the same case study about 2,400 BEVs would need to be charged each day. If all the charging focused on 4 hours⁴⁴ (an extreme worst-case scenario) peak power demand would be 45 MW at the city level. For countries that are highly industrialized, the amount of power needed for a city of 1 million is about 1,000 - 1500 MW,⁴⁵ the demand from fast charging would then increase total load by about 3-5%. This load is a relatively low fraction of the total city consumption but could require some additional costs as it would likely occur during peak-times. However, many strategies exist to mitigate fast-charging grid impacts and can be easily implemented. For example combining fast charging with energy storage that discharges at time of peak demand and implementing time-of-use rates are solutions.⁴⁶

Charging EVs in cities remains the most difficult challenge but fast charging hubs undoubtedly offer part of the solution when located appropriately.

³⁸ ICCT, August 2018 (benchmark of fast chargers supply for given metropolitan area population sizes):

https://www.theicct.org/sites/default/files/publications/ZEV_fast_charging_white_paper_final.pdf

³⁹ In average in Europe, there's about one car for two inhabitants and looking at specific European cities indicate a ratio between 0.3 and 0.5 cars per inhabitants in cities. In this situation the share of EVs in the city' fleet is between 17% and 28%, this level of penetration might not be seen much in the next ten years.

⁴⁰ Assumptions: 40% of car-owning dwellings do not have access to a garage or other off-street parking (see below for UK), half of them can't charge at work. Source: UK statistics (DCLG, 2010b) and the SHCS (https://www.racfoundation.org/wp-content/uploads/2017/11/spaced_out-bates_leibling-jul12.pdf)

⁴¹ i.e. around 50 BEVs per fast charger or 300 BEVs per fast charger at city level. One charger for 300 BEVs sufficient for all BEVs to charge during peak hours (see B. Grid impact). As the population of BEVs increases within a country, one fast charger can support more BEVs since initial stations are likely to be under-utilized (50-300 BEVs per fast charger for major markets in 2016-2017) and 700 BEVs per fast charge point in a 'high electric vehicle market', (ICCT, 2018).

⁴² The ratio of BEV per public charger is between 0.5 and 1.

⁴³ Fast charger cost (150 kW): €152,750 (€20,500 for civils, €41,000 for the equipment, €5 for the installation and €86,250 for grid costs. Grid costs are likely to be conservative since in urban areas sites with ample capacity are abundant.

Standard L2 charger (11-22kW): €6,400 (€1,400 for the equipment, €5,000 for the installation, and the grid connection)

⁴⁴ Assumptions: 400 km range, 0.175 kWh/km energy consumption, 30 minutes stops at 150 kW chargers to replenish the battery. 40-50 km average daily mileage.

⁴⁵ 1 MW powers approximately 1,000 homes

<https://www.quora.com/How-much-electricity-does-an-industrialized-city-of-1-million-people-consume>

⁴⁶ *Lessons learned on early electric vehicle fast charging deployment*, ICCT <https://www.theicct.org/publications/fast-charging-lessons-learned>

5. Conclusions & policy recommendations

This study highlights the good progress being made in Western and Northern Europe to develop a basic infrastructure to recharge electric cars. It demonstrates that by 2020 a network of fast chargers will be available along the main motorway networks in these countries to enable EVs to be used for most journeys. The availability of public charging in many cities in Western and Northern Europe is also sufficient for drivers to recharge their cars but may not yet be adequate to encourage those without off-street parking to make the shift to EVs – with the notable exception of the Netherlands where innovative policies are enabling EVs to become practical for almost all users.

In these countries, that represent the overwhelming majority of EV sales the chicken and egg dilemma is largely resolved. The basic infrastructure is in place and it is reasonable to anticipate business will now provide most of the investment required as sales increase and the share of EVs grow. Some incentives may be needed at less optimal sites – especially city centre slow charging but by the mid 2020's the market is expected to be self-sustaining. Current modest sales of EVs are largely the result of minimal supply, limited marketing and discouraging salesmen all of which are within the control of the car industry to address – as they are expected to do to ensure 2020/1 CO2 targets are met.

The availability of recharging points in southern, central and eastern Europe remains much more limited – but still in line with the very small number of vehicle sales. However, a basic infrastructure of fast chargers along highways is being established. The slower progress in these markets is not a barrier to the shift to electromobility as sales are likely to lag those in western and northern Europe by five to 10 years. In summary there is time to build the infrastructure that will be needed as the market expands in these countries. It is nevertheless clear that some level of financial support will be needed to build the basic infrastructure in these markets until the late 2020's.

Beyond 2020 the European Commission has announced a commitment to spending at least 60% of the EU's cross-border infrastructure fund on schemes that help the fight against climate change. Under the proposed budget,⁴⁷ the Connecting Europe Facility (CEF) will have €42.3 billion, of which €30bn will go to transport. The proposal also says 60% of the overall €42.3bn must be used for 'climate spending' to assist in tackling climate change. These funds provide the basis from which to support the shift to electromobility and build the infrastructure needed. There does not appear to be a shortage of money. With this in mind T&E has the following guidance for policy makers.

- 1. EU investment in infrastructure must be targeted.** Substantial sums of private money are already being invested in building recharging infrastructure in some locations and it is important public money is spent in competition. It is also essential to avoid a culture of subsidy and public-private partnership is essential. Incentives will be needed to develop a comprehensive network of recharging to cover less heavily trafficked and populated areas – just as is necessary for the privately owned mobile phone network. In the early 2020's EU funds to support infrastructure will be appropriate across the Union but become progressively focused in first the south and then the east as the EV market matures.
- 2. The Alternative Fuels Infrastructure Directive should be updated.** The AFI appears to have been successful in implementing a basic infrastructure but the indicators (1 charging point per 10 vehicles) are crude and not appropriate. It is also clear different member states need to develop recharging in different ways and at different times. The early experience of the AFI should be used to develop a plan for infrastructure rollout that in particular integrates recharging with renewables

⁴⁷ http://europa.eu/rapid/press-release_IP-18-4029_en.htm

roll-out. For example; in places with a high share of wind overnight charging will be most beneficial whilst in solar dominated areas afternoon charging is optimal. In particular the ambition on deployment on TEN-T Core and Comprehensive networks should be raised to have full coverage of TEN-T Core network by 2020 and TEN-T Comprehensive network by 2025 using CEF funds.

3. **The EU should create a fund dedicated to urban recharging.** Striking the balance between encouraging electric car sharing; and providing slow or fast charging for cars without off-street parking will be a challenge for cities whilst also seeking to accelerate the transition to electromobility and funds will be crucial both for charging points and grids upgrades. European think-tank Brugel suggests that “*such a fund could be created by making better use of existing financial resources, such as from the Connecting Europe Facility for Transport (CEF-T) or from the Structural and Cohesion Funds. For the period 2014-20, CEF-T has a budget of €24 billion (European Commission, 2018a), while the Cohesion Fund and the European Regional Development Fund have a budget for transport and energy network infrastructure of €71 billion*”. Similar mechanism has existed in the past, with the successful example of Wifi4EU⁴⁸. This fund could be directed in priority to cities with bad air quality, little resources, or in outreach/peripheral regions to reinforce EU cohesion and preventing market or health gaps. This could be a big help for cities that often lack resources or private investment and are currently unable to access EU funds directly. Municipalities should be able to apply directly to these funds and bypassing ministries which would make it more accessible since the bureaucracy of EU funding mechanisms has reportedly been a big hurdle and a discouraging process. This fund could also be very useful for cities to upgrade their grid (see below).
4. **Investment in grid upgrades is a priority.** In some locations local peak loads will increase as more EVs are charged requiring upgrading of local grids. Smart charging can reduce peak loads but in some locations and whilst McKinsey doesn't expect EVs to substantially increase the power demand by 2030 some grid reinforcements and upgrades will be needed to prepare for tomorrow's integration of EVs in the energy system. The EU funds could provide a potential contribution to these costs.
5. **Tackling the barriers to recharging for tenants.** Today, many tenants face huge administrative, time and cost barriers to installing a private charger in multi-occupancy buildings even where they have a parking space.⁴⁹ City underground parking must also be considered in this framework. But strict fire safety measures often prevent installation. Similarly Governments need to put in place to private off-street charging mentioned above, work charging if key for adoption of e-mobility. Companies should play a leading role in the acceptance of the e-mobility ecosystem and the adoption of new habits. More than half of the car registrations in the EU are made by companies, this create an exceptional chance for private companies that care about the environment and public health to drive the change. National action is needed on all these issues.⁵⁰
6. **Create tailored loan and grant schemes for small and medium enterprises.** Small innovative players that are taking the initial loss and risks usually face difficulties to provide the bank guarantees or the inspire the confidence required by investors or institutions. This is also partly due to the uncertainty in the speed of the e-mobility market uptake and could be improved with long

⁴⁸ Each Member State had a minimum of 15 “vouchers” of €15,000 for municipalities to apply directly (via simple website) in order to build infrastructure. The Commission judges and selects the projects and each municipality is limited to one “voucher”.

⁴⁹ <https://www.golem.de/news/elektromobilitaet-regierung-bremst-bei-anspruch-auf-private-ladesaeulen-1807-135521.html>

⁵⁰ Only ground level and one level below ground (-1). Total power cannot exceed 500kW, fire-proof walls every 10 EVs, etc..

term targets and regulations. Moreover, this could also be improved if CEF money was dedicated to risk mitigation and supporting low or zero interest rates for e-mobility. Such low-risk bank loans would encourage private investment without being a burden on the budget.

7. **A seamless e-mobility service.** The user experience should be improved by adoption of open standards, streamlined payment options and transparent and fair pricing. Some e-mobility service providers (eMSP) providing the customer-facing service to EV drivers do not allow access to their service to unregistered users which means that they are not able to charge. As it was done for telecommunication roaming fees in Europe, eMSP should grant universal access to their charging services. According to a recent survey by the ICCT, the complex and variable pricing structures causes uncertainty to consumers seeking to fast-charging networks.

The biggest constraint on the ⁵¹shift to electromobility is the availability of vehicles to buy and as a result carmakers are failing to achieve their own targets for sales of battery electric and plug-in hybrid models as they do not increase the offer of these vehicles fast enough. Whilst manufacturers complain about a lack of recharging infrastructure and incentives, there are just about 30 battery and fuel cell electric models on sale compared to about 370 conventionally-fuelled models. But it is now clear many models are simply not available for sale in showrooms and others have long waiting times.

The very limited choice of electric cars, long waiting times to receive these cars, limited availability and crucially a lack of advertising investment are contributing for carmakers' lack of sales. Data purchased from leading marketing analytical company Ebiquity shows that carmakers are making very little effort to market electric models. Whilst around 30% of British, French and German consumers say they would consider buying an electric car, just 1.5% of advertisement spend was on zero emission models and 1.4% on plug-in hybrid models in the EU's largest car markets: Germany, France, UK, Italy and Spain.

Across the EU, advertising spend is likely to be significantly lower than this percentage as little promotion of zero emission models is likely out of the major new car markets. In Norway (where 4 out of 10 cars sold were battery or plug-in hybrids in 2017), OEM's advertising spend on zero emission cars as a proportion was much higher (10%), indicating companies tending to follow demand rather than creating a new market. Analysis of future market growth by carmakers shows expectations are for strong growth, such that by 2025, 26% of new cars sold are expected to be electric.

But past performance suggests without regulations they will fail to achieve their aspirations. This is why the forthcoming car CO₂ regulation is so important in defining the speed of transition to zero emission solutions and in particular a binding sales target of 20%, either through a sales target or through a crediting-debiting system for Zero and Low Emission Vehicles, along with CO₂ reduction targets of 50-60% in 2030, and 25% in 2025.

Many companies (e.g. charge point operators, e-mobility service providers, DSOs, etc...) have anticipated and invested in the transition to e-mobility. However due to low number of electric cars on the road today and thus low utilization of their services and infrastructures, their business is not yet viable. It is a market failure regulation must address.

⁵¹ https://www.transportenvironment.org/sites/te/files/2018_06_EV_announcements_report.pdf

Annex: Planned European ultra-fast charging networks

Name	#stations #sites	Partners	Location	Comment
Ionity	400 / ~2,400	BMW, Mercedes, Ford, VW Group (Porsche and Audi)	24 countries	By 2020 Partner with Shell
Ultra-e	25 / ~100	Allego, Audi, BMW, Magna, Renault, Hubject	Netherlands (5), Belgium (4), Germany (12) and Austria (4)	Completion by summer 2018. Sites at average distance of 150- 200 km
E-Via Flex-E	14 / ~60	Enel (coordinator), EDF, Enedis, Verbund, Nissan, Renault and Ibil	Italy (8), Spain (4), France (2)	
MEGA-E	39 / 322	Allego	20 countries (Central Europe and Scandinavia)	Focuses on metropolitan areas with e-charging hubs
Central European Ultra Charging	118 / N.A.	Verbund (coordinator), CEUC, Enel X, Smatrics, Greenway, OMV	Austria, Czech Republic, Italy, Hungary, Romania, Bulgaria and Slovakia	EU financed 20% of the total cost (€12M out of €61M)
NEXT-E	30 / N.A.	E.ON, MOL, HEP, PETROL, Nissan, BMW	Czech Republic, Slovakia, Croatia, Hungary, Slovenia, and Romania	222 fast (50kW) chargers are also included
E.ON x Clever	180 / N.A.	E.ON and Clever	Germany, France, Norway, Sweden, UK, Italy and Denmark	2-6 chargers per station
Instavolt network	N.A. / 200	Instavolt	UK	Equipement from ChargePoint
Fastned network	25	Fastned	Germany, Netherlands, UK	Equipement from ABB. More sites expected
Pivot Power and the National Grid	45 / 100		UK	50 MW battery storage
EnBW	100-1000 ⁵² / 800	EnBW and OMV	Germany	2 chargers per sites first, cooperation with gas provider OMV, focus on urban areas
Porsche (private)	N.A.			private network, cooperation with gas provider OMV

⁵² The arrangement between enBW and OMV is part of a wider strategy that will see the South German utility provide and maintain more than 1,000 ultra-fast charging sites by 2020.